Sodium Phosphates

processing

Executive Summary

Sodium orthophosphates (mono-, di-, and tri-sodium phosphates) have a wide variety of uses in conventional food processing, but is currently restricted to dairy products only for organic processing. The petition requests soy-based dairy substitutes be allowed to use sodium phosphates for purposes similar to those allowed for dairy products.

The TAP Reviewers all agreed that sodium orthophosphates are synthetic. The reviewers all agreed that the current National List refers only to sodium orthophosphates, and that any other sodium phosphates should be considered and listed separately. While two reviewers were in favor of permitting broader use of this additive, they were not able to reach consensus on the appropriate annotation.

The reviewers concluded that the petitioner did not adequately justify that sodium phosphates are essential for use in soy products. Each cited alternative methods to produce similar products. Two raised concerns about possible nutritional imbalance between calcium and phosphorus due to the addition of sodium phosphates in foods. However, all reviewers shared the consensus that the levels used in food manufacture should not pose a serious health risk for most consumers.

Of the two reviewers who thought it should be listed as a permitted use, one suggested changing the existing annotation to place stringent conditions on all uses of sodium orthophosphates. This would allow all FDA permitted uses, but only with a case-by case determination of need, essentiality, nutritional impact, and alternatives.

The other reviewer in favor of listing the material suggests allowing their use in any product, limited only by 21 CFR requirements. This reviewer felt that since dairy use is permitted it is only consistent that all uses should be permitted.

The reviewer opposed to listing the material found that the combination of concerns was enough to recommend prohibition for all uses in organic products. This reviewer suggested that sodium phosphates be prohibited in all products labeled organic, but permitted in products labeled "made with organic ingredients."

All reviewers agreed that sodium orthophosphates should be permitted in all products labeled "made with organic" (70% or greater organic ingredients).

Identification

Chemical Name:
sodium phosphates (mono-, di-, and tri-)

Other Names:
monobasic, dibasic, and tribasic sodium phosphate; mono- di- or tri-sodium phosphate; di-hydrogen sodium phosphate (monosodium); monohydrogen sodium phosphate (di-sodium); MSP (mono-), DSP (di-), TSP (tri-); sodium orthophosphates.

Trade Names: Many, often contained in blends with calcium phosphates, polyphosphates, and other mixes.

CAS Numbers:
monobasic: 7558-80-7; dibasic: 7558-79-4;
tribasic: 7601-54-9

International Numbering System (INS) Numbers:
339 sodium phosphates
339(i) monosodium orthophosphate
339(ii) disodium orthophosphate
339(iii) trisodium orthophosphate

Other:
NIOSH Registry Number: WC4600000

```
CNUM=2766


X 4A:    LOWEST EFFECT LEVEL OBSERVED IN ALL AVAILABLE RAT OR MOUSE STUDIES

UDY:     2            COMPLETENESS:     RANKING FACTOR: 5.190E-3
ECIES:   RAT                            LEL:    4000    MG/KG BW/DAY
FECTS:   CELLULAR HYPERTROPHY
         HYPERPLASIA
TES:     PARATHYROID GLAND
MMENTS:  HYPERTROPHY AND HYPERPLASIA OF PARATHYROID
         MALES ONLY

-------------------------------------------------------------------------------

X 4C:    LOWEST EFFECT LEVEL OBSERVED IN ALL AVAILABLE STUDIES

UDY:     2            COMPLETENESS:     RANKING FACTOR: 0.000E0
ECIES:   RAT                            LEL:    4000    MG/KG BW/DAY
FECTS:   CELLULAR HYPERTROPHY
         HYPERPLASIA
TES:     PARATHYROID GLAND
MMENTS:  HYPERTROPHY AND HYPERPLASIA OF PARATHYROID
         MALES ONLY

-------------------------------------------------------------------------------

X 7:     ACUTE TOXICITY INFORMATION

UDY:     3                              SOURCE: AM IND HYG ASSOC J 43:B51-B52
ECIES:   RAT                            YEAR:  1982
                                        LD50:  6500    MG/KG BW
MMENTS:

-------------------------------------------------------------------------------

X 8:     HIGH CONCERN EFFECTS

FECT:    HYPERPLASIA
TE:      PARATHYROID GLAND
ECIES:   RAT                            RANKING FACTOR: 5.190E-3
LSTUDY:  2            COMPLETENESS:     LEL:    4000    MG/KG BW/DAY
ELSTDY:               COMPLETENESS:     HNEL:
MMENTS:  HYPERPLASIA OF PARATHYROID

-------------------------------------------------------------------------------

X 9:     ORAL TOXICITY STUDIES (OTHER THAN ACUTE)

UDY:     1            COMPLETENESS:     SOURCE: J EXP MED 61:319-333
YPE:     SHORT TERM                     YEAR:  1935
PECIES:  RAT                            LEL:    5293    MG/KG BW/DAY
```

Summary of TAP Reviewer Analyses [1]

95% organic

Synthetic / Non-Synthetic:	Allowed or Prohibited:	Suggested Annotation:
Synthetic (3-0)	*Allowed (2)* *Prohibited (1)*	*Reviewer 1:* Any of the three salts of Sodium Orthophosphate should be allowed for use as direct additives in foods labeled as organic when used in accordance with good manufacturing practice provided that: (a) the use is established as necessary for the processing of the food; (b) the use is established as having no adverse nutritional impact on the "target population" intended to consume the food; <u>and</u> (c) no non-synthetic, "less synthetic" or environmentally less impactful substance can be used in place of the sodium phosphate salt. *Reviewer 2:* prohibited, no annotation. *Reviewer 3:* allowed as listed in 21 CFR.

Made with organic

Synthetic / Non-Synthetic:	Allowed or Prohibited:	Suggested Annotation:
Synthetic (3-0)	*Allowed (3-0)*	See the 95%+ annotation for Reviewer 1 and 3. Reviewer 2: no annotation.

Characterization

Composition:

monosodium phosphate: NaH_2PO_4
disodium phosphate: Na_2HPO_4
trisodium phosphate: Na_3PO_4

Properties:

All forms are either anhydrous or contain one or more molecules of water of hydration. The anhydrous forms are white, crystalline powders or granules. The hydrated forms occur as white or transparent crystals or granules. The anhydrous form is hygroscopic. It is freely soluble in water and insoluble in alcohol (Budavari, 1996). The pH of the three orthophosphates ranges from the moderately acid monosodium phosphate (pH=4) to the slightly alkaline disodium phosphate (pH=9) to the strongly alkaline trisodium phosphate (pH=12) (Considine and Considine, 1982).

How Made:

Sodium phosphates are generally prepared by the partial or total neutralization of phosphoric acid using sodium carbonate or sodium hydroxide (Ashford, 1994). Crystals of a specific hydrate can then be obtained by evaporation of the resultant solution within the temperature range over which the hydrate is stable (Gard, 1996).

Specific Uses:

Sodium phosphates are used as antimicrobials (Davidson, 2000), pH control agents (buffers), boiler water additives, cleaners, coagulants, dispersants, leavening agents, stabilizers, emulsifiers, sequestrants, texturizers, nutrients, and dietary supplements. Sodium phosphate (mono-, di-, and tri-) is used as a buffering salt in foods. The principal use is for pH stabilization of food systems for fruit and vegetable product systems (Fennema, 1985). Monosodium phosphate is used as an acidulent (Ashford, 1994) and also in medicine as a cathartic, an excipient, and in saline solutions (Budavari, 1996). The petition states, "The addition of sodium phosphates increases the shelf life of soy products" (Amin, 2001).

---

[1] *This Technical Advisory Panel (TAP) review is based on the information available as of the date of this review. This review addresses the requirements of the Organic Foods Production Act to the best of the investigator's ability, and has been reviewed by experts on the TAP. The substance is evaluated against the criteria found in section 2119(m) of the OFPA [7 USC 6517(m)]. The information and advice presented to the NOSB is based on the technical evaluation against that criteria, and does not incorporate commercial availability, socio-economic impact or other factors that the NOSB and the USDA may want to consider in making decisions.*

```
 CNUM=2766

                         U.S. FOOD AND DRUG ADMINISTRATION
                           FOOD ADDITIVE SAFETY PROFILE
-----------------------------------------------------------------------------
SODIUM PHOSPHATE, TRIBASIC

 S#:    007601549      HUMAN CONSUMPTION:     20.7627       MG/KG BW/DAY/PERSON
 SP#:   2766           MARKET DISAPPEARANCE:  24500000.000  LBS/YR
 PE:    ASP            MARKET SURVEY:         87
 S#:    0199           JECFA:                 FU-C
 MA#:                  JECFA ADI:             70            MG/KG BW/DAY/PERSON
 AS#:                  JECFA ESTABLISHED:     1983
                       LAST UPDATE:           921215

 :      163.94         DENSITY:               LOGP:

 RUCTURE CATEGORIES:   A7

 MPONENTS:

 NONYMS:               TRISODIUM PHOSPHATE
                       SODIUM ORTHOPHOSPHATE
                       SODIUM PHOSPHATE (NA3PO4)
                       PHOSPHORIC ACID, TRISODIUM SALT
                       SODIUM ORTHOPHOSPHATE, TRIBASIC
                       TRISODIUM ORTHOPHOSPHATE
                       PHOSPHATE, TRISODIUM

:EMICAL FUNCTION:      F

:CHNICAL EFFECT:       EMULSIFIER OR EMULSIFIER SALT
                       PH CONTROL AGENT
                       SEQUESTRANT
                       ANTICAKING AGENT OR FREE-FLOW AGENT
                       DRYING AGENT
                       HUMECTANT
                       FORMULATION AID
                       NUTRIENT SUPPLEMENT

'R REG NUMBERS:        182.6778        182.1778        150.161
                       133.179         133.173         133.169
                       150.141         173.310         182.5778
                       182.8778

:NIMUM TESTING LEVEL: 3

)MMENTS:  STUDY 1 FROM SCOGS-32
-----------------------------------------------------------------------------
```

Action:

The emulsification abilities of sodium phosphates are not completely understood, but the phosphate interacts with proteins, such as casein, to function as emulsifiers and prevent the separation of both fat and water in cheese (Gard, 1996). The addition of sodium phosphate (tri) to evaporated milk prevents separation of the butter fat and aqueous phases and prevents gel formation (Fennema, 1985). One source notes considerable debate about the mechanisms of phosphate functionality, with reference to water holding capacity of meat and fish (Miller, 1996). The addition of phosphates to muscle food homogenates, raw and cooked meats, in sausages, hams, poultry and seafood will decrease the amount of drip loss, enhance waterbinding and water holding capacity resulting in enhanced sensory characteristics (Fennema, 1985). Orthophosphates can bind with and sequester metals (Considine and Considine, 1982). Sodium phosphate salts can be used as chelating agents (sequesterant) that act to bind to metallic and alkaline earth ions to form complexes that alter the properties and stability of foods such as by binding copper and ferrous ions to slow down the rate of lipid oxidation in foods (Fennema, 1985).

Combinations:

Sodium phosphates are combined with calcium phosphates as leavening agents (Horsford, 1864; Ellinger, 1972; FMC, no date). Sodium orthophosphates are often combined with insoluble sodium metaphosphate (IMP) and various polyphosphates (Ellinger, 1972; FMC, no date). The addition of other salts, such as sodium chloride, can have a synergistic effect on water-holding capacity (Gordon and Klimek, 2000). Typical commercial mixtures contain 30-60% soluble orthophosphates and 40-70% IMP (Gard, 1996). Starches are often used as carriers (Ashford, 1994). Trisodium phosphate used for cleaning is often combined with sodium hypochlorite (bleach) (Ashford, 1994). Sodium aluminum phosphate and sodium acid pyrophosphates are also used as a leavening agents (Food Chemicals Codex, 1996). The sodium phosphates are often used in combination with various gels such as agar, alginates, carageenan, pectins, and various gums (Ellinger, 1972).

The previous sodium phosphates TAP Review (NOSB, 1995) only reviewed the forms mono-, di-, and tri-sodium phosphates. . This TAP Review does not cover other forms such as metaphosphates, pyrophosphates, polyphosphates, or combinations of sodium phosphates with any elemental constituents other than hydrogen.

Status

Historic Use:

The earliest documented use of refined sodium phosphates was with a double salt with calcium phosphates in baking powder (Horsford, 1864).

One reference states that the use of phosphate emulsifiers in cheeses began in the 1890s and cited Kraft's patent as the source for that information (Heidolph and Gard, 2000). However, Kraft's patent makes no reference to sodium phosphate or any other phosphate emulsifier (Kraft, 1916). The historical use of phosphates in soy-based dairy substitutes is not well documented. The historical use of sodium phosphates in organic dairy products does not appear to predate the NOSB's recommendation in 1995.

OFPA, USDA Final Rule:

Section 205.605(b)(33) synthetics allowed: sodium phosphates— for use only in dairy foods.

Regulatory:

See Table 1, below, for FDA references to sodium phosphates.

EPA/NIEHS/Other Sources:

EPA – Both disodium phosphate and trisodium phosphates are considered hazardous materials under the Comprehensive Environmental Response, Cleanup, and Liability Act (CERCLA) with reportable quantities of 5,000 pounds (USEPA, 1998b). Disodium and trisodium phosphates are designated hazardous substances under the Clean Water Act (40 CFR 116.4). Disodium phosphate were reclassified to EPA List 4B (60 *Fed. Reg. 35397).* The EPA's List of Pesticide Product Inert Ingredients also classifies monosodium phosphate and trisodium phosphate as EPA List 4B, but a corresponding *Federal Register* notification of reclassification was not found. (EPA, 1995).

NIEHS – National Toxicology Program database (NTP, 2001):

Toxicity

Acute Toxicity:

Type Dose	Mode	Species	amount unit
LD_{50}	orl	rat	12,930 mg/kg
LD_{lo}	ipr	rat	1,000 mg/kg

```
CNUM=2764


NIMUM TESTING LEVEL: 3


MMENTS:  STUDIES 1-4 FROM SCOGS-32

-----------------------------------------------------------------------------------

X 7:    ACUTE TOXICITY INFORMATION

UDY:     5                                  SOURCE: FOOD ADDIT HANDBOOK(R J LEWIS):396-397
ECIES:   RAT                                YEAR:  1989
                                            LD50:  17000   MG/KG BW
MMENTS:

-----------------------------------------------------------------------------------

X 8:    HIGH CONCERN EFFECTS

FECT:    NECROSIS
TE:      KIDNEY
ECIES:   RAT                                RANKING FACTOR: 5.677E-3
LSTUDY:  2               COMPLETENESS:      LEL:    5000    MG/KG BW/DAY
ELSTDY:                  COMPLETENESS:      HNEL:
MMENTS:  NECROSIS OF KIDNEY

-----------------------------------------------------------------------------------

X 9:    ORAL TOXICITY STUDIES (OTHER THAN ACUTE)

UDY:     3               COMPLETENESS:      SOURCE: AM J PATHOL 33:621
PE:      SHORT TERM                         YEAR:  1957
ECIES:   RAT                                LEL:    10000   MG/KG BW/DAY
RATION:  3 DAYS                             HNEL:
FECTS:   HISTOPATHOLOGY OBSERVATION(S) NOT ELSEWHERE CLASSIFIED
TES:     KIDNEY
MMENTS:  ONE DOSE LEVEL ONLY
         HISTOPATH OTHER = HISTOCHEMICAL AND HISTOLOGICAL CHANGES;
         EFFECTS NOT SPECIFIED

UDY:     1               COMPLETENESS:      SOURCE: ARZNEIM FORSCH 9:501-503
PE:      CHRONIC RODENT                     YEAR:  1959
ECIES:   RAT                                LEL:    >       MG/KG BW/DAY
RATION:  182 DAYS                           HNEL:   4590    MG/KG BW/DAY
FECTS:   NO EFFECTS
TES:
MMENTS:  SLIGHT RENAL CALCIFICATION OBSERVED
         RENAL CALCIFICATION ALSO OBSERVED IN SOME CONTROLS
         NO STATISTICAL ANALYSIS; ONE DOSE LEVEL ONLY

UDY:     4               COMPLETENESS:      SOURCE: ARZNEIM FORSCH 8:286-289
```

*Sax toxicity evaluation: not available
*carcinogenicity: not available
*mutagenicity: not available
*teratogenicity: not available

ipr=intraperitoneal
LD_{50}=lethal Dose for 50% of the test organisms
LD_{lo}=lowest published lethal dose
orl=oral

Standards, Regulations & Recommendations:
OSHA: none
ACGIH: none
NIOSH criteria document: none
NFPA hazard rating: health (h): none
flammability (f): none
reactivity (r): none
Other toxicity data: not available
Acute/chronic hazards:
Toxic. May cause irritation on contact. Hazardous decomposition.
Minimum protective clothing: not available
Recommended glove materials: Permeation data indicate that latex gloves may provide protection from contact with this compound. Latex over latex gloves is recommended. However, if this chemical makes direct contact with your gloves, or if a tear, hole or puncture develops, remove them at once.

Recommended respirator: Where the neat test chemical is weighed and diluted, wear a NIOSH-approved half face respirator equipped with an organic vapor/acid gas cartridge (specific for organic vapors, HCl, acid gas and SO2) with a dust/mist filter.

Spills and leakage: If you spill this chemical, you should dampen the solid spill material with water, then transfer the dampened material to a suitable container. Use absorbent paper dampened with water to pick up any remaining material. Seal your contaminated clothing and the absorbent paper in a vapor-tight plastic bag for eventual disposal. Wash all contaminated surfaces with a strong soap and water solution. Do not reenter the contaminated area until the safety officer (or other responsible person) has verified that the area has been properly cleaned.

Skin contact: Immediately flood affected skin with water while removing and isolating all contaminated clothing. Gently wash all affected skin areas thoroughly with soap and water. If symptoms such as redness or irritation develop, immediately call a physician and be prepared to transport the victim to a hospital for treatment.

Inhalation: Immediately leave the contaminated area; take deep breaths of fresh air. If symptoms (such as wheezing, coughing, shortness of breath, or burning in the mouth, throat, or chest) develop, call a physician and be prepared to transport the victim to a hospital. Provide proper respiratory protection to rescuers entering an unknown atmosphere. Whenever possible, self-contained breathing apparatus (scba) should be used; if not available, use a level of protection greater than or equal to that advised under respirator recommendation.

Eye contact: First check the victim for contact lenses and remove if present. Flush victim's eyes with water or normal saline solution for 20 to 30 minutes while simultaneously calling a hospital or poison control center. Do not put any ointments, oils, or medication in the victim's eyes without specific instructions from a physician. Immediately transport the victim after flushing eyes to a hospital even if no symptoms (such as redness or irritation) develop.

Ingestion: Do not induce vomiting. If the victim is conscious and not convulsing, give 1 or 2 glasses of water to dilute the chemical and immediately call a hospital or poison control center. Be prepared to transport the victim to a hospital if advised by a physician. If the victim is convulsing or unconscious, do not give anything by mouth, ensure that the victim's airway is open and lay the victim on his/her side with the head lower than the body. Do not induce vomiting. Immediately transport the victim to a hospital.

Other Sources – Disodium phosphate is subject to state Right-to-Know laws in Massachusetts, New Jersey, and Pennsylvania.

CNUM=2764

U.S. FOOD AND DRUG ADMINISTRATION
FOOD ADDITIVE SAFETY PROFILE

```
---------------------------------------------------------------------------

SODIUM PHOSPHATE, DIBASIC

S#:    007558794       HUMAN CONSUMPTION:      28.3898        MG/KG BW/DAY/PERSON
SP#:   2764            MARKET DISAPPEARANCE:   33500000.000 LBS/YR
PE:    ASP             MARKET SURVEY:          87
S#:    2398            JECFA:                  FU-C
MA#:   2398            JECFA ADI:              70             MG/KG BW/DAY/PERSON
AS#:   3               JECFA ESTABLISHED:      1983
TENTIAL BEVERAGE USE   LAST UPDATE:            921215

:      141.96          DENSITY:                LOGP:

RUCTURE CATEGORIES:    A7

MPONENTS:

NONYMS:                DISODIUM PHOSPHATE, ANHYDROUS
                       SODIUM ACID PHOSPHATE, ANHYDROUS
                       DISODIUM PHOSPHATE
                       SODIUM PHOSPHATE, EXSICCATED
                       DISODIUM ORTHOPHOSPHATE
                       DISODIUM HYDROGEN PHOSPHATE, ANHYDROUS
                       PHOSPHORIC ACID, DISODIUM SALT
                       DISODIUM HYDROGEN PHOSPHATE
                       PHOSPHATE, DISODIUM

EMICAL FUNCTION:       F

CHNICAL EFFECT:        PH CONTROL AGENT
                       STABILIZER OR THICKENER
                       EMULSIFIER OR EMULSIFIER SALT
                       TEXTURIZER
                       MALTING OR FERMENTING AID
                       FLAVOR ENHANCER
                       FLAVORING AGENT OR ADJUVANT
                       ANTIMICROBIAL AGENT
                       ANTICAKING AGENT OR FREE-FLOW AGENT
                       DRYING AGENT

R REG NUMBERS:         182.1778         135.110          182.6290
                       182.6778         173.310          182.5778
                       139.110          150.141          133.169
                       150.161          133.179          133.173
                       137.305          139.115          139.117
                       139.135          182.8778
```

Status Among U.S. Certifiers:

California Certified Organic Farmers (CCOF) - CCOF Certification Handbook (2000), Section 8.3.3 Processing and Handling Materials, "Allowed Non-Organic, Use as an ingredient restricted to dairy foods."

Oregon Tilth Certified Organic (OTCO) - OTCO Generic Materials List (April 30, 1999), Processing Materials, "Allowed, Non-Organic Ingredient, Use as an ingredient restricted to dairy foods." The petition included a letter from OTCO stating, "OTCO has considered your request for use of di-sodium phosphate in soymilk drink to prevent protein coagulation upon heating. The reason for using di-sodium phosphate and the lack of alternatives was clearly explained by Mr. Amin, from Carousel Foods. OTCO would extend allowance of the use of sodium di-phosphate to soymilk... ." (OTCO, 2000).

Organic Crop Improvement Association International (OCIA) - OCIA International Certification Standards, effective date July 1, 2001, Section 9.4.3, regulated for use in the NOI (non-organic ingredient) class with specifications "use as an ingredients restricted to dairy foods."

Quality Assurance International (QAI) - Petition included a letter from QAI stating, "According to the current organic practices, di-sodium phosphate is allowed in the processing of soy products... .When the National Organic Program goes into effect this will no longer be an allowed material... ." (QAI, 2000).

Texas Department of Agriculture (TDA) Organic Certification Program - TDA Organic Certification Program Materials List (February 2000), restricted for use in processing with comments, "Use as a non-organic ingredient is restricted to dairy foods."

Washington State Department of Agriculture (WSDA) Organic Food Program - Chapter 16-158-060 WAC (rev. January 18, 2001), listed in the section "Minor Ingredients and Processing Aids" as "sodium phosphate— for dairy processing only."

International
CODEX - Not listed.
EU 2092/91 - Not listed.
Japanese Agricultural Standard - Not listed.
IFOAM - Not listed.
Canada - Not listed.
Other International Certifiers - Could not find any that allow any sodium phosphates for any purpose.

Section 2119 OFPA U.S.C. 6518(m)(1-7) Criteria

1. The potential of the substance for detrimental chemical interactions with other materials used in organic farming systems.
The substance is used in processing and therefore would not interact directly with other materials used in organic farming systems.

2. The toxicity and mode of action of the substance and of its breakdown products or any contaminants, and their persistence and areas of concentration in the environment.
The toxicity of sodium phosphates is generally related to the sequestration of calcium and the subsequent reduction of ionized calcium (Gosselin, et al., 1984). Ingestion may injure the mouth, throat, and gastrointestinal tract, resulting in nausea, vomiting, cramps, and diarrhea (Chermishinoff, 2000). Feeding studies on human subjects showed no adverse chronic effects. However a number of feeding studies that involved rodent models showed kidney damage and calcium deposits in test animals (Ellinger, 1972). Also see processing criteria 3, below.

3. The probability of environmental contamination during manufacture, use, misuse, or disposal of the substance.
See processing criteria 2, below.

4. The effects of the substance on human health.
Most of the human health references are related to its medical, rather than food, use. The Reviewers considered the literature citations of the effect of sodium phosphate purgatives to be not directly relevant to food use. However, for the sake of completeness, these studies are briefly noted, but not exhaustively reviewed. A number of the adverse health effects are related to the use of phosphates purgatives. In a number of cases, bowel cleansers were not used according to label instructions or were given to patients with reduced renal function where the use of phosphate purgatives is medically contraindicated.

```
CNUM=2765


                    172.892         150.161         182.8778
                    163.135         163.140         163.145
                    163.155         163.150         163.153


NIMUM TESTING LEVEL: 3


MMENTS:  STUDIES 1 AND 2 FROM SCOGS-32

-----------------------------------------------------------------------------

X 4A:   LOWEST EFFECT LEVEL OBSERVED IN ALL AVAILABLE RAT OR MOUSE STUDIES

UDY:    7           COMPLETENESS: C  RANKING FACTOR: 1.572E-4
ECIES:  RAT                          LEL:   1500    MG/KG BW/DAY
FECTS:  WATER INTAKE INCREASE
        URINALYSIS OBSERVATION(S) NOT ELSEWHERE CLASSIFIED
TES:
MMENTS: DECREASED URINARY CALCIUM AND MAGNESIUM
        MALES ONLY; ONE DOSE LEVEL ONLY

-----------------------------------------------------------------------------

X 4C:   LOWEST EFFECT LEVEL OBSERVED IN ALL AVAILABLE STUDIES

UDY:    7           COMPLETENESS: C  RANKING FACTOR: 0.000E0
ECIES:  RAT                          LEL:   1500    MG/KG BW/DAY
FECTS:  WATER INTAKE INCREASE
        URINALYSIS OBSERVATION(S) NOT ELSEWHERE CLASSIFIED
TES:
MMENTS: DECREASED URINARY CALCIUM AND MAGNESIUM
        MALES ONLY; ONE DOSE LEVEL ONLY

-----------------------------------------------------------------------------

X 7:    ACUTE TOXICITY INFORMATION

UDY:    5                            SOURCE: GRM 000100 5:1027-1028
ECIES:  RAT                          YEAR:  1974
                                     LD50:  4100    MG/KG BW
MMENTS:

UDY:    4                            SOURCE: GRM 000100 5:1025-1026
ECIES:  MOUSE                        YEAR:  1974
                                     LD50:  3700    MG/KG BW
MMENTS:

UDY:    9                            SOURCE: GRM 000100 11:2281-2289
ECIES:  GUINEA PIG                   YEAR:  1950
```

Because phosphates react slowly, systemic reactions are unlikely. Low calcium (hypocalcemia) has been reported in certain susceptible individuals (Gosselin, et al., 1984; Boivin and Kahn, 1998). Continuous contact may cause skin irritation and can be minimally to moderately irritating to unwashed eyes.

Trisodium phosphate is caustic (Gosselin, et al., 1984). Most of the adverse reactions reported in the medical literature involve the use of relatively high levels of sodium phosphate administered to patients where such use is contraindicated. Also, trisodium phosphate reportedly promotes bladder cancer initiated by an experimental nitrosoamine in rats, while monosodium phosphate does not (Shibata et al., 1991, cited in Shibata, et al., 1993). See also processing criteria 3 and 5, below.

5. The effects of the substance on biological and chemical interactions in the agroecosystem, including the physiological effects of the substance on soil organisms (including the salt index and solubility of the soil), crops and livestock.
This is a processing material that is not applied to soil.

6. The alternatives to using the substance in terms of practices or other available materials.
See processing criteria 1 and 7, below.

Its compatibility with a system of sustainable agriculture.
See processing criteria 6, below.

Criteria From the February 10, 1999 NOSB Meeting

A PROCESSING AID OR ADJUVANT may be used if:
1. It cannot be produced from a natural source and has no organic ingredients as substitutes.
No documentation could be found of natural sources of food grade sodium phosphates. Lecithin from organic soybeans is a possible substitute for certain applications as an emulsifier.

2. Its manufacture, use, and disposal do not have adverse effects on the environment and are done in a manner compatible with organic handling as described in section 6513 of the OFPA.
The manufacturing processes for sodium carbonate and sodium hydroxide (see "How Made" section, above) are covered in previous TAP reviews. Sodium hydroxide and sodium carbonate were reviewed by the NOSB and added to the National List. Manufacture of food-grade phosphoric acid involves the removal of heavy metals and radioactive waste. The environmental impact of mining calcium phosphate is covered in the TAP review for triple superphosphate.

A primary environmental concern of sodium phosphates is their release into water. Phosphate detergents caused algal blooms and eutrophication of the Great Lakes. This was remedied by the development of low-phosphate detergents and bans on high-phosphate detergents in the states that drain into the Great Lakes (US EPA, 1997). This is primarily related to trisodium phosphate used as a detergent or cleaner, and is generally not related to use as a food additive.

3. If the nutritional quality of the food is maintained and the material itself or its breakdown products do not have adverse effects on human health as defined by applicable Federal regulations.
Calcium and phosphorous are metabolically linked by their common absorptive mechanism through Vitamin D. Vitamin D_3 stimulates absorption of calcium in the intestine. This maintains the homeostasis of calcium and phosphorus in bone formation from those two minerals (Watkins, 2000). The distribution of phosphorous in foods is so wide that deficiencies do not seem to exist. It is always linked to calcium in skeletal mass and exists as a phosphate salt in bone as phospho proteins, phospho lipids and nucleic acids in the cell (Alais and Linden, 1991). Its addition raises both sodium and phosphorous levels in the food.

Nutritional disorders are of particular concern with infants and children raised on a vegan diet and are being fed soy beverages as a milk substitute (Anil, et al., 1996; Carvalho, et al., 2001). One Reviewer raised the concern that soy beverages are not nutritionally equivalent to milk and soy-based dairy substitutes also have different nutritional compositions.
An additional review of health effects (not included in original materials sent to Reviewers) reported on a study that examined the effect of an intentionally high phosphate additive diet (potato chips, processed cheese carbonated beverages, etc) This resulted in measurably lower calcium serum levels. (Bell, cited in Molins, 1991) This report also estimated that phosphate additives in the ordinary American diet may increase P intake on the order of 25-100%.

Disodium phosphate anhydrous is not considered hazardous by known governmental definitions (FMC, 1996).

```
CNUM=2765

                      U.S. FOOD AND DRUG ADMINISTRATION
                        FOOD ADDITIVE SAFETY PROFILE
-----------------------------------------------------------------------------

SODIUM PHOSPHATE, MONOBASIC

.S#:     007558807       HUMAN CONSUMPTION:      0.2358       MG/KG BW/DAY/PERSON
.SP#:    2765            MARKET DISAPPEARANCE:   278333.333   LBS/YR
PE:      ASP             MARKET SURVEY:          87
.S#:     0198            JECFA:                  FU-C
MA#:                     JECFA ADI:              70           MG/KG BW/DAY/PERSON
AS#:                     JECFA ESTABLISHED:      1983
TENTIAL BEVERAGE USE     LAST UPDATE:            921215

:        119.98          DENSITY:                LOGP:

RUCTURE CATEGORIES:      A7

MPONENTS:

NONYMS:                  MONOSODIUM PHOSPHATE
                         MONOSODIUM PHOSPHATE, ANHYDROUS
                         SODIUM DIHYDROGEN PHOSPHATE, ANHYDROUS
                         MONOSODIUM ORTHOPHOSPHATE
                         MONOSODIUM DIHYDROGEN PHOSPHATE
                         SODIUM BIPHOSPHATE
                         SODIUM DIHYDROGEN PHOSPHATE
                         SODIUM ACID PHOSPHATE
                         PHOSPHORIC ACID, MONOSODIUM SALT
                         SODIUM PHOSPHATE (NAH2PO4)
                         MONOSODIUM MONOPHOSPHATE
                         PHOSPHATE, MONOBASIC SODIUM
                         PHOSPHATE, MONOSODIUM


IEMICAL FUNCTION:        F

CHNICAL EFFECT:          EMULSIFIER OR EMULSIFIER SALT
                         PH CONTROL AGENT
                         ANTIMICROBIAL AGENT
                         LEAVENING AGENT
                         FLAVORING AGENT OR ADJUVANT
                         FLAVOR ENHANCER
                         ANTICAKING AGENT OR FREE-FLOW AGENT
                         DRYING AGENT
                         HUMECTANT

R REG NUMBERS:           182.1778        182.6085        173.310
                         182.6778        182.5778        150.141
                         160.110         133.169         133.179
                         163.123         163.130         133.173
```

The primary adverse human health effect is the elevation of sodium levels and the substitution of sodium for calcium. Sodium phosphate does not appear to increase the amount of calcium excreted in urine (calciuria) in normal healthy individuals (Whiting, Andersen, and Weeks, 1997). One text in food chemistry provides the following quote (de Man, 1990):

> "The importance of phosphates in the diet as it relates to the absorption of calcium depends on the amount of calcium, iron, strontium and aluminum present in the diet. The literature suggests that a diet containing more phosphorous than calcium can be as detrimental as a simple calcium deficiency. The ratio of calcium to phosphorous in the bone is 2:1. In early infancy the ratio should be 1.5:1, in adults 1:1. The estimated annual per capita intake in the US is 1-g calcium and 2.9-g phosphorous; thus providing a ratio of 0.35. Therefore a danger in raising phosphorous levels in the diet may increase the unavailability of calcium."

4. Its primary purpose is not as a preservative or used only to recreate/improve flavors, colors, textures, or nutritive value lost during processing except in the latter case as required by law.
Sodium phosphates possess antimicrobial properties (Davidson, 2000). The primary purpose in the petition is not as a preservative. The specific functionality is not described in any detail in the petition (Amin, 2001). However, the primary petitioned function could possibly be described as 'textural.' Phosphates stabilize proteins during processing so they improve finished product texture (Yazici, et al., 1997).

The primary use, as described in the petition, would be to make dairy product substitutes (Ellinger, 1972). Monosodium phosphate can be used to impart a certain flavor (Tidridge, 1962). It is also used as a nutritional supplement to replace or enhance phosphate levels.

5. Is Generally Recognized As Safe (GRAS) by FDA when used in accordance with Good Manufacturing Practices (GMP), and contains no residues of heavy metals or other contaminants in excess of FDA tolerances.
M\Mono-, di-, and tri-basic sodium phosphates are all considered GRAS as multiple purpose ingredients (21 CFR 182.1778). The Food Chemicals Codex (1996) specifications for all three forms are as follows:

Identification: A 1 in 20 solution gives positive tests for Phosphate and Sodium.
Arsenic: Not more than 3 mg/kg
Heavy metals (as Pb) Not more than 10 mg/kg
Fluoride: Not more than 0.005%
Insoluble substances: Not more than 0.2%

Table 1 summarizes the FDA references to sodium phosphates in the EAFUS database. Note that polyphosphates and pyrophosphates are covered under separate references.

---

5 - HEALTH HAZARD DATA

CARCINOGENICITY: NTP: NO IARC: NO Z LIST: NO OSHA REG: NO
EFFECTS OF OVEREXPOSURE
CONTACT WITH SKIN OR EYES MAY CAUSE SEVERE IRRITATION OR BURNS.
DUST MAY IRRITATE NOSE AND THROAT.
INGESTION MAY RESULT IN SEVERE INTESTINAL IRRITATION WITH BURNS TO MOUTH.
INGESTION MAY CAUSE NAUSEA AND VOMITING.
PROLONGED EXPOSURE MAY CAUSE DERMATITIS.
TARGET ORGANS: NONE IDENTIFIED
MEDICAL CONDITIONS GENERALLY AGGRAVATED BY EXPOSURE: NONE IDENTIFIED
ROUTES OF ENTRY: NONE INDICATED
EMERGENCY AND FIRST AID PROCEDURES
IN CASE OF CONTACT, IMMEDIATELY FLUSH EYES WITH PLENTY OF WATER FOR AT LEAST 15 MINUTES. FLUSH SKIN WITH WATER.

---

6 - REACTIVITY DATA

STABILITY: STABLE HAZARDOUS POLYMERIZATION: WILL NOT OCCUR
DECOMPOSITION PRODUCTS: OXIDES OF PHOSPHORUS, OXIDES

---

7 - SPILL AND DISPOSAL PROCEDURES

STEPS TO BE TAKEN IN THE EVENT OF A SPILL OR DISCHARGE
WEAR SELF-CONTAINED BREATHING APPARATUS AND FULL PROTECTIVE CLOTHING.
WITH CLEAN SHOVEL, CAREFULLY PLACE MATERIAL INTO CLEAN, DRY CONTAINER AND COVER; REMOVE FROM AREA. FLUSH SPILL AREA WITH WATER.
DISPOSAL PROCEDURE
DISPOSE IN ACCORDANCE WITH ALL APPLICABLE FEDERAL, STATE, AND LOCAL ENVIRONMENTAL REGULATIONS.

---

8 - PROTECTIVE EQUIPMENT

VENTILATION: USE ADEQUATE GENERAL OR LOCAL EXHAUST VENTILATION TO KEEP FUME OR DUST LEVELS AS LOW AS POSSIBLE.
RESPIRATORY PROTECTION: NONE REQUIRED WHERE ADEQUATE VENTILATION CONDITIONS EXIST. IF AIRBORNE CONCENTRATION IS HIGH, USE AN APPROPRIATE RESPIRATOR OR DUST MASK.
EYE/SKIN PROTECTION: SAFETY GLASSES WITH SIDESHIELDS, UNIFORM, PROPER GLOVES ARE RECOMMENDED.

---

9 - STORAGE AND HANDLING PRECAUTIONS

SAF-T-DATA(TM) STORAGE COLOR CODE: ORANGE (GENERAL STORAGE)
SPECIAL PRECAUTIONS
KEEP CONTAINER TIGHTLY CLOSED. SUITABLE FOR ANY CHEMICAL STORAGE AREA.

---

10 - TRANSPORTATION DATA AND ADDITIONAL INFORMATION

DOMESTIC (D.O.T.)
PROPER SHIPPING NAME SODIUM PHOSPHATE, DIBASIC
HAZARD CLASS ORM-E LABELS NONE
REPORTABLE QUANTITY 5000 LBS.
INTERNATIONAL (I.M.O.)
PROPER SHIPPING NAME CHEMICALS, N.O.S. (NON-REGULATED)

Table 1
FDA References to Sodium Phosphates

21 CFR	Section heading	Form*	Notes/Limitations
73.85	caramel color	1,2,3	Salts that may be employed to assist caramelization, in amounts consistent with good manufacturing practice.
133.169	pasteurized process cheese	1,2,3	Optional ingredient as an emulsifier, not to exceed 3% by weight of the product.
133.173	pasteurized process cheese food	1,2,3	Optional ingredient as an emulsifier, not to exceed 3% by weight of the product.
133.179	pasteurized process cheese spread	1,2,3	Optional ingredient as an emulsifier, not to exceed 3% by weight of the product.
135.110	ice cream and frozen custard	2	Optional ingredient.
137.305	enriched farina	2	Optional ingredient at not less than 0.5 percent and not more than 1 percent by weight. The enzymes pepsin and papain may be used as substitutes to reduce cooking time.
139.110	macaroni products	2	Optional ingredient in a quantity not less than 0.5 percent and not more than 1.0 percent of the weight of the finished food. When disodium phosphate is used the label shall bear the statement "Disodium phosphate added for quick cooking."
150.141	artificially sweetened fruit jelly	1,2,3	Optional ingredient in an amount not exceeding 2 ounces avoirdupois per 100 pounds of the finished food.
150.161	artificially sweetened fruit preserves and jams	1,2,3	Optional ingredient in an amount not exceeding 2 ounces avoirdupois per 100 pounds of the finished food.
160.110	frozen eggs	1	Optional ingredient not to exceed 0.5 percent of the weight of the frozen eggs.
172.892	food starch-modified	1	Residual phosphate in food starch-modified not to exceed 0.4 percent calculated as phosphorus.
173.310	boiler water additive	1,2,3	The amount of additive is not in excess of that required for its functional purpose, and the amount of steam in contact with food does not exceed that required to produce the intended effect in or on the food.
175.210	acrylate ester copolymer coating	2	Not to exceed the amount required as a preservative in emulsion defoamer.
175.300	resinous and polymeric coatings	2	Miscellaneous material.
178.1010	sanitizing solutions	1,3	Approved for use in combination with sodium hypochlorite, sodium lauryl sulfate, and potassium permanganate (b)(37); limitations described in detail at 21 CFR 178.1010(c)(32)(ii).
181.29	stabilizers	2	Disodium hydrogen phosphate classified as a stabilizer, when migrating from food- packaging material.
182.1778	sodium phosphate	1,2,3	Multiple Purpose GRAS Food Substances. GRAS when used in accordance with GMPs.
182.6085	sodium acid phosphate	1	Sequestrants: GRAS when used in accordance with GMPs.
182.6290	disodium phosphate	2	Sequestrants: GRAS when used in accordance with GMPs.
182.6778	sodium phosphate	1,2,3	Sequestrants: GRAS when used in accordance with GMPs.
182.8778	sodium phosphate	1,2,3	Nutrients: GRAS when used in accordance with GMPs.

* 1= sodium phosphate, monobasic (CAS #7558-80-7); 2= sodium phosphate, dibasic 7558-79-4;
3= sodium phosphate, tribasic (CAS #7601-54-9)

Source: EAFUS.

6. Its use is compatible with the principles of organic handling.
Additives used for stabilization and prolonging shelf life have generally not been considered compatible with principles of organic processing (Raj, 1991). Draft principles of organic handling proposed by NOSB in June, 2001 include the statement "Organic products are handled using processing methods that maintain the organic integrity and quality of the products." The NOSB considered a petition for the general use of sodium phosphates in 1995, and restricted that use to dairy products. A reasonable argument could be made that the same logic could be applied to plant-derived dairy substitutes. A counter-

MSDS for SODIUM PHOSPHATE, DIBASIC, ANHYDROUS

1 - PRODUCT IDENTIFICATION

PRODUCT NAME: SODIUM PHOSPHATE, DIBASIC, ANHYDROUS
FORMULA: NA2HPO4 FORMULA WT: 141.96
CAS NO.: 07558-79-4 NIOSH/RTECS NO.: WC4500000
COMMON SYNONYMS: DISODIUM HYDROGEN PHOSPHATE; SODIUM MONOHYDROGEN PHOSPHATE
PRODUCT CODES: 3828
EFFECTIVE: 10/08/85 REVISION #01

PRECAUTIONARY LABELLING

BAKER SAF-T-DATA(TM) SYSTEM
HEALTH - 1 SLIGHT
FLAMMABILITY - 0 NONE
REACTIVITY - 1 SLIGHT
CONTACT - 2 MODERATE

HAZARD RATINGS ARE 0 TO 4 (0 = NO HAZARD; 4 = EXTREME HAZARD).
LABORATORY PROTECTIVE EQUIPMENT: SAFETY GLASSES; LAB COAT
PRECAUTIONARY LABEL STATEMENTS
WARNING CAUSES IRRITATION
AVOID CONTACT WITH EYES, SKIN, CLOTHING.
KEEP IN TIGHTLY CLOSED CONTAINER. WASH THOROUGHLY AFTER HANDLING.
SAF-T-DATA(TM) STORAGE COLOR CODE: ORANGE (GENERAL STORAGE)

2 - HAZARDOUS COMPONENTS

COMPONENT	%	CAS NO.
SODIUM PHOSPHATE, DIBASIC, ANHYDROUS	90-100	7558-79-4

3 - PHYSICAL DATA

BOILING POINT: N/A VAPOR PRESSURE(MM HG): N/A
MELTING POINT: N/A VAPOR DENSITY(AIR=1): 4.9
SPECIFIC GRAVITY: 0.00 EVAPORATION RATE: N/A
(H2O=1) (BUTYL ACETATE=1)
SOLUBILITY(H2O): APPRECIABLE (MORE THAN 10 %) % VOLATILES BY VOLUME: 0
APPEARANCE & ODOR: WHITE ODORLESS POWDER.

4 - FIRE AND EXPLOSION HAZARD DATA

FLASH POINT (CLOSED CUP N/A FLAMMABLE LIMITS: UPPER - N/A % LOWER - N/A %
FIRE EXTINGUISHING MEDIA
USE EXTINGUISHING MEDIA APPROPRIATE FOR SURROUNDING FIRE.
SPECIAL FIRE-FIGHTING PROCEDURES
FIREFIGHTERS SHOULD WEAR PROPER PROTECTIVE EQUIPMENT AND SELF-CONTAINED BREATHING APPARATUS WITH FULL FACEPIECE OPERATED IN POSITIVE PRESSURE MODE.
MOVE EXPOSED CONTAINERS FROM FIRE AREA, IF IT CAN BE DONE WITHOUT RISK.
USE WATER TO KEEP FIRE-EXPOSED CONTAINERS COOL.
UNUSUAL FIRE & EXPLOSION HAZARDS
CLOSED CONTAINERS EXPOSED TO HEAT MAY EXPLODE.
TOXIC GASES PRODUCED: PHOSPHORUS OXIDE

argument could be made in support of real dairy products being more natural and therefore more compatible with organic principles than plant-derived substitutes that require synthetic additives. (Sodium phosphates are not used in fluid milk, but are more likely to be used in frozen milk products or shelf stable dairy creamers.)

Imitation products have historically been regarded as less 'organic' than the real product they seek to imitate, particularly when synthetic chemical additives are necessary to give the impression to the consumer that the imitation is similar to the real product. A clear consensus is not available on current consumer preference regarding use of stabilizers and other additives in organic products, and could be further investigated.

7. There is no other way to produce a similar product without its use and it is used in the minimum quantity required to achieve the process.

The petition states, "Our lengthy research and development has determined that the sodium phosphates provide essential and incomparable functionality in our organic soy products… . Without the use of sodium phosphates in producing our soy food and beverage products similar to dairy products, we would not be able to create products acceptable to consumers" (Amin, 2001). Information included with the petition focused more on dairy products and other applications and only included data on sodium hexametaphosphate (not reviewed in this TAP review).

Soy milk and other soy-based dairy substitutes in the US are evaluated by comparison with cow's milk rather than the traditional product of soy milk (Wong, 1964; Shurtleff and Aoyagi, 1985). Therefore, the question of what is a 'similar' product is more difficult to resolve than usual, given that the petition explicitly requests to be evaluated as 'similar to or equivalent to' dairy products, rather than as soy products (Amin, 2001). The logical conclusion is that an organic dairy product is, by definition, similar.

Traditional Chinese recipes involved the soaking of soybeans in water, grinding them into a slurry, cooking, and filtering to remove the insoluble cell wall and hull fractions, with no mention of sodium phosphates or any other chemical sequestrants (Piper and Morse, 1923, cited in Wong, 1964; Hui, 2000). Product development researchers explored a number of processing modifications in the 1960s and 1970s, with an extensive number of references that compared the resulting products to dairy foods rather than to the traditional Asian beverage (Wong, 1964; Shurtleff and Aoyagi, 1985). This included methods to make blander flavors or to produce a yogurt-like texture (Wong, 1964). Later efforts went into creating frozen desserts, such as ice creams (Shurtleff and Aoyagi, 1985). Soybean variety selection appeared to be more significant than either preparation methods or the use of additives in eliminating what were deemed off-flavors in at least one series of experiments (Wong, 1964).

Potassium citrate is a viable alternative cited in a comparative study of the effects of sodium hexametaphosphate and potassium citrate on 'soymilk' heat stability. The authors found, "on a weight-for-weight basis, potassium citrate provided higher heat stability compared to sodium hexametaphosphate." In their abstract, the authors state that "samples with 1.25% potassium citrate had the best heat stability" (Yaziki, et al., 1997).

Sodium citrate is an alternative to trisodium phosphate in condensed, evaporated, and non-fat milk processing (Ellinger, 1972) and in processed dairy cheese manufacture (Rippen, 1986). Calcium citrate, sodium citrate, and potassium citrate are all Federally approved emulsifiers to make processed cheese and permitted under the organic rules [21 CFR 133.173(e)(1) and 7 CFR 205.605(b)(5, 26, 31)].

Di-potassium phosphate could be used to prevent coagulation in non-dairy creamers (Considine and Considine, 1982; FMC, no date). This would limit the non-dairy creamer to a 'made with organic' claim [7 CFR 205.605(b)(29)].

Organic ice cream producers make ice cream without added stabilizers and emulsifiers by producing in small batches with low over-run (Wright, 1994).

Sodium phosphates are not listed in any of the recipes and formulations contained in one of the few references devoted to soy dairy substitutes (Shurtleff and Aoyagi, 1985). Among the ingredients used in formulations described that are already on the National List include guar gum [205.606(b)] and lecithin [205.605(b)(15) and 205.606d]. Agar, alginic acid, pectins, potassium alginate, sodium alginate, and starches are also possible emulsifiers, stabilizers, and thickeners (Considine and Considine, 1982). Calcium sulfate (Buena Park, 2001) and carageenan (NOSB, Orlando, 1995) were not included on the National List; both were recommended for inclusion by the NOSB.

NOSB Materials Database

OFPA Criteria

2119(m)1: chemical interactions Not Applicable
2119(m)2: toxicity & persistence Not Applicable
2119(m)3: manufacture & disposal consequences

2119(m)4: effect on human health

2119(m)5: agroecosystem biology Not Applicable
2119(m)6: alternatives to substance

2119(m)7: Is it compatible?

References

TAP Reviewer Discussion[2]

Reviewer 1 *[East Coast--Ph.D. in biochemistry with food industry experience]*
1. The three salts of Sodium Orthophosphate, FCC, are SYNTHETIC.

2. The three salts of Sodium Orthophosphate are already on the National List.

3. Any of the three salts of Sodium Orthophosphate should be allowed for use as direct additives in foods labeled as organic when used in accordance with good manufacturing practice provided that:
   (d) the use is established as necessary for the processing of the food;
   (e) the use is established as having no adverse nutritional impact on the "target population" intended to consume the food; and
   (f) no non-synthetic, "less synthetic" or environmentally less impactful substance can be used in place of the sodium phosphate salt.

4. Assessment as to the completeness and accuracy of database and evaluation.
Criterion 3 [nutritional quality and adverse effects on human health]. This aspect is not adequately addressed in the document, particularly as it relates to the petitioned use of sodium orthophosphate in soy beverages purported to be nutritionally equivalent to cows' milk.

Relevant analyses were not provided on the effect of sodium phosphate use in a soy beverage purported to be nutritionally equivalent to cows' milk (a so-called "soymilk") and specifically on the overall mineral balance of the product. Soy is rich in phosphorus and poor in calcium. A varying proportion of the phosphorus is present as phytate (inositol hexaphosphate), which binds minerals like calcium and reduces their bioavailability. Adding phosphates can aggravate a nutritional imbalance between calcium and phosphorus. Similarly, adding sodium salts can create an imbalance between sodium and potassium.

Vegan parents sometimes feed soy beverages to their toddlers and small children as "milk." To gauge the nutritional impact of the use of sodium phosphate in these foods requires chemical analysis of the major minerals (calcium, phosphorus, magnesium, sodium, potassium, and chloride) in a soy beverage purported to be nutritionally equivalent to milk.

It may be that added phosphates are necessary for nutritional reasons, to meet compositional requirements for a soy beverage labeled as "soymilk" should FDA establish a standard of identify for foods so labeled.

Criterion 4 [technical effect in the food] is specified in the petition.

Criterion 5 [compatibility with organic handling]. The same reasoning that culminated in allowance of sodium orthophosphates for dairy products should hold for soy-based foods, except where nutritional considerations become critical due to the intended use and labeling of the food.

Criterion 7 [availability of alternative means]. The intended effect of sodium phosphate is to stabilize protein during heating or acidification. The petitioner so states: "The use of phosphates is always considered an essential part of a food formula whenever the food formulation contains protein that is subjected to heat or an acidic environment" (page 8, NOSB Petition of March 21, 2001).

However, this statement is an untrue overgeneralization in its use of the words "always," "essential" and "whenever." The petitioner has provided no objective evidence that alternative sequestrants (e.g., potassium citrate, sodium citrate, potassium phosphate, and potassium acid tartrate) cannot substitute for sodium phosphate. I am personally aware that citrates can replace phosphates in at least some of these applications (e.g., evaporated milk).... Thus, to paraphrase the language of the NOSB, "there is another way to produce the product without its use ... " The citrate salts are more environmentally friendly and more sustainable than the phosphates, and they are already on the National List and allowed for use in organic foods.

---

[2] *OMRI's information is enclosed is square brackets in italics. Where a reviewer corrected a technical point (e.g., the word should be "intravenous" rather than "subcutaneous"), these corrections were made in this document and are not listed here in the Reviewer Comments. The rest of the TAP Reviewer's comments are edited for any identifying comments, redundant statements, and typographical errors. Text removed is identified by ellipses [...]. Statements expressed by reviewers are their own and do not reflect the opinions of any other individual or organizations.*

NOSB Materials Database

Identification

Common Name **Sodium phosphates**

Chemical Name

Other Names Monobasic, Dibasic, Tribasic; Disodium (Mono- or Tri- sodium) Monohydrogen Phosphate

Code #: CAS

Code #: Other

N. L. Category Synthetic Allowed

MSDS ● yes ○ no

Chemistry

Family

Composition NaH_2PO_4, Na_2HPO_4, Na_3HPO_4

Properties All forms are anhydrous or contain one or more molecules of water of hydration. White, crystalline powder or granules. Anhydrous form is hygroscopic. Freely soluble in water and insoluble in alcohol.

How Made

Use/Action

Type of Use Processing

Specific Use(s) pH control agent (buffer), "Coagulant", stabilizer; emulsifier; texturizer; nutrient; dietary supplement.

Action

Combinations

Status

OFPA

N. L. Restriction

EPA, FDA, etc FDA-GRAS

Directions

Safety Guidelines

State Differences

Historical status

Internationl status

Comments on the petition.

The term "soymilk" is not universally accepted as the "common or usual name" of the beverage made with whole soybeans. The *FDA Consumer* magazine has published articles on soy. According to one article, "*'Soymilk,'* the name some marketers use for a soy beverage, is produced by grinding dehulled soybeans and mixing them with water to form a milk-like liquid. It can be consumed as a beverage or used in recipes as a substitute for cow's milk. Soymilk, *sometimes fortified with calcium*, comes plain or in flavors such as vanilla, chocolate and coffee. For lactose-intolerant individuals, it can be a good replacement for dairy products." (*FDA Consumer)* [Emphasis the reviewer's.]

In 1997, the Soyfoods Association of North America (SANA) filed a citizen petition requesting that FDA issued a regulation to recognize the term "soymilk" as the common or usual name for these products. See FDA/CFSAN Docket No. 97P0078/CP. SANA also proposed compositional specifications for products bearing the name of "soymilk." However, in May 2000, only 1 in 8 commercially available "soymilk" products met the compositional requirements for "soymilk" proposed by SANA [May 24, 2000, letter of C. Burnett of White Wave, Inc. to FDA].

The TAP document not withstanding, the petitioner is requesting allowance of far more than just the sodium salts of orthophosphate. The petitioner makes the statement "These phosphates . . . may be composed of aluminum . . . or sodium salts" (page 9). EAFUS and 21CFR 182.1781 show that "sodium aluminum phosphate" is allowed in food. Several recipes in the petition contain "sodium phosphate" but it is sodium ***aluminum*** phosphate . . . [*in*] Fanny's fat-free foods Ingredient Statement pages, and others. [Emphasis the reviewer's.]

The TAP document not withstanding, the petitioner is requesting allowance of sodium salts of far more than just orthophosphoric acid. The "Selected Definitions" page shows "sodium hexametaphosphate." Other recipes show sodium acid pyrophosphate and sodium tripolyphosphate. "Polyphosphates are made by heating mixtures of orthophosphates to high temperatures where they condense into phosphate chains." (FMC "Food Phosphates" document). This latter statement indicates that a separate TAP review of polyphosphates and pyrophosphates is needed due to the more drastic conditions required for their production.

The petitioner points out four abstracts as being critical but included none of the full articles in the petition. The abstracts are not detailed enough for thorough evaluation.

Reviewer 2 *[West coast--Consultant to organic certifiers]*

CHEMICAL/PROCESSING PROPERTIES, CATEGORIZATION AS SYNTHETIC OR NON-SYNTHETIC:

Sodium phosphates are easily soluble in water. They have a variety of uses in food processing, as mentioned in the database. This reviewer has not found any sources that describe sodium phosphates as being derived from natural sources. Rather, production comes from a neutralization of phosphoric acid by sodium hydroxide or sodium carbonate (Davidson, 2000). As such, sodium phosphates should be considered synthetic materials under OFPA guidelines.

NOSB processing criterion #1 states: "A synthetic processing aid or adjuvant may be used if it cannot be produced from a natural source and has no organic ingredients as substitutes." This is partially fulfilled for the case of sodium phosphates. There are no non-synthetic sources available. However, non-synthetic additives do exist that have similar effects on soy products as requested by the petitioner. Also, organic ingredients could conceivably be used – examples might be lecithin, oils, and starches, either by themselves or in combination, with or without inclusion of non-synthetic additives, to achieve the desired effect. For example, soymilk has been manufactured for many years without sodium phosphates. Additional ingredients to the soybeans include such things as calcium carbonate, lecithin, vegetable oils, kombu, and others. See below under "Uses/Essentiality/Compatibility" for more discussion.

ENVIRONMENTAL CONSIDERATIONS:

Manufacture of sodium phosphates is an industrial process. . . Production of sodium phosphates from the reactants involves yet more processes, each having concomitant added environmental impact.

Sodium phosphates are readily soluble in water into their ionic components. These ions are found in all organisms, and in and of themselves do not necessarily pose a significant environmental hazard, unless they occur at abnormally high levels. The control of effluent from sites of high sodium phosphate concentration could have detrimental impact on soils due to increased sodium content. Release of large amounts of phosphates into aquatic systems has been shown to cause algal blooms that in turn result in the death of higher species, as the algae deprive the other organisms of oxygen and other nutrients necessary for survival. This would be the case more for trisodium phosphate than for the mono- and di-sodium forms. . .

Please address the 7 criteria in the Organic Foods Production Act:

(comment in those areas you feel are applicable)

(1) the potential of such substances for detrimental chemical interactions with other materials used in organic farming systems;

Not Known.

(2) the toxicity and mode of action of the substance and of its breakdown products or any contaminants, and their persistence and areas of concentration in the environment;

Not Known.

(3) the probability of environmental contamination during manufacture, use, misuse or disposal of such substance;

Not Known.

(4) the effect of the substance on human health;

– Anhydrous forms may cause mild irratation of skin, mucous membranes

(5) the effects of the substance on biological and chemical interactions in the agroecosystem, including the physiological effects of the substance on soil organisms (including the salt index and solubility of the soil), crops and livestock;

Not Known.

(6) the alternatives to using the substance in terms of practices or other available materials; and

Not Known.

(7) its compatibility with a system of sustainable agriculture.

~~Ok~~ only for specific application – i.e. boiler descaling, sugar refining and sequaterant.

The amounts and concentrations proposed for use in the processing of organic foods do not necessarily approach the toxic levels needed to cause the results mentioned above. Presumably discharge of such concentrations into the environment could and should be regulated by other governmental agencies.

There are some precautions to be taken when handling certain sodium phosphates (Cherimishinoff, 1999), but these do not appear to be unduly onerous, especially when compared with other materials one might encounter in a processing facility that manufactures both conventional and organic products.

NOSB processing criterion #2 is, in the opinion of this reviewer, fulfilled.

NUTRITIONAL / HUMAN HEALTH EFFECTS:

Both phosphate and sodium are essential ions in human metabolism. Some studies offered by the database suggest that sodium taken in the diet as sodium phosphates may be correlated to displacement of calcium from the body (Boivin and Kahn, 1998), but there is equally compelling data which suggest that perhaps this is not a significant threat (Whiting, et al, 1997).

Elevated sodium intake is widely known to contribute adversely to a number of circulatory and other diseases in humans, but the amounts afforded by the proposed use of sodium phosphates is not deemed by this reviewer to constitute a significant added threat, especially if normal food labeling guidelines are followed by the manufacturer, whereby sodium content of the food product would be noted. Furthermore, concerns about sodium content in the human diet should not be based solely on one type of food product. Overall dietary consumption of sodium is part of a larger regimen; those persons concerned with excessive sodium intake should simply avoid foods made with extra sodium, and many alternatives exist, even if sodium phosphates were allowed in organic systems as proposed by the petitioner. . .

In the types of processes and amounts proposed for use by the petitioner, there is no reason to suspect any short-term negative consequences of their inclusion in human food, from a nutritional or health standpoint. Again, the long-term effects of ingestion are not conclusive. It is the opinion of this reviewer that NOSB processing criterion #3 is fulfilled to an extent that would not categorically prohibit the use of sodium phosphates from processing of organic foods.

On the other hand, there is nothing presented in the database or by the petitioner that indicates any positive nutritional or health effect from use of sodium phosphates in processing of organic food. It is clear that phosphate and sodium both can be gained in the diet through a multitude of other more unquestionably beneficial food sources. In summary, evaluations of the effects of sodium phosphates in the human diet are at best neutral, and may in time be shown to be detrimental, either slightly or more significantly so.

Uses / essentiality / compatibility with organic systems and principles:

One of the petitioner's reasons for wanting to use sodium phosphates is that they increase the stability of soy-based products. Such functions as they pertain to preservative types of actions should be construed as not meeting NOSB processing criterion #4 ("...it is not used as a preservative... "). . .

The petitioner does not dispute such ideas when considering more traditional soy-based products, but rather presents other rationale for the use of sodium phosphates. This rationale is based on the desire to produce certain food products whose organoleptic characteristic differ from those soy-based products that are made using already accepted additives (such as magnesium chloride, nigari, calcium sulfate, lecithin, other emulsifiers, oils, already approved non-synthetic non-organic ingredients, etc.). This may in fact be the case for certain formulated products that the petitioner wishes to market as organic. The combination of the sodium phosphate(s) with certain ingredients and using specific manufacturing techniques may indeed result in products with different textures and usability than those made without it. What the petitioner seems to be claiming is that use of sodium phosphates is essentially creating characteristics of the final food that would otherwise not be possible.

NOSB/OFPA criteria for evaluation of materials used in processing of organic foods do not specifically address such proposals. NOSB criterion #4 refers to the re-creation of flavors, textures, etc., but not the actual creation of new or otherwise unachievable characteristics. Organic certification is a process-based certification. The basis of standards is therefore not a list of materials, but rather is a set of practices, the materials being a support to that, and not vice versa. The question then arises as to whether or not such additives in organic foods are appropriate, given the fact that sodium phosphates are synthetic materials arising from industrial processes that themselves have environmental impact, and have not evolutionarily been included as part of the human diet. This is especially relevant when considering the uncertainty of the human health effects caused by more regular intake of sodium phosphates, as noted earlier in this review.

TAP REVIEWER COMMENT FORM for USDA/NOSB

Use this page or an equivalent to write down comments and summarize your evaluation regarding the data presented in the file of this potential National List material. Complete both sides of page. Attach additional sheets if you wish.

This file is due back to us by: August 29, 1995

Name of Material: Sodium Phosphates

Reviewer Name: Dr. Joseph Montecalvo

Is this substance Synthetic or non-synthetic? Explain (if appropriate)

Synthetic - ie for Mono, Di and tribasic forms.

If synthetic, how is the material made? (please answer here if our database form is blank)

Manufacturing in "Faith, Keyes and Clark's Industrial Chemicals - John Wiley N.Y. 4th ed, 1975) - I do not have a copy and none in Library.

This material should be added to the National List as:

✓ Synthetic Allowed ____ Prohibited Natural

or, ____ Non-synthetic (Allowed as an ingredient in organic food)

____ Non-synthetic (Allowed as a processing aid for organic food)

or, ____ this material should not be on the National List

Are there any use restrictions or limitations that should be placed on this material on the National List?

Please comment on the accuracy of the information in the file: -O.K.

Any additional comments? (attachments welcomed)

- Used as a Sequestrant, Emulsifier and buffer in foods. As a mordant in dyeing in tanning, in manufacture of Enamels, ceramics, detergents and boiler compounds ⊛ in baking powders. Tribasic is used as clarifying agent in sugar refining and removing boiler scale.

Do you have a commercial interest in this material? ____ Yes; [✓ No]

Signature

Date 7/31/95

The petitioner claims that the essentiality of sodium phosphates in the formulations desired for marketing in the organic sector are manufactured as such so that they may mimic and compete with similar products that are dairy-based (Amin, 2001).

From such considerations as elaborated in the preceding two paragraphs, this reviewer is of the opinion that NOSB processing criterion #6 ("its use is compatible with the principles of organic handling") is not met.

Furthermore, to label such formulations as "organic food" seems to fail NOSB criterion #7, which states: "there is no other way to produce a **similar** product without its use and it is used in the minimum quantity required to achieve the process" (emphasis added). The petitioner claims that their food products made with additives other than sodium phosphates do not adequately equal traditional dairy-based counterparts, even though the products are in fact similar. On the other hand, labeling such foods as being "made with organic ingredients" would be a true statement."

Conclusion: 95% organic— synthetic, prohibited, no annotation. Made with organic— synthetic, allowed, no annotation.

Reviewer 3 *[West Coast–Ph.D., Food Science and Nutrition professor with inspection and certification experience]*

Overview

All life forms known to exist contain phosphorus as the phosphate anion. Polyphosphates to include di- and tri-phosphates play a central role in energy metabolism since it is the transfer of one phosphate of adenosine triphosphate that provides the means of energy transfer for every living cell. Phosphorous in the form of the phosphate anion is a constituent of nearly every type of food consumed by living organisms (Ellinger, 1972). Therefore the role of phosphorous in human cell bioenergetics is well established in the biochemical literature.

Phosphate in Food Processing

Functionality of phosphates in food depends on their ability to form complexes and reaction products with constituents of foods.

Phosphates have been used in food in the preparation of beverage powders, as leavening acids in chemical leavening systems, in cheese and dairy product beverages, puddings, coffee whiteners, whipped toppings, ice cream products, cream cheese and cheese spreads, and egg products. Additionally, phosphates are used in the refining of food oils, and reduction in the rate of lipid oxidation in muscle food systems. Phosphates have also shown to function as microbiological inhibitors Therefore, phosphates in the mono, di and tri forms have been and are used extensively in many food systems (Considine, 1982).

Regulatory Status

The US Food and Drug Administration considers use of sodium mono, di and tri phosphates as generally recognized as safe. Initially some types of phosphate were thought not to be safe. For example the cyclic metaphosphates showed upon ingestion a high urinary output. Further research has shown that the metaphosphate must first be hydrolyzed to the triphosphate and then to the orthophosphate before it can be absorbed (Ellinger, 1972). Sodium phosphate in the mono, di and tri basic forms are provided GRAS status (Ellinger, 1972).

Nutritional and Toxicological Issues

Sodium phosphate in all of its chemical forms has been approved as a dietary supplement (Ash and Ash, 1995). However, recent evidence suggests that there may be a relationship between high dietary levels of protein and phosphate that may increase urinary calcium excretion. Additionally, a recent report indicated that oral sodium phosphate when taken for bowel preparation (i.e. examination) may cause electrolyte shifts in patients resulting in death of elderly or seriously ill patients (Boivin and Kahn, 1998). Additionally, a study comparing bladder tumor promoting characteristics of sodium phosphate and sodium diphosphate with preformed nitrosamines showed that sodium phosphate, a urine alkalizer, demonstrated tumor promoting activity in rats initiated by N-butyl-N-4hydroxy butyl nitrosamine (BBN) (Shibata, et al, 1993). The authors suggested further study to better understand how the sodium phosphate in the presence of carcinogens such as nitrosamines function to possibly act as tumor promoters.

Overall, the literature contains many studies on the nutritional and potential toxicological effects of phosphates in food. However, after over forty years of research, few definitive conclusions have been made.

Additional Effects of Phosphates

It is well known that phosphate detergents may play a significant role in eutrophication. However, a database may be useful if detergents and/or cleaning compounds containing phosphate come up for review. Additionally, I think it would be wise to collect basic information on phosphate mining, sodium hydroxide and sodium carbonate manufacture...

Please address the 7 criteria in the Organic Foods Production Act:
(comment in those areas you feel are applicable)

(1) the potential of such substances for detrimental chemical interactions with other materials used in organic farming systems;

NO ISSUE

(2) the toxicity and mode of action of the substance and of its breakdown products or any contaminants, and their persistence and areas of concentration in the environment;

NO ISSUE

(3) the probability of environmental contamination during manufacture, use, misuse or disposal of such substance;

MINING! SODIUM CARBONATE (TRONA)
PHOSPHATE ROCK

(4) the effect of the substance on human health;

SODIUM & PHOSPHATE ARE ESSENTIAL MINERALS

(5) the effects of the substance on biological and chemical interactions in the agroecosystem, including the physiological effects of the substance on soil organisms (including the salt index and solubility of the soil), crops and livestock;

POSITIVE

(6) the alternatives to using the substance in terms of practices or other available materials; and

CITRATES CAN REPLACE PHOSPHATES IN SOME DAIRY APPLICATIONS

(7) its compatibility with a system of sustainable agriculture.

OK

Summary of Findings

Sodium phosphate in its mono-, di-, and tri- forms is being petitioned for inclusion on the NOP. Presently it is approved for use in dairy products. Sodium phosphate (mono, di and tri) is GRAS as determined by FDA [XXX note this conflicts with his answer below] Overall, since the NOSB approved its use for dairy products, it is hard to argue on any scientific basis why it cannot be used in other food systems. It is clearly a synthetic food additive that should have been prohibited in 1995 if only organic principles were applied. Therefore, I feel that on a purely scientific basis, sodium phosphate (mono-, di-, and tri-) should be classified as synthetic, allowed with a suggested annotation to the usage levels as required by FDA 21 CFR, inclusive of any product categories (i.e., not just dairy and soy).

The TAP Reviewers were also asked the following questions:

Similar questions were posted to the OMRI web site, and no information was received from the public by the deadline. Where a Reviewer is not mentioned, the Reviewer did not have comments on the question.

1) *Additional references requested.*

All three reviewers provided additional references that were integrated into the TAP review. Other comments:

Reviewer 1: The petitioner failed to include references establishing the essentiality of "sodium phosphate" for a purported "soymilk" manufacture. Thus, specific references documenting the use of sodium phosphates in "soymilk' cannot replace specific references that should prove that sodium phosphates are essential for "soymilk" manufacture.

The literature citations of effects of sodium phosphate purgatives are not relevant to food use. This is especially true when the bowel cleansers were not used according to label instructions and were given to patients where the use of phosphate purgatives was medically contraindicated.

Relevant literature was not provided on the effect of sodium phosphate use in a so-called "soymilk" on the overall mineral balance of the product. Soy is rich in phosphorus, with a varying proportion of it bound as phytate (inositol hexaphosphate). Adding phosphates can create a nutritional imbalance between calcium and phosphorus. Similarly, adding sodium salts can create an imbalance between sodium and potassium.

Reviewer 3: Review of the literature provides little evidence of the ability of phosphates to function as tumor promoters and play a role in carcinogenisis.

2) *OMRI did not include numerous references to dairy products for which the petitioner is substituting. If any of these are particularly relevant, please let OMRI know. Ellinger's 1972 survey has over 1,000 references, and many more references have come out since then. Very few seem to specifically address what is in the petition or the OFPA criteria.*

Reviewer 1: The physical and technological effects may be quite similar but the nutritional impact of added sodium phosphate on a calcium-rich milk system with a balanced calcium-to-phosphorus ratio is very different than the impact of added sodium phosphate on a calcium-poor so-called "soymilk" containing a lot of phosphorus.

Reviewer 3: According to the petition page 4, there are no other acceptable substitutes for phosphates, perhaps based on cost, functionality, product stability requirements during large scale manufacturing operations, and required product stability for shelf life considerations. I am sure that the soymilk I may make at home does not require phosphates because it is consumed in a matter of hours or days without any further processing. Therefore the petition seems to suggest that commercial manufacture requires the soymilk to be stabilized and therefore lies the nature or reason for the petition.

3) *Is there any documentation on sodium phosphates' uses in certified organic products prior to the 1995 NOSB recommendation for use in dairy products?*

Reviewer 1: I believe that the answer is yes, according to my recollection of the correspondence to the NOSB from industry in 1992-1995 on soy-based beverages.

Reviewer 2: A wide variety of soy-based products have been manufactured for a very long time without the use of sodium phosphates. From this standpoint, the need for sodium phosphates could be deemed to not be essential.

Reviewer 3: I have no references to document use of sodium phosphate in certified organic product prior to 1995.

TAP REVIEWER COMMENT FORM for USDA/NOSB

Use this page or an equivalent to write down comments and summarize your evaluation regarding the data presented in the file of this potential National List material. Complete both sides of page. Attach additional sheets if you wish.

This file is due back to us by: August 29, 1995

Name of Material: Sodium Phosphates

Reviewer Name: R THEUER

Is this substance Synthetic or non-synthetic? Explain (if appropriate)

SYNTHETIC

If synthetic, how is the material made? (please answer here if our database form is blank)

This material should be added to the National List as:

✓ Synthetic Allowed

___ Prohibited Natural

or, ___ Non-synthetic (Allowed as an ingredient in organic food)

___ Non-synthetic (Allowed as a processing aid for organic food)

or, ___ this material should not be on the National List

Are there any use restrictions or limitations that should be placed on this material on the National List?

LIMITED BY GOOD MANUF. PRACTICES

Please comment on the accuracy of the information in the file:

GOOD

Any additional comments? (attachments welcomed)

SIMILAR TO POTASSIUM PHOSPHATE

Do you have a commercial interest in this material? ___ Yes; ✓ No

Signature ______ **Date** 8/28/95

4) *What do other soy milk manufacturers use?*
Reviewer 2 did not answer this question regarding soy milk but provided considerable comment on ingredients used in various other dairy substitutes.

5) *There is substantial literature on the medical applications and health effects of sodium phosphates that OMRI has not summarized in the TAP review, other than to note that it exists. Some potential areas to include for OFPA criteria question 4--The effects of the substance on human health:*

Reviewer 1: The health effects discussion in the document is too heavily weighted to pharmacological, pharmaceutical and toxicological aspects and not enough to the nutritional aspects.

Reviewer 3 did not respond to any of the items below in reference to 5, but instead verified the references used for processing criteria question 2 and suggested that it may be appropriate to cite additional references.

a) *One source describes trisodium phosphate as a tumor promoter, but it is not listed as such by NTP or IARC. Are there any additional references of any of the sodium phosphates?*

Reviewer 1: Trisodium phosphate is an extremely caustic material; note the pH value of 12 described in the base document. In a food system the use of a sodium phosphate is 'normally' at levels consistent with good manufacturing practices. I can think of no foods with a pH of 12 (equivalent to 0.01 N sodium hydroxide).

Reviewer 2: . . . the OMRI database includes reference to promotion of bladder cancer in rats fed trisodium phosphate (Shibata, et al), but this study in and of itself does not seem to be strong enough evidence to support significant concern of the petitioner's proposed use of sodium phosphates.

Reviewer 3: Review of the literature provides little evidence of the ability of phosphates to function as tumor promoters and play a role in carcinogenisis.

b) *What is the connection between sodium phosphates and osteoporosis? Specifically, do sodium phosphates increase, decrease, or have no effect on osteoporosis? Is there a difference between use in dairy foods and soy foods based on the different calcium and phosphate levels contained in those foods?*

Reviewer 1: I believe that the evidence is convincing that a high phosphate, low calcium diet will predispose to osteoporosis. More critically, a high calcium intake prior to menarche increases the bone calcium level in women. Thus, the use of added phosphate salts in a so-called "soy<u>milk</u>" needs to be guided by nutritional considerations of calcium-to-phosphorus ratio, etc.

Reviewer 2: Questions have been posed as to whether or not increased ingestion of sodium phosphates contributes in some way to osteoporosis, but there is no conclusive research offered to show that this is absolutely the case. These issues may be part of a larger question regarding the intake of phosphates in general, and their relation to calcium use by the body.

Uncertainty stems from several factors, among which are: (i) The interactions of phosphates and calcium in the body is not completely understood. Balance of the two is also dependent on a variety of other physiological factors, including hormone and vitamin levels (Vander, 1980). Much of the interactions on a cellular and wider physiological level are simply not adequately known. (ii) Individual human metabolism varies considerably from one person to another, based on genetics, body type, diet, lifestyle, and environmental exposure. (iii) Patterns of osteoporosis in the human population have not been well discerned to date. It is possible that increased documentation of the incidence of osteoporosis in the population over the next generation or so will reveal more convincing patterns. . . .

Reviewer 3 provided references that were incorporated in, and made the following statement:
In principle I am not in favor of the use of any synthetic additive or ingredient in organic food systems. In reality a decision was made to allow phosphates for use in dairy products. The literature warns us of the effects of increased phosphorous in the diet and its negative effect on calcium absorption and retention in bone. However, the usage levels as mandated by FDA mitigate this concern..
. . . [U]se of phosphates, in my opinion will contribute to the amount of phosphorous in the diet and may contribute to less calcium being absorbed. This is especially important in young children and older people who may be in osteoporatic conditions. It would be interesting to know what the ratio of calcium to phosphorous is in soymilk with and without the

NOSB/NATIONAL LIST
COMMENT FORM
PROCESSING

Material Name: #22 Sodium Phosphates

Please use this page to write down comments, questions, and your anticipated vote(s).

COMMENTS/QUESTIONS:

---

1. In my opinion, this material is:
_____ Synthetic _____ Non-synthetic.

2. Should this material be allowed in an "organic food" (95% or higher organic ingredients)? _____ Yes _____ No
(IF NO, PROCEED TO QUESTION 3.)

3. Should this substance be allowed in a "food made with organic ingredients" (50% or higher organic ingredients)? _____ Yes _____ No

added sodium phosphates. Without this data, it would be difficult to assess the specific availability of calcium from soy food and beverage products.

c) *Does sodium phosphate increase the excretion of calcium in [urine]? Most studies seem to suggest that it does not, but individual cases have been reported in the literature. Should the adverse health impact on a subgroup of the population be listed, even if adverse health impacts are not observed on most people?*

Reviewer 1: The chronic (rather than acute) effects of "soymilk" consumption by children and adolescents (rather than by elderly individuals with kidney failure) are much more relevant to the OFPA criteria in evaluating sodium phosphate use in a food labeled as "soymilk."

Reviewer 2: There is the possibility that increased intake of phosphates in the diet may lead to calcium depletion from the body, but this could likely be due to all types of phosphates as opposed to only sodium phosphates. For example, the increased consumption, especially by female youths and teenagers, of soft drinks containing phosphoric acid (in the diet in place of milk, fruit juices, plain water, or other non-synthetic drinks) may eventually show itself convincingly to be part of a pattern that leads to such diseases as osteoporosis. However, despite the possible validity of such concern, without some solid epidemiological or similar public health data, it is too early to actually draw such conclusions. For these reasons, it does not seem reasonable to this reviewer at this time to dwell on adverse health effects of sodium phosphates as recorded in individual cases, or to assume that the problems linked to dietary intake of phosphates (sodium or otherwise) is that simple or straightforward.

d) *Any other medical and health effects that should be included in the TAP review?*
None of the reviewers suggested anything specific. Reviewer 1 referred to the response to 5c.

6) *Compatibility (Processing criteria question 6: Its use is compatible with the principles of organic handling.): Any references to add in the discussion of the compatibility of imitation v. real products in organic?*

Reviewer 1: I believe that the regulators best make this value judgment. "Soymilk" is not a legal term, since "milk" has a legal definition. What we refer to as "soymilk" is a "soy beverage." These foods are "real' soy beverages. Should the FDA ever create a standard of identity for "vegetable milk," this would be the forum for substantive and philosophical comments.

7) *Alternatives (Processing criteria question 7: There is no other way to produce a similar product without its use and it is used in the minimum quantity required to achieve the process.): By definition, dairy products are similar. However, there is a segment of consumers that demand organic vegan substitutes for dairy products. How is this best explored and explained?*

Reviewer 1: Potassium citrate can replace sodium phosphate in both dairy and in soy beverage processing, with some documentation available on a case-by-case basis.

The Food and Drug Administration and the Federal Trade Commission are charged with enforcing true and non-misleading labeling and advertising, respectively, with regard to these foods. Thus, this question is outside the aegis of both the NOSB and the USDA except as it relates to the use of the term 'organic'.

Reviewer 2: The choice of some consumers to buy and eat non-dairy foods is valid. However, the need to market such foods as being functionally and organoleptically equivalent to their dairy-based analogues is, in this reviewer's opinion, questionable. The need for consumers to have substitute or "mock" products so that they can alter their nutritional intake by simply substituting their habitual food choices with "fake" analogues is questionable. Consumers of organic food might consider a more broad or holistic approach to food preparation to satisfy their own dietary choices. The NOSB might want to address the question, Do such substitutions result in as complete a diet and nutrition for the consumer? As a simplistic example, soymilk is not recommended to replace dairy milk for feeding infants. It must be acknowledged that despite continual advances, mankind's knowledge of his nutritional requirements is incomplete. Compliance with organic certification requirements often demands creativity of the farmer, and of the processor… .

Reviewer 3: In review of the petition and from review of the literature I am not aware of a suitable alternative to sodium phosphate that possesses the same functionality, cost, availability and usage levels. In my opinion there is not available any non-synthetic alternative.

NOSB NATIONAL LIST
FILE CHECKLIST

PROCESSING

MATERIAL NAME: #22 Sodium Phosphates

✓ NOSB Database Form

✓ References

✓ MSDS (or equivalent)

✓ FASP (FDA)

✓ TAP Reviews from: Joe Montecalvo, Rich Theuer

References

*Note: * = included in packet*

Alais, E. C. and G. Linden. 1991. *Food Biochemistry* West Sussex, UK: Ellis Horwood.

* Amin, S.R. 2001. Petition to the National Organic Standards Board to amend the National List of Allowed Substances to include sodium phosphates for use in food and beverage products formulated with soymilk and dry soymilk similar to or equivalent to dairy products. Farmingdale, NY: Carousel Foods of America.

Anil M., S. Demirakca S, J. Dotsch, and W. Kiess. 1996. [Hypocalcemic tetany in 'alternative' soy milk nutrition in the first months of life] [Article in German; reviewers relied on abstract in English] *Klinische Padiatrie* 208: 323-6

Abteilung Allgemeine Padiatrie und Neonatologie, Justus Liebig Universitat Giessen.

* Ash, M. and I. Ash. 1995. *Handbook of Food Additives.* Brookfield, VT: Gower Publishing.

Ashford, R.D. 1994. *Ashford's Dictionary of Industrial Chemicals.* London: Wavelength Publishers, Ltd.

Astaris LLC. No date. Food phosphates. St. Louis, MO: Solutia.

* Boivin, M.A. and S.R. Kahn. 1998. Symptomatic hypocalcemia from oral sodium phosphate: A report of two cases. *American Journal of Gastroenterology* 93: 2577-2579.

Budavari, S. 1996. *Merck Index.* Whitehouse Station, NJ: Merck & Co.

Burnett, C. 2000. Comment on [FDA] docket number 97P0078/CP.

California Certified Organic Farmers (CCOF). 2000. *Certification Handbook.*

Canadian General Standards Board (CGSB). 1999. *Organic Agriculture.* Ottawa: CGSB.

Carvalho N.F., R.D. Kenney, P.H. Carrington PH, and D.E. Hall 2001. Severe nutritional deficiencies in toddlers resulting from health food milk alternatives. *Pediatrics* 107. http://www.pediatrics.org/cgi/reprint/107/4/e46.pdf

* Cheremishinoff, N.P. 1999. *Handbook of Industrial Toxicology and Hazardous Materials.* New York: Marcel Dekker.

* Considine, D.M. and G.D. Considine. 1982. *Foods and Food Production Encyclopedia.* New York: Van Nostrand Reinhold.

* Davidson, P.M. 2000. Antimicrobial compounds, in F.J. Francis (ed.) *Encyclopedia of Food Science and Technology* 1: 63-75. New York: Wiley.

de Man, J. (ed.) 1990. *Principles of Food Chemistry*, 2nd ed.. New York: Van Nostrand Reinhold.

* Dybing, S.T. and D.E. Smith. 1998. The ability of phosphates or κ-carrageenan to coagulate whey proteins and the possible uses of such coagula in cheese manufacture. *Journal of Dairy Science* 81: 309-317.

* Ellinger, R.H. 1972. Phosphates in food processing, in T.E. Furia (ed.) *CRC Handbook of Food Additives* (2nd ed.): 617-780. Cleveland, OH: CRC Press.

European Communities. Council Regulation (EEC) No 2092/9 of 24 June 1991 on organic production of agricultural products and indications referring thereto on agricultural products and foodstuffs.

FAO/WHO Joint Standards Programme. 1999. *Codex Alimentarius Guidelines for the Production, Processing, Labelling and Marketing of Organic Processed Foods.*CAC/GL 32-1999. Rome, Italy: FAO/WHO.

Fennema, O. (ed). 1985. *Principles of Food Chemistry* Ed. New York: Dekker.

FMC Corporation. no date. Food phosphates: Chemistry, nomenclature, and general functions. Philadelphia: FMC Corporation.

* Gard, D.R. 1996. Phosphoric acids and phosphates, in J.I. Kroschwitz (ed.) *Kirk-Othmer Encyclopedia of Chemical Technology,* (4th ed.) 18: 669-718. New York: John Wiley & Sons.

Gordon, D.T. and J.M. Klimek. 2000. Minerals, in G.L. Christen and J.S. Smith (eds) *Food Chemistry: Principles and Applications.* West Sacramento, CA: Science Technology Systems.

* Gosselin, R.E., R.P. Smith, and H.C. Hodge. 1984. *Clinical Toxicology of Commercial Products* (5th ed.) Baltimore: Williams and Wilkins.

* Heidolph, B.B. and D.R. Gard. 2000. Phosphates and food processing in F.J. Francis (ed.) *Encyclopedia of Food Science and Technology* 3: 1881-1885. New York: Wiley.

Horsford, E.N. 1864. Improved double phosphate of lime and soda for culinary and other purposes. US Patent #42,140.

Hui, Y.H. 2000. Soybeans and Soy Processing, in F.J. Francis (ed.) *Encyclopedia of Food Science and Technology* 4: 2185-2190. New York: Wiley.

International Federation of Organic Agriculture Movements (IFOAM) General Assembly 2000. IFOAM Basic Standards for Organic Production and Processing. IFOAM, Tholey-Theley, Germany.

Kraft, J.L. 1916. Process of sterilizing cheese and an improved product produced by process. US Patent #1,186,524.

Lindsay, R.C. 1996. Food Additives, in O.R. Fennema (ed.) Food Chemistry: 767-823. New York: Marcel Dekker.

Miller, D.D. 1996. Minerals, in O.R. Fennema (ed.) Food Chemistry: 617-649. New York: Marcel Dekker.

Ministry of Agriculture, Forestry and Fisheries of Japan. Japanese Agricultural Standard of Organic Agricultural Products, Notification No. 59, Unofficial Translation 2001. Ministry of Agriculture, Forestry and Fisheries, Japan.

* Molins, R.A. 1991. *Phosphates In Food*: 8-13, 235-251. CRC Press.

*NOSB. 1995. Technical Advisory Panel Review, Sodium Phosphates.

* _____. 1995. Final Minutes of the National Organic Standards Board Full Board Meeting. Austin, Texas. October 31-November 4, 1995. Vote and decision on sodium phosphates.

Piper, C.V. and W.J. Morse. 1923. *The Soybean.* New York: McGraw-Hill.

Organic Crop Improvement Association (OCIA). July 1, 2001. *International Certification Stnadards.*

Oregon Tilth Certified Organic (OTCO). April 30, 1999. *Generic Materials List.*

______. December 7, 2000. Letter from Anne Plotto to Herb Stein of Natural Flavors.

Quality Assurance International (QAI). December 14, 2000. Letter from Samara Perrell to Carousel Foods.

Raj, S. 1991. *The Attitudes of Processors and Distributors Towards Processing and Processing Guidelines in the Natural / Organic Foods Industry.* Syracuse, NY: Syracuse University Unpublished Ph.D. Dissertation.

Rippen, A.L. 1986. Cheesemaking Mechanization, in C.W. Hall, A.W. Farrell, and A.L. Rippen, *Encyclopedia of Food Engineering* 129-143. Westport, CT: AVI Press.

Shibata, M-A, M. Kagawa, M. Kawabe, A. Hagigara, and S. Fukushima. 1991. Comparative promoting activities of phosphate salts on rat two-stage bladder carcinogenesis under conditions of equalized urinary Na^+ or K^+ levels. *Teratogenicity, Carcinogenicity, Mutagenicity* 11: 305-316.

Cher mishnoff ~~2000~~ 1999

hysician. EYES or SKIN: flush with water; *Toxicity by alation (Threshold Limit Value)*: Data not available; *ort-Term Inhalation Limits*: Data not available; *Toxicity by Ingestion*: Grade 3, LD_{50} 50-500 mg/kg; *Late Toxicity*: Data not available; *Vapor (Gas) Irritant Characteristics*: Data not available; *Liquid or Solid Irritant Characteristics*: Data not available; *Odor Threshold*: Data not available.

Sodium Oxalate — (i) Chemical Designations — *Synonyms*: Ethanedioic acid; disodium salt; *Chemical Formula*: $Na_2C_2O_4$; **(ii) Observable Characteristics —** *Physical State (as shipped)*: Solid; *Color*: White; *Odor*: None; **(iii) Physical and Chemical Properties —** *Physical State at 15 °C and 1 atm.*: Solid; *Molecular Weight*: 134.0; *Boiling Point at 1 atm.*: Not pertinent (decomposes); *Freezing Point*: Not pertinent; *Critical Temperature*: Not pertinent; *Critical Pressure*: Not pertinent; *Specific Gravity*: 2.27 at 20 °C (solid); *Vapor (Gas) Specific Gravity*: Not pertinent; *Ratio of Specific Heats of Vapor (Gas)*: Not pertinent; *Latent Heat of Vaporization*: Not pertinent; *Heat of Combustion*: Not pertinent; *Heat of Decomposition*: Not pertinent; **(iv) Health Hazards Information —** *Recommended Personal Protective Equipment*: Dust mask; goggles or face shield; rubber gloves; *Symptoms Following posure*: Inhalation or ingestion causes pain in throat, ophagus, and stomach; mucous membranes turn white; other symptoms include vomiting, severe purging, weak pulse, cardiovascular collapse, neuromuscular symptoms, and kidney damage. Contact with eyes or skin causes irritation; *General Treatment for Exposure*: *Act promptly!* INHALATION: move to fresh air; if exposure to dust is severe, get medical attention. INGESTION: give dilute calcium lactate, lime water, or milk; administer gastric lavage; consult physician; watch for edema of the glottis and delayed constriction of esophagus. EYES or SKIN: flush with water; *Toxicity by Inhalation (Threshold Limit Value)*: Data not available; *Short-Term Inhalation Limits*: Data not available; *Toxicity by Ingestion*: Grade 3, LD_{50} 50-500 mg/kg; *Late Toxicity*: Data not available; *Vapor (Gas) Irritant Characteristics*: Data not available; *Liquid or Solid Irritant Characteristics*: Data not available; *Odor Threshold*: Data not available.

Sodium Phosphate — (i) Chemical Designations — *Synonyms*: "Sodium phosphate" is generic term and includes the following: (1) monosodium phosphate (MSP; sodium phosphate, monobasic), (2) disodium phosphate (DSP; sodium phosphate dibasic), (3) trisodium phosphate (TSP; sodium phosphate, tribasic), (4) sodium acid pyrophosphate (ASPP; SAPP; disodium pyrophosphate (TSPP), (6) sodium metaphosphate (insoluble sodium metaphosphate), (7) sodium trimetaphosphate, and (9) sodium tripolyphosphate (STPP; TPP); *Chemical Formula*: (1) NaH_2PO_4; (2) Na_2HPO_4; (3) Na_3PO_4; (4) $Na_2H_2P_2O_7$; (5) $Na_4P_2O_7$; (6) $(NaPO_3)_n$; (7) $(NaPO_3)_3$; (8) $(NaPO_3)_n$ NaO; (9) $Na_5P_3O_{10}$; **(ii) Observable Characteristics —** *Physical State (as shipped)*: Granular or powdered solid; some may appear glassy; *Color*: White; *Odor*: None; **(iii) Physical and Chemical Properties —** *Physical State at 15 °C and 1 atm.*: Solid; *Molecular Weight*: Values for anhydrous salt run from 120 to high polymer values; *Boiling Point at 1 atm.*: Not pertinent (decomposes); *Freezing Point*: Not pertinent; *Critical Temperature*: Not pertinent; *Critical Pressure*: Not pertinent; *Specific Gravity*: 1.8-2.5 at 25 °C (solid); *Vapor (Gas) Specific Gravity*: Not pertinent; *Ratio of Specific Heats of Vapor (Gas)*: Not pertinent; *Latent Heat of Vaporization*: Not pertinent; *Heat of Combustion*: Not pertinent; *Heat of Decomposition*: Not pertinent; **(iv) Health Hazards Information —** *Recommended Personal Protective Equipment*: U.S. Bu. Mines toxic dust mask; protective gloves; chemical-type goggles; full-cover clothing; *Symptoms Following Exposure*: Inhalation of heavy dust may irritate nose and throat. Ingestion may injure mouth, throat, and gastrointestinal tract, resulting in nausea, vomiting, cramps and diarrhea; pain and burning in moth may occur. Contact with eyes produces local irritation; can lead to chronic damage. Contact with skin produces local irritation; repeated or prolonged contact can lead to dermatitis; *General Treatment for Exposure*: If the following measures do not eliminate the symptoms, see a physician. INHALATION: give large amounts of water or warm salty water to induce vomiting; repeat until vomitus is clear; milk, eggs, or olive oil may then be given to soothe stomach. EYES: immediately flush with large amounts of water for at least 15 min., holding eyelids to ensure flushing or entire surface; avoid chemical neutralizers. SKIN: flush with water; avoid chemical neutralizers; *Toxicity by Inhalation (Threshold Limit Value)*: Data not available; *Short-Term Inhalation Limits*: Data not available; *Toxicity by Ingestion*: Data not available; *Late Toxicity*: Data not available; *Vapor (Gas) Irritant Characteristics*: Data not available; *Liquid or Solid Irritant Characteristics*: Data not available; *Odor Threshold*: Data not available.

Sodium Silicate — (i) Chemical Designations — *Synonyms*: Water glass; Soluble glass; *Chemical Formula*: Na_2SiO_3-$NaSiO_4$-H_2O; **(ii) Observable**

* Shibata, M-A, S. Masashi, T. Shirai, K. Imaida, and S. Fukushima. 1993. Epithelial hyperplasia in the renal papilla and pelvis, but not the urinary bladder of the male F344 rats associated with dietary sodium phosphates after uracil exposure. *Toxicology and Applied Pharmacology* 121: 303-312.

Shurtleff, W. and A. Aoyagi. 1985. *Tofutti and Other Soy Ice Creams.* Lafayette, CA: The Soyfoods Center.

Texas Department of Agriculture (TDA) Organic Certification Program. February 2000. *TDA Organic Certification Program Materials List.*

* Tidridge, W.A. and R. Pais. 1962. Dry Acidulents. US Patent No. 3,030,213.

US Environmental Protection Agency (EPA). 1995. List of Pesticide Product Inert Ingredients. Washington, DC: USEPA.

_______. 1997. The Clean Water Act: A Snapshot of Progress in Protecting America's Waters. http://www.epa.gov/owow/cwa/25report.html.

_______. 1998a. *EPCRA Section 313 Reporting Guidance for Food Processors.* Washington, DC: EPA Office of Pollution Prevention and Toxics.

_______. 1998b. *Title III List of Lists: Consolidated List of Chemicals Subject to the Emergency Planning and Community Right-to-Know Act (EPCRA) and Section 112(r) of the Clean Air Act, as Amended.* Washington, DC: EPA Office of Solid Waste and Emergency Response.

Vander, A.J. 1980. *Renal Physiology*, 2nd ed. New York: McGraw-Hill.

Wanasundara, P.K.J.P.D. and F. Shahidi. 1997. Functional properties of acylated flax protein isolates. *Journal of Agricultural and Food Chemistry* 45: 2431-2441.

Washington State Department of Agriculture (WSDA) Organic Food Program. January 18, 2001. *Chapter 16-158-060 WAC* in the section titled "Minor Ingredients and Processing Aids."

Watkins, B.A. 2000. Vitamins, in G.L. Christen and J.S. Smith, *Food Chemistry: Principles and Applications.* West Sacramento, CA: STS.

* Whiting, S.J., D.J. Anderson, and S.J. Weeks. 1997. Calciuric effects of protein and potassium bicarbonate but not sodium chloride or phosphate can be detected acutely in adult women and men. *American Journal of Clinical Nutrition* 65: 1465-1472.

Wong, M.M-Y. 1964. Effect of processing methods on the chemical and physical properties of soybean milks. Corvallis: Oregon State University Unpublished M.S. Thesis.

Wright, S. 1994. Other organic food products, in S. Wright (ed.) *Handbook of Organic Food Processing and Production:* 126-150. London: Blackie Academic and Professional.

* Yazici, F., V.B. Alvarez, M.E. Mangino, and P.M.T. Hansen. 1997. Formulation and processing of heat stable calcium-fortified soy milk. *Journal of Food Science* 62: 535-538.

This TAP review was completed pursuant to United States Department of Agriculture Purchase Order 40-6395-0-2900.

phates, which consists in spraying a solution of a sodium phosphate compound into a desiccating gaseous medium substantially inert with respect thereto to provide the phosphate in a substantially dry powdered condition, and then subjecting it while suspended in the said desiccating medium to heat of an intensity sufficient to convert the powdered phosphate to pyro-phosphate.

5. The method of preparing pyro-phosphates, which includes the step of heating particles of a sodium hydrogen phosphate while in suspension and in motion.

Signed at New York in the county of New York and State of New York this 14th day of November, A. D. 1923.

WALTER H. DICKERSON.

Patented Dec. 27, 1927. **1,654,283**

UNITED STATES PATENT OFFICE.

WALTER H. DICKERSON, OF EAST ORANGE, NEW JERSEY, ASSIGNOR TO INDUSTRIAL WASTE PRODUCTS CORPORATION, OF DOVER, DELAWARE, A CORPORATION OF DELAWARE.

METHOD OF PREPARING PYROPHOSPHATES.

No Drawing. Application filed November 15, 1923. Serial No. 675,012.

The invention relates to a method of treating materials to produce therein a desired physical or chemical change, or both, purely by the action of heat on said material, and has to do particularly with the production of pyrophosphate from sodium hydrogen phosphate. Operations of this character have ordinarily been carried on heretofore essentially as a furnacing operation, that is to say the material under treatment is subjected in mass to the action of heat and in a suitable furnace.

As a rule, certain definite critical temperature limits are necessary in the treatment of the material; and it is highly desirable, and in many cases necessary, that the temperature be maintained uniformly within the critical limits upon the said material thruout the heat treating process. This latter requirement, however, is difficult to meet when thus treating the material in mass, as different parts thereof will receive different degrees of heat.

Furthermore, some treatments of this character involve chemical action between the material and hot gases. The process forming the subject of the present invention does not, however, contemplate such action, but relates solely to a thermal effect. It has for its object a mode of heat treatment for materials, particularly sodium phosphate compounds, whereby the heat action may more effectively and more efficiently be applied to the material and which treatment will admit, also, of a close thermal control. To this end, the novel method of treatment consists essentially in first preparing the material in a dry and finely divided or comminuted state and then subjecting the same to heat of sufficient intensity to effect therein the desired physical or chemical change, or both, as by suspending, for example thru a spraying operation, the material in a gaseous medium in respect to which it is substantially inert. If the material processed is initially in liquid form this operation involves also a desiccating action, it being understood that the final effect on said material is due purely to thermal action and that the gaseous medium is substantially inert with respect to the material, serving merely as a convenient vehicle therefor in its finely subdivided state.

In the production of sodium phosphate compounds, known as pyro-phosphates, the present practice is to subject the sodium phosphate compounds to heat treatment, in trays, in a furnace where the temperatures on the material are maintained at approximately 425°–450° F. the material being removed after a predetermined time and ground to the desired degree of fineness. In accordance with the novel process forming the subject matter of the present application, the sodium phosphate compounds in finely divided state are for an appreciable period to be subjected to a heating zone at a temperature of from 426°–450° F., as while in suspension in a gaseous medium inert with respect to the material. The dry powdered material is then cooled and collected and is ready for use without any further processing. The process may also be carried out in a single step by spray-drying sodium phosphate solution, in manner well understood, and maintaining for an appreciable period the terminal temperature on the dry product to bring about the desired heat reaction necessary to produce the pyro-phosphate.

I claim:—

1. The method of preparing pyro-phosphates, which consists in preparing a sodium phosphate compound in a dry powdered condition, and subjecting the same while in suspension in a gaseous medium substantially inert with respect thereto to heat of intensity sufficient to convert the sodium phosphate compound to a pyro-phosphate.

2. The method of preparing pyro-phosphates, which consists in preparing a sodium phosphate compound in a dry powdered condition, subjecting the same in finely divided state to the action of a gaseous medium substantially inert with respect thereto and heated to an intensity sufficient to convert the sodium phosphate compound to a pyro-phosphate, and collecting the pyro-phosphate product.

3. The method of preparing pyro-phosphates, which consists in preparing a sodium phosphate compound in a dry powdered condition, and subjecting the same while in suspension in a gaseous medium substantially inert with respect thereto to a temperature of 425°–450° F. for an appreciable period.

4. The method of preparing pyro-phos-

Carousel Foods of America, Inc.
Manufacturers of Carousel • Cloud Ten
Missy's • Best Little Baker • Gel-eez • Preferred Soy
Fine Desserts

1

March 21, 2001

National Organic Standards Board
C/o Robert Pooler
Agricultural Marketing Specialist
USDA/AMS/TM/NOP
Room 2510-So.
Ag Stop 0268
P.O. Box 96456
Washington, D. C. 20090-6456

Received by OMRI
APR 27 2001

Subject: **Petition to Amend the National List**

Substances Petitioned: **Sodium Phosphates**

Specific Amendment Request: **To Include Sodium Phosphates on the National List for Use in Food and Beverage Products Formulated with Soymilk and Dry Soymilk Similar to or Equivalent to Dairy Products**

Dear Mr. Pooler,

We are writing you to request that the National Organic Standards Board consider the enclosed petition to amend the National List in its June 2001 meeting.

The reason for this petition is quite simple. Sodium phosphates are allowed for use in dairy products due to their versatility in food processing and their ability to allow researchers to create acceptable product formulations. Sodium phosphates are both commonly used and safe.

For the last 14 years, I have worked with soy directly or indirectly. I have been exposed to a full range of manufacturing and marketing activities with soy products. During 36 years of experience in the food industry, particularly in the dairy industry, I have come to appreciate the effort required to develop and market new products successfully. In my work with soy, I have felt that soy products, especially the dairy-like soy foods and beverages, have not received the level of consumer acceptance they deserve. I believe

45. W. D. Loomis and J. Battaile, "Plant Phenolic Compounds and Isolation of Plant Enzymes," *Phytochemistry* **5**, 423–438 (1966).
46. W. S. Pierpoint, "Phenolics in Food and Feedstuffs," in C. F. Van Sumere and P. J. Lea, eds., *Annual Proceedings of the Phytochemical Society of Europe*, Clarendon Press, Oxford, 1985, pp. 427–451.
47. A. Pollard and C. F. Timberlake, "Fruit Juice," in A. C. Hulme, ed., *The Biochemistry of Fruits and Their Products*, Vol. 2, Academic Press, New York, 1971.
48. I. Flament, "Coffee, Cocoa, and Tea," *Food Rev. Int.* **5**, 317–414 (1989).
49. S. C. Fry, "Incorporation of Cinnamate into Hydrolase-Resistant Components of the Primary Cell Wall of Spinach," *Phytochemistry* **23**, 59–64 (1984).
50. M. D. Pierson and N. R. Reddy, "Inhibition of *Clostridium botulinum* by Antioxidants and Related Phenolic Compounds in Comminuted Pork," *J. Food Sci.* **47**, 1926–1929 (1982).
51. J. D. Baranowski et al., "Inhibition of *Saccharomyces cerevisiae* by Naturally Occurring Hydroxycinnamate," *J. Food Sci.* **45**, 592–594 (1980).
52. A. G. Marvan and C. W. Nagel, "Microbial Inhibitors of Cranberries," *J. Food Sci.* **51**, 1009–1013 (1986).
53. D. F. Splittstoesser, J. J. Churey, and C. Y. Lee, "Growth Characteristics of Aciduric Sporeforming *Bacilli* Isolated from Fruit Juices," *J. Food Prot.* **57**, 1080–1083 (1994).
54. D. E. Pratt, "Natural Antioxidants from Plant Material," in M. T. Huang, C. T. Ho, and C. Y. Lee eds., *Phenolic Compounds in Food and Their Effects on Health II*, American Chemical Society Symposium Series 507, ACS, Washington, D.C., 1992.
55. I. Musci, "Combined Antiviral Effect of Quercetin and Interferon on the Multiplication of Herpes Simplex Virus in Cell Culture," in L. Farkas, M. Gabor and F. Kallay, eds., *Flavonoids and Bioflavonoids*, Elsevier, Amsterdam, The Netherlands, 1986.
56. M. T. Huang and T. Ferraro, "Phenolic Compounds in Food and Cancer Prevention," in M. T. Huang, C. T. Ho, and C. Y. Lee, eds., *Phenolic Compounds in Food and Their Effects on Health II*, American Chemical Society Symposium Series 507, ACS, Washington, D.C., 1992.
57. T. Tanaka et al., "Protective Effects against Liver, Colon, and Tongue Carcinogenesis by Plant Phenols," in M. T. Huang, C. T. Ho, and C. Y. Lee, eds., *Phenolic Compounds in Food and Their Effects on Health II*, American Chemical Society Symposium Series 507, ACS, Washington, D.C., 1992.
58. M. G. L. Hertog et al., "Dietary Antioxidant Flavonoids and Risk of Coronary Heart Disease: The Zutphen Elderly Study," *Lancet* **342**, 1007–1011 (1993).
59. P. Knekt et al., "Flavonoid Intake and Coronary Mortality in Finland: A Cohort Study," *Br. Med. J.* **312**, 478–481 (1996).
60. M. F. Muldoon and S. B. Kritchevsky, "Flavonoids and Heart Disease," *Br. Med. J.* **312**, 458–459 (1996).
61. V. E. Tyler, "Importance of European Phytomedicinals in the American Market: An Overview," in L. D. Lawson and R. Bauer, eds., *Phytomedicines of Europe*, American Chemical Society Symposium Series 691, ACS, Washington, D.C., 1998.

CHANG Y. LEE
Cornell University
Geneva, New York

See also COLORANTS: POLYPHENOLS; PHYTOCHEMICALS: BIOTECHNOLOGY OF PHENOLIC PHYTOCHEMICALS FOR FOOD PRESERVATIVES AND FUNCTIONAL FOOD APPLICATIONS.

PHOSPHATES AND FOOD PROCESSING

HISTORICAL DEVELOPMENT AND GENERAL USE

Phosphates exhibit functional properties in a wide variety of foods produced by all segments of the processed food industry. The availability of sodium, potassium, ammonium, calcium, and magnesium phosphates offers food technologists and food scientists formulation flexibility to control taste, nutritional, and other technical properties. The commercial use of food phosphates may be traced to 1864 when the first U.S. patent was granted for a phosphate-containing baking powder (1). The use of emulsifying salts in Europe for production of process cheese products began about 1895 and has been reviewed (2). Principal development in the United States began in 1916 (3). Since World War II new uses have developed in food products, including meats, poultry, seafood, beverages, dairy products, infant foods, cereals, desserts, produce, and nutritional supplements. Various detailed reviews have been published (4–6).

The largest market for food phosphates in the world is the United States where processing techniques and advanced food technology follow the consumer trends and demands for high-quality convenient foods. Phosphate use in food applications is an important segment of the overall industrial phosphate market. The U.S. consumption of food phosphates was estimated to be 87,000 t P_2O_5 in 1993, excluding phosphates sold into dentifrice applications and phosphoric acid sold directly into the food industry (7). The second largest market of food phosphates, Western Europe, is approximately 37,000 t P_2O_5 (1993), including the dentifrice market (7). The growth rate of food phosphates in the United States was predicted to be 1.5 to 2.3% annually (1993–1998, including phosphoric acid) while that predicted for Western Europe (1993–1997) was relatively flat (7). The bakery market segment represents approximately 40% of the food phosphates consumed in the United States while the meat, poultry, and seafood applications represent an estimated 30% of the phosphate consumed, followed by dairy (14%) and other (16%) (7).

NOMENCLATURE AND STRUCTURE

Of the phosphoric acids formed by the reaction between phosphorus pentoxide and water, orthophosphoric acid (H_3PO_4) is the simplest and most commonly encountered (8,9). One, two, or all three protons may be replaced by metal ions to form the orthophosphate salts. The acid orthophosphate salts can be dehydrated to form linear chains (polyphosphates) and rings (metaphosphates) wherein phosphate tetrahedrons share oxygen atoms. The polyphosphates have the general formula $M_{n+2}P_nO_{3n+1}$ (M equals one equivalent of hydrogen or metal ion), which approaches the formula of the cyclic metaphosphates as the chain length increases $(MPO_3)_n$.

Several systems of phosphate nomenclature exist, reflecting the historical changes in the understanding of the phosphate structures. Older names such as pyrophosphate and tripolyphosphate for the smallest of the polyphosphate that soy researchers have not focused on creating products similar enough to dairy products to please the general consumer.

Now that so many people of all ages look to soy products for their many health benefits, it is the duty of the soy food industry and of soy food formulators to develop and bring to market products that will be acceptable to a wide range of consumers.

Initially, soy was, and still is, marketed primarily as soymilk, veggie patties, and meat analogues. Efforts have been made to produce and market cultured and fermented soy products such as yogurt, smoothies, and cheeses. Over the past several years of concentrated research and development work aimed at creating cultured soy products and shelf-stable soy drinks, I have found that it is absolutely essential to use sodium phosphates, in one or another form, to produce acceptable soy food and drink products.

The addition of phosphates helps to extend the stability of soymilk, produces acceptable textures in desserts and snacks, and offers the opportunity to produce heat-treated or retorted (sterilized) shelf-stable drinks with fruits and flavors that appeal to consumers.

Since phosphates are widely used in dairy product manufacturing, as well as, it appears, in non-organic soymilk foods and beverages, I have pursued soy product formulation using phosphates, particularly sodium phosphate. Now, the imminent establishment of the National List as law will deprive me and other researchers into organic soy products of our ability to use sodium phosphates.

I have tried my best to use other phosphates and it is practically impossible to produce the soy foods and drinks mentioned above without the use of sodium phosphates. I believe that sodium phosphates used in soy products are not included on the National List because no one, until now, has asked for their inclusion.

DAV' Davidson. 2000. Wiley Encyclopedia of Food Science and Technology 1: 63-75

foods (43). In nearly all studies, the concentration of phenolic antioxidants required for inhibition in a food, especially a meat product, is significantly higher than that needed for *in vitro* inhibition. This is probably because the presence of lipid or protein dramatically decreases the activity of phenolic antioxidants due to binding (44). Application studies in lower fat and protein products have shown more promise.

PHOSPHATES

Some phosphate compounds, including sodium acid pyrophosphate (SAPP), tetrasodium pyrophosphate (TSPP), sodium tripolyphosphate (STPP), sodium tetrapolyphosphate, sodium hexametaphosphate (SHMP), and trisodium phosphate (TSP), have variable levels of antimicrobial activity in foods (45). Gram-positive bacteria are generally more susceptible to phosphates than Gram-negative bacteria. TSPP, SAPP, STPP, and SHMP have been shown to inhibit *Bacillus subtilis*, *Enterococcus faecalis*, *Clostridium sporogenes*, *C. bifermentans*, and *Staphylococcus aureus* (45,46). Sodium polyphosphates at 1% inhibited lag and generation times of *Listeria monocytogenes* in BHI broth, especially in the presence of NaCl (47). Wagner and Busta (48) found that SAPP has no effect on the growth of *C. botulinum* but delayed or prevented toxicity to mice. It was theorized that this was due to binding of the toxin molecule or inactivation of the protease responsible for protoxin activation.

Phosphate derivatives also have antimicrobial activity in food products (49). SAPP, SHMP, or polyphosphates enhance the effect of nitrite, pH, and salt against *C. botulinum* (45). Phosphates, sodium chloride, reduced water activity, water content, reduced pH, and lactic acid interact to prevent the outgrowth of *C. botulinum* in pasteurized process cheese (50). A 10% sodium tetrapolyphosphate dip preserved cherries against the fungal growth by *Penicillium*, *Rhizopus*, and *Botrytis* (45). Various phosphate salts have antimicrobial activity against rope-forming *Bacillus* in bread and *Salmonella* in pasteurized egg whites (51). Trisodium phosphate (TSP) at levels of 8 to 12% reduces pathogens, especially *Salmonella*, on poultry most likely due to a physical removal process or high pH (11–12) (52,53).

Several mechanisms have been suggested for bacterial inhibition by polyphosphates. The ability of polyphosphates to chelate metal ions, such as magnesium, appears to play an important role in their antimicrobial activity (45). Knabel et al. (54) stated that the chelating ability of polyphosphates is responsible for growth inhibition of *B. cereus*, *L. monocytogenes*, *S. aureus*, *Lactobacillus*, and *Aspergillus flavus*. In addition, inhibition is reduced at lower pH due to protonation of the chelating sites on the polyphosphates. It was concluded that polyphosphates inhibited Gram-positive bacteria and fungi by removal of essential cations from binding sites on the cell walls of these microorganisms (54).

NATURALLY OCCURRING COMPOUNDS AND SYSTEMS

Nisin

Nisin, a polypeptide produced by *Lactococcus lactis* spp. *lactis*, was isolated, characterized, and named by Mattick and Hirsh (55). The peptide has 34 amino acids and a molecular weight of 3,500 Da, however it usually occurs as a dimer. The solubility of the compound depends on the pH of the solution. At pH 2.2, the solubility of nisin is 56 mg/mL, at pH 5.0, 3 mg/mL, and it is less soluble at neutral and alkaline pH. Nisin solution in dilute HCl at pH 2.5 is stable to autoclaving (121°C) with no marked loss of antimicrobial activity. At pH 7.0, inactivation occurs even at room temperature. Nisin remains stable for years in the dry form, but activity is gradually lost in foods. The effectiveness of nisin increases as pH decreases. Nisinase from *Streptococcus thermophilus*, *Lactobacillus plantarum*, other lactic acid bacteria, and certain *Bacillus* species inactivate nisin (55). In addition, resistance to nisin may develop in cells exposed to the compound through alterations of the cell surface or cell membrane (18).

Nisin has a narrow spectrum affecting only Gram-positive bacteria, including lactic acid bacteria, streptococci, bacilli, and clostridia. By itself, it does not generally inhibit Gram-negative bacteria, yeasts, or molds. Nisin is inhibitory to the spore formers *Bacillus* and *Clostridium*, including *Clostridium botulinum*. Nisin concentrations necessary to inhibit *Clostridium botulinum* in brain heart infusion broth were 200, 80, and 20 μg/mL for types A, B, and E, respectively (56). In contrast, the concentration required to inhibit *C. botulinum* in cooked meat medium (CMM) was beyond the highest tested for types A (>200 μg/mL) and B (>80 μg/mL). It was theorized that the higher levels required in CMM were due to binding of the nisin by meat particles. Nisin reduces the heat resistance of spore formers. The sensitivity of vegetative bacteria to nisin varies. *Staphylococcus*, *Enterococcus*, *Pediococcus*, *Leuconostoc*, *Lactobacillus*, and *Listeria monocytogenes* have all been shown to be sensitive to nisin (57–60). Gram-negative bacteria are resistant to nisin activity, but they can be sensitized by disruption of the outer membrane either chemically with chelators, such as EDTA, or mechanically. This expands the spectrum of nisin to Gram-negative pathogens such as *Escherichia coli*, *Salmonella*, *Yersinia* (61).

The application of nisin as a food preservative has been studied extensively. Nisin-producing starter cultures were first used to prevent gas or "blowing" of Swiss-type cheese caused by *Clostridium tyrobutyricum* and *C. butyricum* (62). Nisin has been recommended for use in canned vegetable products to prevent the outgrowth of *Clostridium botulinum* when less severe sterilization conditions are desired or required (61). The compound has been shown to have potential benefit in some meat products, although, as already stated, binding to meat may be a problem. Nisin has been suggested as an adjunct to nitrite in cured meats to prevent the growth of clostridia (61). The compound has been tested as a preservative in seafood, dairy products, vegetables, soups, sauces, beer and ale (61). Nisin was less active against *L. monocytogenes* in milk and ice cream with increasing fat concentrations (63,64). This was probably due to binding of nisin to fat globules.

Nisin is permitted for use in foods in many countries including the U.S. It was approved by the U.S. FDA for use in pasteurized cheese spreads and pasteurized process

The individuals in charge of scientific affairs at Quality Assurance International and Oregon Tilth understand my position and have sided with me. I have enclosed copies of their letters.

Based upon all of this, we submit the attached well-documented petition for your review, evaluation, and approval.

We appreciate your attention to this matter. If you require further information, please let me know without hesitation and we will be glad to provide you with whatever you ask for. Looking forward to your favorable response, I am

Sincerely yours,

S. R. Amin, M.S.
Executive Vice President

CORPORATE OFFICE
12526 High Bluff Drive, Suite 300
San Diego, CA 92130 • USA
858-792-3531 • 858-792-8665 Fax

BRANCH OFFICES
VERMONT (East Coast)
ONTARIO (Canada)
TOKYO (Japan)

QAI
QUALITY ASSURANCE INTERNATIONAL

Received by OMRI
APR 27 2001

Fax

To:	Tom Timons	**From:**	QAI/ Samara
Company:	Caracel Foods	**Pages:**	(including cover) 1
Fax:	631-694-3141	**Date:**	12/14/00
Re:	Di-sodium Phosphate	**CC:**	

☐ **Urgent** ☐ **For Review** ☐ **Please Comment** ☐ **Please Reply** ☐ **Please Recycle**

Dear Tom and Amin,

Here is the letter you requested.

According to the current organic practices, di-sodium phosphate is allowed in the processing of soy products. However, di-sodium phosphate is not on the National list of allowed synthetics approved by the Secretary of Agriculture by the USDA. Therefore, when the National Organic Program ruling goes into effect this will no longer be an allowed material unless petitioned for review by the National Organic Standards Board.

I strongly suggest you complete a form to have this material petitioned. There are directions on how to do so on the OMRI web site. (www.omri.org).

Thank you,

Samara Perrell
Client Services

Organ weights

The relative organ weights are shown in Table VIII. It is seen that rats of the 5% PP group had increased relative weights of heart, liver, spleen, stomach, intestines, kidney and testes. Of these, in comparison with the control group, the relative weights of heart, stomach, intestines (females only), kidneys and testes reached a high level of significance. Increases in relative weight were not found in other groups, except for intestines in females of the 1% PP group and kidneys in the 5% OP (males) group and 2½% PP and 5% OP (females) groups. The females of the 1% PP group had smaller spleens than normal, but no reason for this could be established.

Differences in relative heart weight between control and 5% PP groups could be accounted for to a large extent by the difference in body weight of the groups, but differences in body weight could not account entirely for differences noted in weight of the other organs.

Autopsy and histology

The results of macroscopic examination of the organs of rats kept individually in cages are shown in Table IX. Apart from these, no other abnormalities were noted. Of the organs examined, only the kidneys showed micropathological changes. The stomachs of the 2½% PP and 5% PP groups appeared to be microscopically normal.

Table IX

Appearance of organs on autopsy of rats fed on diets containing pyrophosphate or orthophosphate

Appearance of organ	Number of each group with abnormality (10 animals/group)									
	Male					Female				
	Control	Pyrophosphate			Ortho-phosphate	Control	Pyrophosphate			Ortho-phosphate
		1%	2½%	5%	5%		1%	2½%	5%	5%
Pale, pitted kidneys	—	—	—	6	6	—	—	2	5	7
Calcification of kidneys (macroscopic)	—	—	—	5	6	—	—	2	5	5
Hypertrophy of cardiac/pyloric border of stomach	—	—	—	4	—	—	—	3	6	—
Haemorrhages at this site	—	—	—	4	—	—	—	3	4	—

Renal pathology is summarised in Table X. It is seen that with the lower doses of pyrophosphate, the changes were chiefly in the cortex. The medullary zone was more affected in rats receiving the high concentrations of pyrophosphate and orthophosphate.

Table X

Microscopical appearance of kidneys of rats fed on diets containing pyrophosphate or orthophosphate

	% of each group with abnormality				
	Control	Pyrophosphate			Orthophosphate
		1%	2½%	5%	5%
Renal damage	25	95	100	100	100
Cortical atrophy	15	60	60	15	15
Cortical hyaline degeneration	10	55	55	20	10
Cortical calcification	0	5	10	10	5
Medullary calcification	0	5	30	70	75
Medullary necrosis	0	5	10	60	65
Tubular casts	5	0	30	55	55
Haemorrhages and exudate	5	45	50	60	60
Chronic inflammatory changes	0	0	5	70	70

Discussion

The acute studies show marked differences between oral and parenteral LD_{50} levels. The oral figure is in the region of 4 g./kg., whereas the parenteral is less than 250 mg./kg. body weight. Death on intraperitoneal injection was probably due to effects that are unlikely to occur after oral administration. The difference between oral and parenteral toxicity may also be related to the conversion of pyrophosphate into orthophosphate, since the orthophosphate has much file

Received by OMRI
APR 27 2001

OTCO
Oregon Tilth
Certified Organic
1860 Hawthorne NE Suite 200 • Salem OR. 97303 • Phone (503) 378-0690 Fax (503) 378-0809
email: organic@tilth.org

December 7, 2000

Herb Stein
Natural Flavors
268 Doremus Avenue
Newark, NJ 07105
Fax: 973-589-0016

Re: Phosphates in organic soy drinks

Dear Herb Stein:

OTCO has considered your request for use of di-sodium phosphate in soymilk drink to prevent protein coagulation upon heating. The reason for using di-sodium phosphate and the lack of alternatives was clearly explained by Mr. Amin, from Carousel Foods.

On the principle, OTCO would extend allowance of the use of sodium di-phosphate to soymilk. However, a complete formulation of the final product, and description of the process would, need to be submitted for review for a complete approval of the final product that would include the di-sodium phosphate.

Do not hesitate to call if you have any further question.

Best regards,

Anne Plotto, PhD
OTCO Processing Technical Director

Table VI

Liver and kidney function of rats fed diets containing pyrophosphate or orthophosphate

Group	Liver function. mg. of BSP/100 ml. serum after 20 min.	Kidney function: Phenol red test (% excreted in ½ h.)	Kidney function: Concentration test (sp. gr.)
Males			
Control	0·53 ± 0·09	16·72 ± 2·11	1·0622 ± 0·0026
1% Pyrophosphate	0·43 ± 0·14	9·64 ± 2·36	1·0547 ± 0·0047
2½% ,,	0·63 ± 0·12	15·32 ± 4·07	1·0429 ± 0·0061*
5% ,,	0·37 ± 0·12	16·10 ± 5·59	1·0432 ± 0·0051*
5% Orthophosphate	0·65 ± 0·10	12·74 ± 2·30	1·0488 ± 0·0018**
Females			
Control	0·55 ± 0·20	36·94 ± 2·66	1·0592 ± 0·0024
1% Pyrophosphate	0·55 ± 0·09	35·55 ± 2·26	1·0628 ± 0·0026
2½% ,,	0·42 ± 0·14	40·63 ± 4·36	1·0561 ± 0·0015
5% ,,	0·39 ± 0·13	27·62 ± 5·78	1·0445 ± 0·0014**
5% Orthophosphate	0·38 ± 0·15	29·78 ± 2·78	1·0513 ± 0·0025*

* Significantly different from control group $P < 0·05$
** Significantly different from contol group $P < 0·01$

Table VII

Haematological findings in rats fed on diets containing pyrophosphate or orthophosphate

Group	Red blood cells, millions/cu.mm.	Haemoglobin, g./100 ml.	Lymphocytes per cu.mm.	Granulocytes per cu.mm.	Monocytes per cu.mm.
Males					
Control	7·51 ± 0·20	13·1 ± 0·17	10,968 ± 1767	2664 ± 513	908 ± 204
1% Pyrophosphate	7·95 ± 0·25	12·8 ± 0·24	6324 ± 455*	2511 ± 504	995 ± 97
2½% ,,	7·75 ± 0·17	12·4 ± 0·21*	10,080 ± 1720	2787 ± 619	723 ± 226
5% ,,	7·67 ± 0·18	12·5 ± 0·25	14,839 ± 3413	4139 ± 1328	1242 ± 377
5% Orthophosphate	8·25 ± 0·31	13·9 ± 0·29*	8759 ± 1485	2686 ± 358	265 ± 96*
Females					
Control	7·30 ± 0·18	12·4 ± 0·51	11,204 ± 1871	1875 ± 258	361 ± 98
1% Pyrophosphate	7·21 ± 0·15	12·0 ± 0·46	8051 ± 1366	1723 ± 70	242 ± 96
2½% ,,	7·00 ± 0·19	12·9 ± 0·23	11,318 ± 1597	2449 ± 771	544 ± 138
5% ,,	6·91 ± 0·53	12·1 ± 0·36	7384 ± 563	4275 ± 1084	572 ± 167
5% Orthophosphate	7·92 ± 0·13*	13·2 ± 0·54*	9557 ± 1342	2201 ± 1285	611 ± 408

* Significantly different from control group $P < 0·05$

Table VIII

Organ weights of rats fed on diets containing pyrophosphate or orthophosphate

(weights are mg./100 g. live weight ± standard error)

Organ	Control	1% Pyrophosphate	2½% Pyrophosphate	5% Pyrophosphate	5% Orthophosphate
Males					
Heart	244 ± 4	255 ± 6	251 ± 77	295 ± 19*	256 ± 7
Liver	3170 ± 133	3097 ± 75	3029 ± 87	3452 ± 234	3112 ± 57
Spleen	271 ± 14	233 ± 7	261 ± 16	286 ± 15	256 ± 13
Stomach	378 ± 12	365 ± 15	388 ± 12	608 ± 39**	407 ± 14
Intestine	2229 ± 112	2108 ± 111	1964 ± 83	2716 ± 239	1940 ± 99
Adrenals	13 ± 1	11 ± 0·6	12 ± 0·9	13 ± 0·7	12 ± 0·4
Kidneys	634 ± 21	598 ± 17	648 ± 24	769 ± 34*	741 ± 15**
Testes	962 ± 42	900 ± 29	905 ± 42	1233 ± 79*	1005 ± 37
Females					
Heart	278 ± 4	273 ± 5	295 ± 10	311 ± 9*	285 ± 9
Liver	3146 ± 33	3045 ± 80	3048 ± 129	3292 ± 92	3021 ± 65
Spleen	297 ± 14	304 ± 24	305 ± 20	334 ± 20	285 ± 30
Stomach	451 ± 16	459 ± 15	506 ± 22	721 ± 63**	486 ± 23
Intestine	2521 ± 73	2928 ± 149	2626 ± 85	3203 ± 149**	2696 ± 103
Adrenals	27 ± 1·5	26 ± 1·7	26 ± 1·0	26 ± 1·7	25 ± 2·0
Kidneys	601 ± 12	629 ± 21	743 ± 24**	893 ± 42**	838 ± 35**

* Significantly different from control group $P < 0·05$
** Significantly different from control group $P < 0·01$

Received by OMRI
APR 27 2001

Petition

To

The National Organic Standards Board

To Amend the National List Of Allowed Substances

To Include Sodium Phosphates For Use in Food and Beverage Products Formulated with Soymilk and Dry Soymilk Similar to or Equivalent to Dairy Products

March 21, 2001

Submitted by
Carousel Foods of America, Inc.
535 Smith Street
Farmingdale, New York 11735

This analysis divides the food intake into two parts : (1) the food used for each gramme of body weight gained, and (2) the food used to maintain the body at constant weight. The results showed that the amount of food used for unit gain in body weight and maintenance by the males and females fed on the 5% pyrophosphate diet was not significantly different from that used for these purposes by the other groups.

Balance studies

The results of the analyses of food, urine and faeces, summarised in Table V, show that sodium pyrophosphate and orthophosphate are absorbed and excreted and affect calcium metabolism in a similar manner. The pH of urines passed by control, 1% and 2½% PP groups were not significantly different from each other (pH 6·7), but were significantly less alkaline than urine from the 5% PP and 5% OP groups (mean of both = pH 7·5). There were no differences in the concentrations of sodium, potassium or ammonium in the urine of any group. Such similarity suggested that pyrophosphate may be hydrolysed to orthophosphate before or during absorption in the rat gut. This was substantiated by the fact that pyrophosphate could never be detected in the faeces or urine of animals receiving the salt. We have found that rat faeces are capable of hydrolysing pyrophosphate to orthophosphate.

Table V also shows that pyrophosphate was almost completely absorbed by the gut and excreted by the kidneys as orthophosphate. The Ca/P balance was upset by loss of weight in 2 rats of the 5% PP group, when this and the control group were examined, but these 2 rats also showed the almost complete absorption of pyrophosphate.

Table V

Total phosphorus (phosphate and pyrophosphate) and calcium eaten, and % phosphorus (phosphate only, no pyrophosphate found) and calcium excreted and retained by rats fed on basal diet or on a diet containing orthophosphate or pyrophosphate

	Calcium				Phosphorus				mg. Ca retained / mg. P retained	Body weight gain, g.
		% excreted in				% excreted in				
	mg. eaten	faeces	urine	% retained	mg. eaten	faeces	urine	% retained		
Control	99·9 ± 13·86	48·7 ± 0·89	0·65 ± 0·05	51·3 ± 0·92	81·7 ± 11·35	60·1 ± 1·13	11·4 ± 0·18	28·5 ± 1·18	2·2 ± 0·09	3·3 ± 1·1
5% Pyrophosphate	63·3 ± 4·51	43·6 ± 1·95	1·77 ± 0·06	54·7 ± 1·95	236·6 ± 18·76	16·5 ± 0·73	82·5 ± 3·12	0·86 ± 2·60	4·11 ± 0·82	0·5 ± 0·5
5% Orthophosphate	59·2 ± 1·57	47·4 ± 0·74	0·79 ± 0·10	51·8 ± 0·78	211·6 ± 5·73	15·2 ± 1·21	75·2 ± 0·93	9·6 ± 1·27	1·6 ± 0·18	4·1 ± 0·84
5% Pyrophosphate	56·3 ± 2·24	43·9 ± 2·57	1·06 ± 0·06	55·0 ± 2·58	206·6 ± 8·29	14·9 ± 0·78	74·2 ± 3·03	10·9 ± 2·86	2·9 ± 1·47	3·9 ± 0·51

The figures are the mean and standard error of 5 animals from each group

Function tests

The results of the liver and kidney function tests (Table VI) show that liver function, as estimated by the BSP clearance, was not different in experimental and control animals. Of the kidney function tests, the phenol red test was very variable in the males. The females of the 5% PP and 5% OP groups excreted the dye at a slower rate than normal, but the retardation did not reach a statistically significant level.

The concentration tests showed that males of the 2½% PP, 5% PP and 5% OP groups and females of the 5% PP and 5% OP groups had impaired renal function. There was no significant increase in urine albumin or cell content in any group.

Haematology

The results (Table VII) show that although there were some significant differences between certain counts, there were no significant trends towards abnormality as the concentration of pyrophosphate was increased.

Table of Contents

intestine and fluid in the peritoneal cavity. Nothing abnormal was detected in rats killed after 10 days. The intestines of rats killed 1 h. after injection of sodium orthophosphate or of saline appeared to be normal and responded to a pinprick by contracting. The intestines of rats killed 1 h. after an injection of pyrophosphate showed areas of hyperaemia on the surface and these parts did not respond to a pinprick, although other parts of the intestines with normal appearance did.

Fluid from the peritoneal cavity of the rats receiving pyrophosphate contained many red, white and epithelial cells and a considerable concentration of coagulable protein. Fluid from control rats contained no red cells, a few white and epithelial cells and much less coagulable protein. Examination of the blood of rats receiving sodium pyrophosphate at the 800 mg./kg. level showed that their serum calcium was reduced from the normal mean level of 9·4 mg.-% (range 9·0–9·6) to 5·1 mg.-% (range 4·4–6·0). Rats receiving sodium orthophosphate at the same dosage level had a serum calcium level of 7·4 mg.-% (range 7·2–7·6). However, the administration of massive doses of calcium gluconate had no therapeutic effect on animals receiving sodium pyrophosphate. There was marked haemoconcentration in these animals (packed cell volume = approx. 75%, control approx. 50%).

Rats receiving sodium chloride of similar osmolarity, or sodium bicarbonate of similar sodium ion content, to that of sodium pyrophosphate at the 1600 mg./kg. dosage level showed no untoward effects.

Tissue respiration studies showed that concentrations of up to 0·1% of sodium orthophosphate or pyrophosphate did not significantly increase or decrease the respiration rate of liver from its normal value of 2·14 (range 1·47–3·51) μl. of O_2/mg. of dry tissue/h.

Intradermal administration of the phosphates showed that concentrations up to 4% of sodium orthophosphate had only a slight reddening effect on the skin. Solutions of sodium pyrophosphate, 1% or stronger, caused necrosis of the injected area; a 0·5% solution had an effect similar to that of 4% sodium orthophosphate.

(2) *Short term toxicity*

Weight gain and food intake

The mean gain in body weight and mean cumulative food intake of rats of each group (Table IV) show that male and female rats fed on the 5% pyrophosphate diet grew at a slower rate and had a lower food intake than other groups.

Table IV

Mean body weight gains and food intakes of rats fed on diets containing pyrophosphate or orthophosphate

(Mean weight gains and standard errors are in g.)

Group	Males		Females	
	Body weight gain	Food intake	Body weight gain	Food intake
Control	210 ± 20	1309 ± 28	137 ± 7	1184 ± 28
1% Pyrophosphate	245 ± 16	1359 ± 27	129 ± 6	1110 ± 28
2½% Pyrophosphate	229 ± 15	1305 ± 24	129 ± 7	1116 ± 16
5% Pyrophosphate	187 ± 15	1213 ± 48	114 ± 7*	1055 ± 26
5% Orthophosphate	234 ± 14	1363 ± 18	140 ± 8	1168 ± 23

* Significantly different from control group $P < 0{\cdot}05$

The significance of the difference between the 5% PP group males and the other groups was obscured by the slow growth rate of the male control group. These grew at a much slower rate than the 1% and 2½% PP and the 5% OP groups, and control animals of the same stock used in other experiments. The growth rate of our control animals usually follows closely the growth rate of the 1% PP group.

To determine whether the decreased food intake of male and female rats of the 5% PP group would account completely for the decrease in their growth rate, an analysis of covariance of food intake and gain in body weight of each group was made by the method of Crampton.[12]

The Petition

We ask the National Organic Standards Board to amend the National List of Allowed Substances to include sodium phosphates for use in food and beverage products formulated with soymilk and dry soymilk similar to or equivalent to dairy products.

The Company Submitting the Petition: Carousel Foods of America, Inc.

Carousel Foods of America, Inc., is a manufacturer of dairy puddings, shelf-stable cheesecakes, frozen cheesecakes, and organic soy puddings. In business since 1965, Carousel Foods distributes its products throughout the country in a wide variety of retail, institutional, and food service outlets. Carousel Foods also supplies private label dairy products, both traditional and organic, to major supermarket chains and dairy distributors in the Northeast and Mid-Atlantic regions of the U.S.

Carousel Foods is committed to the organic foods industry and the organic soy foods industries. Quality Assurance International has inspected and certified our plant as an organic manufacturer. In the near future, Carousel Foods intends to introduce cultured organic soy products, including organic soy "yogurt-type" foods, organic soy "yogurt-type" smoothee beverages, organic soy cheesecakes, and other organic soy and non-soy products. We have developed a unique technology for processing the soy ingredients that makes our end products particularly appealing to consumers. Sodium phosphates play an important role in this technology. Carousel Foods is also in the early stages of working with a number of other companies in the organic soy business with the intent to introduce a wide range of products based on ingredients created with this technology. These products may reach into almost every segment of the food industry. As the national and international demand for soy products continues to grow, we expect our organic soy products to form a significant portion of our total future business.

Calculation

Total pyrophosphate in sample (as P) =

$$\frac{D_2 - (D_1 \times O_2)/O_1}{P_2 - P_1} \times 10 \times \frac{100}{2} \times \frac{500}{10}\ \mu g. = \frac{D_2 - (D_1 \times O_2)/O_1}{P_2 - P_1} \times 25\ mg.$$

where D_1 and D_2 = O.D. of test solution after 7 min. and 3 h. respectively
O_1 and O_2 = O.D. of orthophosphate standard after 7 min. and 3 h. respectively
P_1 and P_2 = O.D. of pyrophosphate standard after 7 min. and 3 h. respectively

Function tests

(a) *Liver function.*—The bromosulphalein (BSP) clearance test was performed on 5 male and 5 female rats of each group after 110 days. Each rat received 25 mg./kg. body weight of BSP in saline solution by intravenous injection. The dye remaining in the blood after 20 min. was determined colorimetrically (Ahmad & Frazer[9]).

(b) *Kidney function.*—The phenol red excretion test and the concentration test were carried out as described by Sharratt.[10] In the former the percentage of dye excreted in the urine after an intramuscular injection of the dye was determined, and in the latter the specific gravity of urine passed by the animals between 8 and 24 h. after deprivation of water was measured. The albumin and cellular contents of this urine were examined.

Haematology

The usual methods were employed to determine the red cell, white cell and haemoglobin contents of venous blood of 5 male and 5 female rats of each group at the end of the experiment.

Organ weight

The animals living in individual cages were killed by exsanguination under ether anaesthesia. Various organs were removed from the rats, trimmed of fat and adherent tissues and weighed immediately. Organ weights were expressed as mg. of organ/100 g. body weight.

Autopsy

During the determination of organ weights, the organs were examined macroscopically for pathological abnormalities. Autopsies were also carried out on the rats kept 5 to a cage at the end of the experiment.

Histology

The organs were fixed in formol saline, embedded in paraffin and stained with haematoxylin and eosin.

Results

(1) *Acute toxicity*

The median lethal intraperitoneal dose (LD_{50}) of pyrophosphate, calculated by the method of Weil[11] from the figures marked with an asterisk in Table III, was 233 mg./kg. body weight, with 95% confidence that the true value lay between 192 and 282 mg./kg. body weight.

Rats receiving sodium pyrophosphate intraperitoneally at the highest levels became gradually weaker and insensitive to pain and died within 2 h. They did not lose consciousness or the corneal reflex before death. The breathing of many became shallower and slower and some had slow gasping respiration.

Rats receiving lower doses behaved similarly. One of the group receiving 398 mg./kg. body weight died within 2 h. and the rest of the group between 2 and 16 h. All animals that died did so within 16 h.

No effects were seen in the rats receiving doses of 25 and 40 mg./kg., but those receiving 63 mg./kg. became weaker and more reluctant to move than those on the lower doses. Rats receiving 100 mg./kg. were markedly weaker and several showed a gasping type of respiration.

Rats dying within 2 h. showed, post-mortem, slight redness of the serous surface of the small

The Substances:
Sodium Phosphates (Sodium Salts of Phosphoric Acid)

Sodium phosphates are the substances that we wish to have added to the list as allowed for use in soy food and beverage products formulated with soymilk and dry soymilk similar to or equivalent to the use in dairy products. We have attached a definition of the sodium phosphates from the Dictionary of Food Ingredients, Second Edition, and Published by Van Nostrand Reinhold, © 1989. See Appendix 1.

The basis for our petition is four-fold:

- Sodium Phosphates are currently allowed for use but restricted only to dairy foods. Thus, as substances, they have met the various criteria established by the NOSB, including safety, versatility, proportionality, and general acceptance. Sodium phosphates are widely accepted ingredients in the food industry. See Appendix 2.

- Our lengthy research and development has determined that the sodium phosphates provide essential and incomparable functionality in our organic soy products. It appears that producers of non-organic soymilk and soymilk products currently use phosphates of one form or another in their formulations.

- Without the use of sodium phosphates in producing our soy food and beverage products similar to dairy products, we would not be able to create products acceptable to consumers. Thus, other producers, the consumers, and we would be foreclosed from the health and business benefits received from these products. The allowance of sodium phosphates in soymilk and dry soymilk products would permit parity between organic soymilk and dry soymilk manufacturers with dairy manufacturers. With sodium phosphates, soy producers could create and market dairy-like products with the same high functional and performance standards of dairy products. Thus, the consumer demand for soy's benefits offered in dairy-like products would be satisfied.

was determined by the Warburg technique in the presence of sodium pyrophosphate and sodium orthophosphate (pH adjusted to 7·4) up to a final concentration of 0·1% of the salts.

The action of pyrophosphate solution on the intestine and on skin was observed. Two rats injected with the 2% solution of sodium pyrophosphate at the 400 mg./kg. dosage level, two with sodium orthophosphate at the same level and two with normal saline, were killed and examined 1 h. after the injection. A series of concentrations of sodium pyrophosphate and orthophosphate (all adjusted to pH 7·4) ranging from 0·5% to 4·0% was injected intradermally into the shaved backs of rats.

Short term toxicity

(1) *Pilot experiment*

Three groups of 10 rats were given diets containing (*a*) 10% sodium pyrophosphate, (*b*) 5% sodium pyrophosphate and (*c*) no sodium pyrophosphate. The basal diet was a flour/dried milk mixture similar to that described in Table I. The growth rate and food intake of each group were measured daily. It was found that in 2 weeks, the rats with the diet containing 10% sodium pyrophosphate lost weight and 5 died. Their food intake was lower than that for the control group. The rats given 5% sodium pyrophosphate in their diet ate less than the control animals and grew at a slower rate, but appeared normal in all other ways. It was decided to feed a maximum of 5% of the salt in the diet in the longer-term feeding test, since the 10% level was not tolerated.

(2) *General plan of main experiment*

Five groups of rats, each group consisting of 20 male and 20 female animals weighing between 90 and 115 g., were used. Ten males and ten female animals of each group were caged individually and the remainder were kept five to a cage. All animals were housed in a room at 72° ± 2° F under similar conditions of relative humidity and light availability. All were allowed drinking water *ad libitum*.

In this text, the diets will be referred to as control, 1%, 2½% and 5% pyrophosphate and 5% orthophosphate diets, and the animal groups will be referred to as C, 1% PP, 2½% PP, and 5% PP and 5% OP groups respectively.

The weekly weight gain and food intake were determined to the nearest g. for 100 days on each rat caged individually.

After 3 weeks on the diet the food consumption was determined and the faeces and urine collected from 5 male animals each of the C group and of the 5% PP group during a 6-day period. A similar collection was carried out after 8 weeks on 5 male animals each of the 5% PP and the 5% OP groups during a 3-day period. Food, urine and faeces were analysed for calcium by the flame photometric method, for phosphorus by the molybdate colorimetric method and for pyrophosphate by the method described below.

Determination of pyrophosphate in faecal matter and urine

Principle.—The method was based on the observation of Flynn *et al.*[8] that pyrophosphate does not normally give any colour with the molybdate reagent of Fiske & Subbarow, but develops a blue colour when cysteine is added.

Technique.—Total faecal matter was homogenised and made up to 500 ml. Ten ml. of this homogenate were mixed with 10 ml. of perchloric acid (30%), diluted to 100 ml. and filtered. Two ml. of this filtrate were taken in a 25-ml. volumetric flask and diluted to about 20 ml. There were then added 2·0 ml. of molybdate reagent, 1 ml. of cysteine solution and finally 1 ml. of aminonaphtholsulphonic acid (A.N.S.) reagent. (The molybdate reagent, cysteine solution and A.N.S. reagent were prepared as described by Flynn *et al.*[8]) The volume was made up to 25 ml. and the optical density (O.D.) of the blue solution measured at 660 mμ. after 7 min.

Two standards were set up as follows: (i) 2 ml. of orthophosphate solution, containing 20 μg. of P; (ii) 2 ml. of pyrophosphate solution, containing 10 μg. of P, and treated exactly in the same manner. Two ml. of water with all the reagents added as above were taken as a blank. After exactly 3 h. the optical densities at 660 mμ. of all the test and standard solutions were again measured.

- We believe that one of the reasons sodium phosphate usage is restricted on the National List to dairy products is simply that no company or individual has presented the case or applied for the allowance for soymilk or dry soymilk products. Thus, we are applying on behalf of consumers, our own company, and other food and beverage manufacturers.

Necessary Information for Inclusion in the Petition

1. <u>Substance common name</u>:

   Sodium Phosphates. These include Disodium Phosphate, Disodium Phosphate Dihydrate, Disodium Phosphate Duohydrate, Monosodium Phosphate, Trisodium Phosphate, Sodium Hexametaphosphate, and others. The naming of phosphates can be confusing since there are many names for each compound. Monosodium phosphate, for example, has over twenty-five alternate names.

2. <u>The manufacturer's name</u>:

   Astaris LLC, P.O. Box 411160, 622 Emerson Road, St. Louis, MO 63131. This is the supplier used by Carousel Foods. Other suppliers of food grade phosphates include ADM Arkady, Pacific Grain Products, Solutioa, Watson Foods, Dirigo Spice, Penta Mfg., J. Stewart & co., Vivion, Westco Chemicals are name a few among several dozen U.S. suppliers.

3. <u>The intended use</u>:

   The intended use is as a nonagricultural ingredient in processing soy food and beverage products.

References

[1] Tucker, J., Midwest Section, Amer. Ass. Cereal Chem., Chicago, January, 1959

[2] Bonting, S. L., 'Effect of a prolonged intake of phosphoric acid and citric acid in rats', 1952, Thesis, Univ. of Amsterdam

[3] Taylor, A. M., *Food Manuf.*, 1958, **33**, 286

[4] McKay, E. M., & Oliver, J., *J. exp. Med.*, 1934, **61**, 319

[5] van Esch, G. J., Wit, S. J., & van Genderen, H., *Arzneim. Forsch.*, 1957, **7**, 172

[6] Hodge, H., 'Short term oral toxicity tests of condensed phosphates in rats and dogs', 1956, Univ. of Rochester, New York

[7] Spector, W. S., 'Handbook of Toxicology', 1956, Vol. 1 (Philadelphia & London: W. B. Sanders Co.)

[8] Flynn, R. M., Jones, M. E., & Lipmann, F., *J. biol. Chem.*, 1954, **211**, 791

[9] Ahmad, N. U., & Frazer, A. C., *Biochem. J.*, 1953, **54**, xxxvi

[10] Sharratt, M., 'Effects of food on renal function', 1958, Thesis, Univ. of Birmingham

[11] Weil, C. S., *Biometrics*, 1952, **8**, 249

[12] Crampton, E. W., *J. Nutr.*, 1934, **7**, 305

AMMONIA LOSS FROM AMMONIACAL FERTILISERS APPLIED TO CALCAREOUS SOILS

By S. LARSEN and D. GUNARY

Ammonia volatilised from ammonium salts applied to calcareous soils was greatest from ammonium sulphate (AS), about half as much from mono- and di-ammonium phosphates (MAP and DAP) and ammonium nitrate (AN), and negligible from magnesium ammonium phosphate.

Losses of ammonia in 8 days from ammonium salts applied to an initially acid, sandy soil treated with calcium, barium or magnesium carbonates, were: soil treated with $CaCO_3$, AS $\gg$ DAP = AN; with $BaCO_3$, AN $\gg$ AS = DAP; with $MgCO_3$, AS > AN $\gg$ DAP.

Reasons for these findings are discussed. It is evident that factors other than pH are operating.

Introduction

Since the use of chemical fertilisers began more than 100 years ago, it has been recognised that nitrogen can be lost as gaseous ammonia when an ammoniacal fertiliser is applied to calcareous soil. Recent studies, e.g., by Steenbjerg[1] and Jensen & Kjaer,[2] have confirmed this. Steenbjerg presumed that experimental results obtained with ammonium sulphate were also applicable to other ammonia salts. van Schreven,[3] however, found that the rate of loss of ammonia by volatilisation from ammonium salts applied to calcareous soils was dependent on the anion present in the salt. Loss from ammonium sulphate was found to be more rapid than from ammonium nitrate and this was confirmed by Nommik & Warlin.[4] As the loss of ammonia depends on the equilibrium $NH_4^+ \rightleftharpoons NH_3 + H^+$, van Schreven[3] considered that the difference in the rates of loss of ammonia was due to the effect on the hydrogen concentration of the different solubilities of the calcium sulphate and calcium nitrate, formed by reaction of the respective ammonium salts with calcium carbonate. According to his hypothesis the range of ammonia lost by volatilisation should be: DAP > AS > AN.

In order to investigate this hypothesis a series of laboratory experiments was conducted with ammonium sulphate, ammonium nitrate and ammonium phosphates. In some of the experiments the ammonium salt was placed on the surface of the soil and in others it was mixed with the soil. Although the methods of placement might influence the absolute ammonia volatilisation, this was considered to be of no significance as only the comparative volatilisation of ammonia is considered.

4. The substance's mode of action in food processing:

Phosphates play a variety of roles in pharmaceutical and nutritional products. They act as sequestrants, emulsifiers, buffers, protein coagulants, solubility enhancers, stabilizers, and texture enhancers. This well-established food ingredient furnishes a means to control many product appearance and flavor problems. Baked products leavened with phosphates attain excellent texture, color, volume, and lightness. In process cheese products, sodium phosphates provide meltability and mouthfeel. With them, processed meat becomes juicier and tenderer.

Soy products, based on extracts of soybeans, usually do not attain shelf-stability without additives. The addition of sodium phosphates increases the shelf life of soy products. Similarly, fermented soy products, upon cooling and reheating, tend to coagulate. Sodium phosphates, either alone or in association with citrates, prevent soy protein from such precipitation and, thus, they create homogeneous and acceptable end products.

5. Source of the substance:

It is a salt derived from phosphoric acid. In Monsanto Publication No. 9181, the following description occurs under the heading **Phosphate Processes**: "Phosphates, both simple orthophosphates and complex condensed polyphosphates, are made by neutralizing phosphoric acid with appropriate alkaline materials (sodium, potassium, ammonium or calcium salts). Using appropriate ratios of cation to phosphate and varying drying and calcining procedures affords the different phosphate products that we offer.... Monsanto makes phosphoric acid, the precursor to the phosphate salts by burning elemental phosphorus and scrubbing the product with water ...."

less effect when administered parenterally. The site and mechanism of this conversion is being further investigated; it is generally thought that it occurs in the gastrointestinal tract during absorption. Whether the effects observed on cells may have some significance in patients who have had a gastrectomy may be worthy of further study.

When pyrophosphate was fed at a level of 2½% or 5% of the diet, certain effects were observed. At the highest level there was some interference with weight gain. Although this could be accounted for by reduction in food intake, it should, perhaps, be regarded as an indication of a toxic effect. This matter is being further studied, although in this particular investigation the point was not of major importance since other well-defined effects were also present.

Pyrophosphate administration at a level of 5% of the diet caused a significant increase in the relative weight of the small intestine which was not observed when a similar concentration of orthophosphate was fed. This may be related to the metabolic handling of the pyrophosphate; however, the effect was also observed in the stomach, which suggested a slight irritant effect at this level of administration.

The kidney weight was significantly increased and renal function impaired in the groups receiving 2½% and 5% of pyrophosphate and in the group having 5% of orthophosphate, but no difference from the controls was observed in the 1% pyrophosphate group. However, histopathological studies revealed renal damage in all these groups including the 1% level.

These studies show that the administration to rats of pyrophosphate at a concentration of 1% or more in the diet or of orthophosphate at a 5% level resulted in demonstrable changes in the kidneys which showed reduced functional efficiency and increased relative weight. In these studies lower levels of orthophosphate were not fed, but this has been done by others.[4,5]

The clearance level for pyrophosphate on this basis, so far as the rat is concerned and assuming the usually accepted margin of safety of 100×, would be 0·01% in the diet, which for an adult rat corresponds to 6 mg./kg. body weight/day.

There is always some doubt about the validity of transferring information obtained from animals to human subjects and this may be important here, since the rat kidney has exceptional powers of concentration and may be more susceptible to damage from phosphate than kidney from other species. It may also be questioned whether the safety margin of 100× is not unnecessarily low for normal body constituents, such as phosphate. However, if the transference is made, it is apparent that the human daily intake cleared on the basis of these rat studies and a margin of safety of 100× is in the region of 420 mg./day for an adult man of 70 kg. body weight. This is close to the average daily intake of pyrophosphate calculated earlier in this paper. Since pyrophosphate appears to be converted to orthophosphate, it would seem advisable to consider the total phosphate load, which must be considerably greater than the calculated figure for pyrophosphate used as a food additive.

Although there is no indication that present dietary phosphate loads are excessive, these studies suggest that some further investigation of this problem is desirable. In particular, further information is needed on the mechanism and site of conversion of pyrophosphate to orthophosphate, on the toxicological significance of the observed renal changes, on the mechanism by which they are brought about and the extent to which the rat may be particularly susceptible to such changes. From these further investigations, it should be possible to make some assessment of the acceptable limits of phosphate intake for man.

Acknowledgments

The authors thank Dr. O. C. Forbes for examining histological preparations, Miss Janet Deacon for technical assistance with the animal experiments and Messrs. Albright and Wilson Ltd., for supplies of the phosphates and a grant towards expenses. They are grateful to the U.S. Public Health Service for financial assistance for work in this field.

Dept. of Medical Biochemistry & Pharmacology
The University
Birmingham, 15

Received 20 December, 1961: amended manuscript 4 June, 1962

6. A summary of available reviews by State or private certification programs:

See attachment: Organic Materials Review Institute Processing and Handling Materials – February 1999, page 39: Sodium Phosphates, Status A, OMRI Class NOI, Use as an ingredient restricted to dairy foods. See Appendix 2.

7. Information regarding EPA, FDA, and State regulatory authority registrations:

Please see the attached GRAS listing, and refer to page 34."Regulatory Information" of the attached Astaris Phosphates product manual. See Appendix 3.

8. The CAS number or labels of products that contain this substance:

Please see attached Carousel Chocolate Cheesecake and Strawberry Cheesecake labels and product sheets from Kraft and other companies that indicate the use of sodium phosphates in their products. See Appendix 4.

9. The substances physical properties and chemical mode of action, etc.:

The phosphates are salts of phosphoric acid. Various phosphate salts are produced and each phosphate, depending on the structures, the inter-linkages and amounts of sodium molecules, varies in its functionality. They act as sequestrants, emulsifiers, buffers, and texturizers.

Phosphates influence the properties of dairy products through three basic mechanisms: (1) calcium complexing, (2) pH modification, and (3) direct interaction with casein, the principal protein of milk. A particular phosphate might perform all three functions, interacting with the dairy formulation and with other phosphate additives. It is suspected that phosphates perform similar functions in soymilk products. Please see attached copies of two product manuals from FMC Corporation entitled *Phosphates Help Make Dairy Products Better* and *Food Phosphates* for expanded discussions of functions, applications, pH's, and other pertinent information. See Appendix 5.

Table II

Pyrophosphate content of foods and possible daily human intake

Foodstuff	Max. % concn. of pyrophosphate[a]	Foodstuff intake, g./day[b]	Consumption of pyrophosphate, mg./day
Processed cheese	3·0	1·5	45
Cured meats	0·5	4·9	25
Sausage	0·5	14·2	71
Ice cream	0·05	28[c]	14
Flour (self-raising)	0·45	28·8	130
Cheese, scones, etc.	0·25[c]	23·4	58
Instant pudding	2·0	4·0[c]	80
		Total	423 mg.

[a] From Publ. 398, Nat. Res. Coun., Wash., 1956
[b] From Domestic Food Consumption and Expenditure, 1957 (London: H.M.S.O.)
[c] Estimated

The concentration needed in the diet to supply this dosage level to rats has been calculated, assuming that the mean body weight of animals is 250 g. and that they eat 15 g. of food each day. A 250 g. rat must consume 1·508 mg. to receive a dose equivalent to *D* on a mg./kg. body weight basis. This in 15 g. of diet = 100 mg./kg. diet, approximately. Hence a diet containing 10 g./kg. would supply rats with the equivalent of approx. 100 × *D*. It is emphasised that this is an approximate figure only. An independent estimate set the mean intake in England to be 300 mg. per person, but the figure must vary considerably from person to person.

Acute toxicity

The acute effects of parenteral administration were examined in order to determine whether the biological activity of pyrophosphate was altered by passage through the wall of the gastro-intestinal tract. This might be important in those suffering from gastrointestinal lesions, in whom the salt could be absorbed directly into the blood without passing through the gastro-intestinal barrier.

Table III

Intraperitoneal dosage levels of sodium pyrophosphate in LD_{50} determination

Dose, mg./kg. body weight	Number of rats	Number dying in 16 h.
1000	6	6
631	6	6
398*	6	6
251*	6	4
159*	6	0
100*	6	0
63	2	0
40	2	0
25	2	0

* Used for calculation of median lethal dose (LD_{50})

An aqueous solution of sodium pyrophosphate was administered by intraperitoneal injection to male rats weighing between 170 and 210 g., at the dosage levels shown in Table III. The solution was made by dissolving 10 g. of sodium pyrophosphate in 400 ml. of distilled water, adjusting the pH to 7·2 with hydrochloric acid, and making up the volume to 500 ml. with water. The animals were observed for 10 days; all were autopsied.

A 3% aqueous solution of sodium pyrophosphate was administered orally to 10 rats at the 1600 mg./kg. dosage level. They were killed after 10 days and autopsied.

The possibilities that death following parenteral administration was caused by hypocalcaemia, the osmotic effect of the solution, alkalosis, or by an effect on respiratory enzymes were examined.

Sodium pyrophosphate was administered to 4 rats at the 800 mg./kg. level and serum calcium and packed cell volume determinations were made after 1 h.

Sodium chloride, in solution of similar osmolarity to sodium pyrophosphate at the 1600 mg./kg. dosage level, was administered by intraperitoneal injection to 4 rats.

Sodium bicarbonate (2020 mg./kg.), a dose containing the same number of sodium ions as sodium pyrophosphate at the 1600 mg./kg. dosage level, was injected intraperitoneally into 4 rats.

The respiration rate of rat liver slices and rat liver homogenate in isotonic sucrose solution

Physically, in a reaction, they soften the protein in most food formulations. They also help to withstand heat and acidic materials, thus providing buffering and emulsification.

At their low regulated usage levels, and after reacting with water and protein, sodium phosphates do not create any toxicological, environmental, or health issues for humans, soil organisms, crops, or livestock through the product.

10. Safety information about the substance:

This is a GRAS item. See the attached GRAS list and the attached Material Safety Data Sheets from several companies. See Appendix 3 and Appendix 6.

11. Research Information about the substance:

Please see the attached abstracts of articles, patents, and studies that were culled from a wide variety of literature in order to indicate the uses of sodium phosphates, particularly disodium phosphate and hexametaphosphate. See Appendix 7. Please note the list of particularly relevant abastracts included at the beginning of the section. You may wish to refer to several of the articles as they pertain to the use of sodium phosphate or sodium metahexaphosphate in soymilk or okara (soy lees) products.

The use of phosphates is always considered an essential part of a food formula whenever the food formulation contains protein that is subjected to heat or an acidic environment. In these cases, the phosphates provide buffering action as well as emulsifying and texturizing the product.

is increasing.[1] The pure acid is used extensively, instead of citric or tartaric acid, in a certain type of soft drink[2] and the salts are used as sequestering agents, emulsifiers, texturisers and buffers in a wide range of food products.[1, 3]

It has long been known that orthophosphates may cause renal damage when fed to rats.[4] Van Genderen and co-workers[5] observed that both orthophosphates and a mixture of long-chain polyphosphates and pyrophosphates caused a deposition of calcium phosphate in rat kidneys without indication of tissue damage, when present at a 0·5% level in their diet (equivalent to 0·3 g./kg. body weight/day). With diets containing 1% of either preparation (0·6 g./kg./day), formation of concretions was more pronounced, with evidence of tissue damage. Hodge[6] reported that in short-term toxicity tests on rats, condensed phosphates caused kidney damage when included at 2% level in the diet (1·2 g./kg./day). No significant abnormalities were seen in the kidneys of rats receiving a diet containing only 0·2% (0·12 g./kg./day). Dogs fed on the phosphates showed no deleterious effect at the 0·1 g./kg. body weight/day level, but damage was obvious at the 4 g./kg./day level.

In view of the present-day use of pyrophosphates in baking powder, liquid foods, chocolate drink powders, soup thickeners, instant puddings, ice cream, meat and cheese and also of the effects of the sodium salt when administered parenterally to mice, rabbits and dogs,[7] further examination of the acute effects of parenteral administration and the acute and longer-term effects of oral administration of sodium pyrophosphate seemed desirable. This paper describes such an investigation. For administrative reasons outside our control it was not possible in these studies to carry out life-span tests; however, since pyrophosphate is a normal body constituent, life-span studies at low doses may be less important than the acute and medium-term effects of relatively high dosage levels.

Experimental

Materials

Sodium pyrophosphate.—Supplied by Messrs. Albright & Wilson, as Tetron K, analysing as 97·5% sodium pyrophosphate and 2·5% orthophosphate.

Disodium hydrogen phosphate.—Grade used in food manufacture, supplied by Messrs. Albright & Wilson; containing 39·5–40·0% P_2O_5.

Diets.—The composition of the five diets is shown in Table I. They were prepared in 3 kg. batches, as required, and stored in covered tins in a cool room.

Table I

Composition and analysis of diets

(weight of constituent in g. of diet)

Constituent	Control	1% Pyrophosphate	2½% Pyrophosphate	5% Pyrophosphate	5% Orthophosphate
Whole wheat flour	660·0	660·0	643·0	615·0	615·0
Full cream dried milk	330·0	330·0	330·0	330·0	330·0
Salt mix	10·0	—	—	—	—
Casein	—	—	2·0	5·0	5·0
Sodium pyrophosphate	—	10·0	25·0	50·0	—
Disodium hydrogen phosphate dihydrate	—	—	—	—	62·7
Total	1000·0	1000·0	1000·0	1000·0	1012·7
Calorific value, cal./100 g. (calculated)	397	397	398	399	394
Protein content, g./100 g. diet (calc.)	17·2	17·2	17·1	17·1	17·1
Calcium, mg./100 g. diet (determined)	644	—	—	448	446
Phosphorus, mg./100 g. diet (determined)	526	—	—	1650	1598

Animals.—The rats used were from our own breeding stock of Birmingham-Wistar strain.

Dosage and relationship to level of use

The possible daily consumption of sodium pyrophosphate by a 70-kg. man has been calculated from the values in Table II as 423 mg./day (6·03 mg./kg./day). This is the standard daily dietary dose *D* for man.

These phosphates, derived from phosphoric acid, may be comprised of aluminum, calcium, potassium, or sodium salts. Each phosphate has its own merits, and depending upon the formulation, the formulator may decide to use one or another. The FDA has determined that they are safe and it has regulated phosphate usage levels in food products. Many products on the market contain these various phosphates. Some of the products that are offered to consumers are labeled foods and some are not. If they are labeled products, many times the formulator may decide not to declare the phosphates since, in these cases, they are considered to be processing aids.

Hence, there is no adverse position towards phosphates in general or, in particular, towards sodium phosphates usage in soy. In fact, many food formulations, due to the additional functionality provided by the phosphates, make commercially acceptable products with possibly extended shelf lives.

12. Petition Justification Statement:

The FDA has confirmed that the consumption of soy products, as part of a healthy diet, can provide significant health benefits to consumers, especially for cardiovascular health. In fact, soy products with certain nutritional contents may make specific heart-healthy claims on their labels. While U.S. medical researchers continue to explore a wide variety of other health benefits that soy may provide, soy's association with other preventative and treatment benefits for certain cancers, bone and skin diseases, lactose intolerance, menopausal symptom relief, and other human health issues has caused an explosion of demand among consumers for new soy food and beverage products.

in farmyard manure or fertilisers ; 1 ton/acre supplies 270 lb. of Mg/acre. Information on the availability to crops of Mg in this form is limited ; Wolton[4] reported that over a short period it was less efficient than equivalent rates of Mg as sulphate in raising the Mg content of herbage. This may be because of lower solubility or because of the antagonistic effect of Ca. In one experiment on potatoes, each of these sources supplying 27 lb. of Mg/acre gave the same increases in yield. At the high rates of magnesian limestone normally applied, however, it is probable that even with slower availability sufficient Mg would be supplied to the following crop.

Mg deficiency, serious enough to be economically important, seems therefore to be restricted to soils 'low' or 'very low' in exchangeable Mg, even among light soils these are not common. Even on deficient soils the deficiency is often corrected in practice by farmyard manure or fertilisers containing Mg. Serious deficiency can be overcome by liming with magnesian limestone instead of liming materials containing little or no Mg. Where this is too expensive because of high transport costs, or where liming is not needed, 30–40 lb. of Mg/acre can be supplied as the sulphate (either kieserite or Epsom salts) or as calcined magnesite, given every 3 years or so. While there is inadequate information on the necessary rate of frequency of application of Mg, it seems advisable to apply it in relatively small and frequent applications because of the risk of loss by leaching.

References

[1] Russell, (Sir) E. J., & Garner, H. V., *Emp. J. exp. Agric.*, 1941, 9, 217
[2] Holmes, M. R. J., *J. agric. Sci.*, 1962, 58, 281
[3] Walsh, T., & O'Donohoe, T. F., *J. agric. Sci.*, 1945, 35, 254
[4] Wolton, K. M., *Proc. 8th int. Grassland Congr.* (Reading), 1961, p. 544
[5] Hemingway, R. G., *Emp. J. exp. Agric.*, 1961, 29, 16

BIOLOGICAL EFFECTS OF FOOD ADDITIVES.

II.*—Sodium Pyrophosphate

By P. K. DATTA,† A. C. FRAZER, M. SHARRATT and H. G. SAMMONS

The acute effects of oral and parenteral sodium pyrophosphate on rats have been examined, with determination of the intraperitoneal LD_{50} and the cause of death.

Sodium pyrophosphate was included for 16 weeks at 1%, 2½% and 5% levels and sodium orthophosphate at a 5% level in the diet of rats. The effects were assessed by examining gain in body weight, food intake, renal and hepatic function, blood cell counts, organ weights and gross pathology and micropathology. Calcium and phosphorus balance studies were carried out on some groups. Faeces and urine have been analysed for content of pyrophosphate.

The intraperitoneal LD_{50} of sodium pyrophosphate was 233 mg./kg., whereas the oral LD_{50} was probably greater than 4 g./kg. The cause of death was not established.

The low oral acute toxicity, the balance studies and the analyses of faeces and urine all suggest that pyrophosphate is converted to orthophosphate in the body. The site of such a reaction is being further studied.

The longer term studies indicate that a 1% level of pyrophosphate in the diet of rats caused renal damage. The relevance of the finding to the ingestion of phosphate by man is discussed. Further studies are desirable on the metabolism of pyrophosphate and on the assessment of a safe phosphate intake for man.

Introduction

At the present time the use of phosphoric acid and its simple and condensed salts in food

---

* Part I: *J. Sci. Fd Agric.*, 1962, 13, 32

† André Meyer FAO Research Fellow. Present address: India Institute of Hygiene & Public Health, Calcutta 12, India

Yet, no matter what health benefits a food may offer, consumers insist that food products taste as good and perform as well in the diet as traditional foods. Sodium phosphates allow soy producers to create and market soy foods and beverages that meet consumer requirements for quality, taste, texture, and other standards. Since sodium phosphates have long been used in the dairy industry to improve ingredient functionality and product performance, it is our position that the use of sodium phosphates in soymilk and dry soymilk products would bring parity to organic soy producers and organic dairy product producers.

Without the ability to use sodium phosphates in soymilk and dry soymilk products, not only can soy producers not compete with dairy producers, the future business of Carousel Foods and other manufacturers would be seriously curtailed, and a great loss would be caused by lost research and development efforts. Without the use of sodium phosphates, other companies and we would incur large new expenses for further lengthy research and development required to formulate new soymilk and dry soymilk products similar to or equivalent to dairy products.

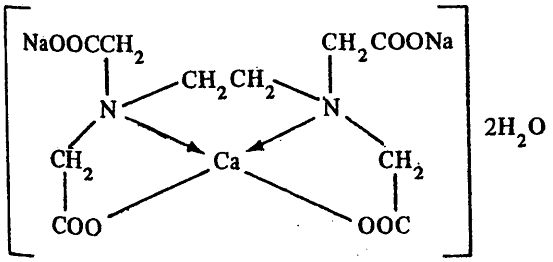
Thus, we urge you to add sodium phosphates to the National List, particularly for use in food and beverage products formulated with soymilk and dry soymilk similar to or equivalent to dairy products.

TABLE 2. BIOLOGICALLY ACTIVE METAL CHELATES

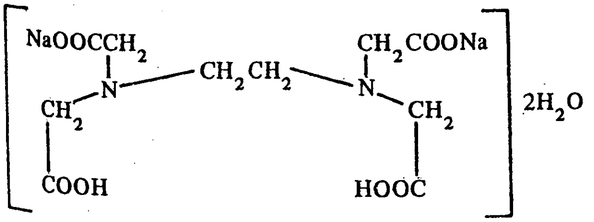
Metal	Metalloenzyme	Other Biological Functions
Mg	Polynucleotide phosphorylase, ATPase, choline acylase, deoxyribonuclease, acetate kinase, adenosine phosphokinase, fructokinase, glyceric kinase, hexokinase	Chlorophyll
Ca	α-Amylase, aldehyde dehydrogenase, lipase	
V		Green algae, blood of marine worm (ascidian)
Cr		Glucose tolerance factor
Mn	Arginase, carnosinase, prolinase, enolase, isocitricdehydrogenase, 3-phosphoglycerate kinase, glucose-1-P kinase	
Fe	Aconitase, formic hydrogenylase, phenylalanine hydroxylase, peroxidase, catalase, cytochromes	Hemoglobin, ferritin, hemosiderin, siderophilin
Co	Aspartase, acetylornithinase	Vitamin B_{12}
Cu	Laccase, phenolase, tyrosinase, uricase	Ceruloplasmin, cytochrome
Zn	Carbonic anhydrase, carboxypeptidase, alcohol dehydrogenase, glutamic dehydrogenase, acylase	
Mo	Nitrate reductase, xanthine oxidase	

pound called *struvite,* which appears to the user to be pieces of glass. Although not harmful, these substances are the cause for rejection. Struvite formation is effectively prevented by the addition of a small amount of pyrophosphate to the canned fish.

EDTA. Ethylenediaminetetracetic acid (EDTA) is an organic chelating agent. A number of salts of EDTA are available with uses essentially similar to the acid. The USP salts are called edetates (calcium disodium, disodium edatates); others are usually abbreviated to EDTA (tetrasodium, trisodium EDTA, etc.). Other salts, known chiefly under trademarked names, are the sodium ferric, dihydrogen ferrous, and a range of disodium salts with magnesium, divalent cobalt, manganese, copper, zinc, and nickel. The formulas of two commonly used EDTA compounds used in the food field are shown below (See also Appendix Table 1):



(Calcium disodium EDTA)



(Disodium EDTA)

Many of the foregoing listed sequestering agents are multifunctional in terms of their role as food chemical additive.

References

Bailar, J. C., Jr. "Chelation," in *The Encyclopedia of Chemistry,* 3rd Edition, (C. A. Hampel and G. G. Hawley, Editors), Van Nostrand Reinhold, New York (1973).

Calvin, M., and A. E. Martell: "Chelation and Metal Chelate Compounds (In Biological Systems)," in *The Encyclopedia of Biochemistry,* (R. J. Williams and E. M. Lansford, Jr., Editors), Van Nostrand Reinhold, New York (1967).

deMan, J. M., and P. Melnchyn, Editors: "Phosphates in Food Processing," Avi, Westport, Connecticut (1971).

Meyer, L. H.: "Food Chemistry," Avi, Westport, Connecticut (1974).

Moledina, K. H., *et al.*: "Effects of Antioxidants and Chelators on the Stability of Frozen Stored Mechanically Deboned Flounder Meat," *J. of Food Science,* 42, (3) 759–765 (1977).

Reents, A. C.: "Chelating Agents," in *Chemical and Process Technology Encyclopedia* (D. M. Considine, Editor), McGraw-Hill, New York (1974).

Staff: "Food Chemicals Codex," National Academy of Sciences, Washington, D.C. (1972). Several supplements have been published during interim.

Ser. Abbreviation for Serine. See also Amino Acid.

SERENDIPITY BERRY. Sweeteners.

SERINE. Amino Acid; Amino Acid Metabolism; Nutrients and Dietary Supplements; Phospholipids; Appendix Table 1.

SERRANO PEPPER. Pepper (Solanaceae).

SESAME SEED AND OIL. The sesame plant, *Sesamum* spp., has been cultivated since antiquity. Reference to the plant is made in very early Egyptian and Assyrian records. The species currently grown commercially is *Sesamum*

Appendixes

TABLE 1. METAL ION AND METAL CHELATE CATALYSIS OF CHEMICAL REACTIONS

Solvolysis and Other Reactions Involving Acid Catalysis by the Metal Ion

Reaction Type	Substrate	Catalyst
Solvolysis	Amino acid esters, peptides, and amides	Cu^{2+}, Co^{2+}, Mn^{2+}
	Phosphate esters	La^{3+}, Cu^{2+}, VO^{2+}
	Fluorophosphates	Cu^{2+}, UO_2^{2+} diamine-Cu(II) complexes
	Polyphosphates	Ca^{2+}, Mg^{2+}
	Schiff bases	Cu^{2+}, Ni^{2+}
Transamination	Schiff bases of pyridoxal and α-amino acids	Fe^{3+}, Cu^{2+}, Al^{3+}, Zn^{2+}, Ni^{2+}, Co^{2+}
Decarboxylation	α-Keto polycarboxylic acids (e.g., oxalacetic and oxalsuccinic acids)	Cu^{2+}, Zn^{2+}, Ni^{2+}, Co^{2+}, Mn^{2+}, Fe^{2+}
Acylation	Acetylacetone	Co(III), Rh(III) or Cr(III) chelates of acetylacetone

Catalysis of Oxidation Reactions by Electron Exchange with Metal Ions or Metal Complexes

Reaction	Substrate	Metal Ion or Complex
Oxidation by molecular O_2	Ascorbic acid, catechols, quinoline, salacylic acid	Fe(III), Fe(III)-EDTA, Cu(II), Cu(II)-EDTA, V(IV)
Oxidation by H_2O_2	Phenol, anisole	Fe(II) (Fenton's reagent), Fe(II)-hydroquinone Fe(II)-EDTA-ascorbic acid
Formation of oxygen	Hydrogen peroxide	Fe^{3+}, Fe(III)-phthalocyanine chelate
Formation of disulfides from mercaptides	Thioglycolic acid	Fe^{3+}, Cu^{2+}

bonium ion structure in which the Fe^{2+} ion is always bound to the same donor atoms, while the interconversion of the substrate occurs through the migration of only protons and electrons.

Some of the more important biological reactions that are catalyzed by metal ions are summarized in Table 2.

The most commonly used sequestrants in the food field are listed and described briefly in Appendix Table 1 and include:

Calcium acetate
Calcium chloride
Calcium citrate
Calcium disodium EDTA
Calcium gluconate
Calcium phosphate, monobasic
Calcium sulfate
Citric acid
Disodium EDTA
Glucono delta-lactone
Oxystearin
Phosphoric acid
Potassium citrate
Potassium phosphate, di- and monobasic
Sodium acid pyrophosphate
Sodium citrate
Sodium diacetate
Sodium gluconate
Sodium metaphosphate
Sodium potassium tartrate
Sodium tartrate
Sodium thiosulfate
Sorbitol
Tartaric acid
Triethyl citrate

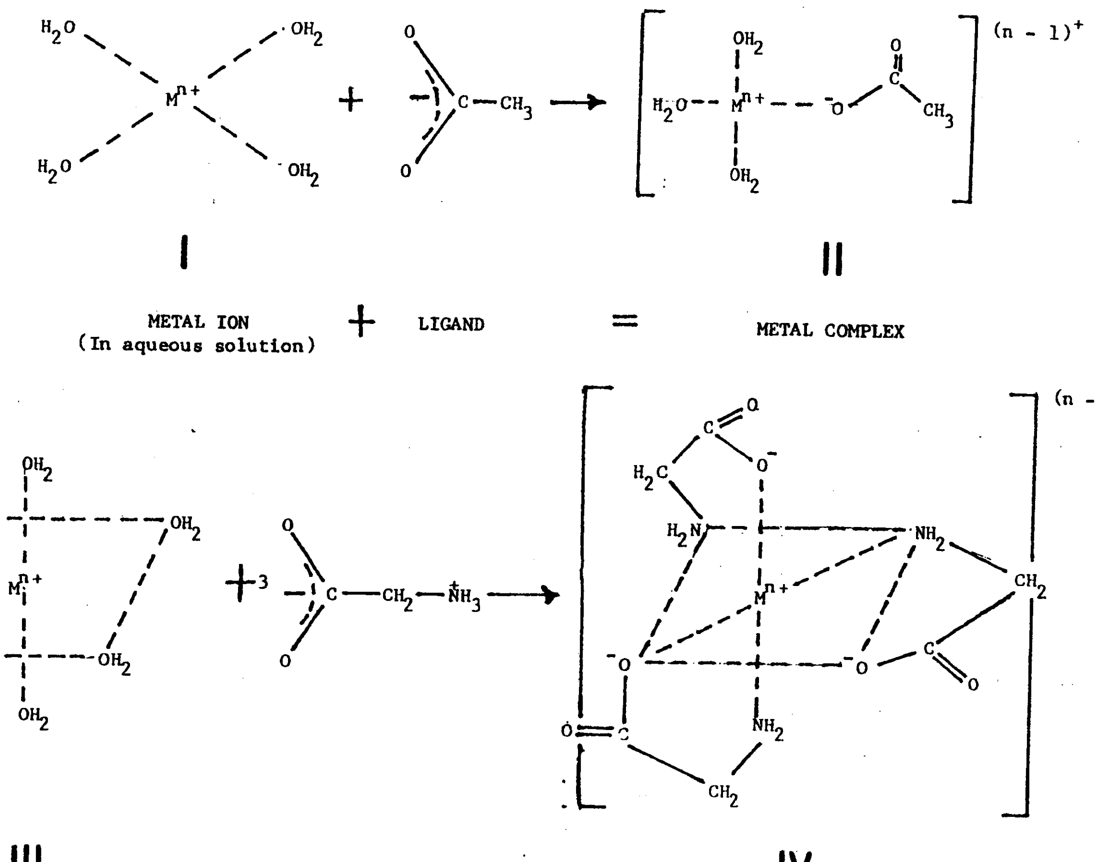
Phosphates. These substances have the ability to combine with metal ions, such as calcium, magnesium, iron, and copper and so render the metals nonactive. Calcium and magnesium are primarily responsible for the hardness of water. The addition of tripolyphosphate or hexametaphosphate will bind these elements and produce soft water. In a similar manner, sequestration is used to soften the skins of fruits and vegetables for faster cooking, and to increase the extraction and recovery of pectrin in fruit. Calcium pectinates, which are insoluble, are converted into sodium pectinates which are soluble and readily extracted.

Pyrophosphates are especially effective sequestrants for iron which catalyzes oxidative darkening of fruits and vegetables. Potatoes, in particular, turn dark after cooking unless the iron in the potato is sequestered. Iron or copper are also responsible for catalyzing oxidative rancidity in meat, poultry, and fish. Moledina, *et al.* (1977) investigated the effectiveness of combinations of an antioxidant, chelating agents and polyphosphates in retarding the chemical and organoleptic deterioration of mechanically deboned flounder meat during frozen storage. Treatment with polyphosphates, usually applied for moisture binding, will also inhibit rancidity and prolong the storage life of various meats. Canned fish frequently develops crystals of a com-

Received by OMRI

APR 27 2001

Sodium Phosphates: Selected Definitions



Examples of metal chelating compounds.

amino and carboxylate groups. Metal chelates have high solution stability, and the metal ions found in natural substances as part of a catalytic enzyme system are usually bound to donor groups of the enzyme through metal chelate rings.

Most of the metal ions that have biological functions have a coordination number of 6, with the donor groups arranged in an octahedral fashion, as indicated by compounds III and IV. There are a few metals, such as Mg^{2+} and Zn^{2+}, that frequently coordinate only 4 donor groups tetrahedrally, and Cu^{+2}, which has 4 coordinations directed to the corners of a square plane with the metal ion at the center of the plane.

Metal Ions and Complexes as Catalysts in Aqueous Systems. Many simple acid-base reactions are catalyzed by both metal ions and hydrogen ions. By virtue of its small size, the electronic interaction of the hydrogen ion with a substrate is much greater than that of a metal ion. The latter, on the other hand, has properties not possessed by hydrogen ions, which are useful in catalysis; the ability to coordinate a large number of electron donor groups simultaneously, the specific geometric orientation of the coordinate bonds of certain metal ions, and the ability of metal ions to undergo oxidation-reduction reactions. Many of these reactions are models of the more complex catalytic effects that occur in biological systems. Since these reactions of simple coordination compounds aid in the understanding of biological reactions, a few of the more common examples are given in Table 1.

The function of the metal ions in the reactions summarized in Table 1 is to attract electrons from the substrate. When this effect takes the form of simple polarization of the functional groups of the substrate, charge variations and electron shifts in these groups facilitate the chemical reactions listed under solvolysis (See **Solvolysis**) and acid catalysis. When the metal ion removes completely one or more electrons from the substrate, the first step in an oxidation reaction occurs. This type of catalysis can be accomplished only by metals capable of existing in more than one valence state.

There is a saturation effect in the coordination of a metal ion by donor groups of both the enzyme and the substrate. Therefore, one would expect that the interaction of a free metal ion with the substrate would be greater than that of the metalloenzyme (in which the metal is already partially coordinated). If this were true, the metal ion would have a greater catalytic effect than the metalloenzyme. The reverse is always the case; thus far, no metal ions, or metal complex enzyme models, have been found to approach the catalytic activities of the corresponding enzyme. This high activity of the enzyme is ascribed to the special environment of the substrate around the active site of the enzyme, through which additional binding of the substrate by adjacent organic groups of the enzyme take place.

The enzyme aconitase, which contains the Fe^{2+} ion at the reactive center, catalyzes the interconversion of citric, isocitric, and aconitic acids. The reaction has been shown to occur through the formation of a single intermediate car-

Sodium Phosphates

Selected Definitions

From **Dictionary of Food Ingredients**
Second Edition
Robert S. Igoe
Van Nostrand Reinhold
© 1989

Monosodium Phosphate NaH2OPO4. An acidulant, buffer, and sequestrant that is mildly acid, with a pH of 4.5 and very soluble in water, with a solubility of 87 g per 100 nml of water at 25°C. It is used as an acidulant in effervescent powders and laxatives. It is also used in soft drink dry-mix formulations, in cheese, and in carbonated beverages. It is also termed monosodium dihydrogen orthophosphate; sodium phosphate, monnobasic; sodium biphosphate; and monosodium monophosphate.

Disodium Phosphate Na2HPO4. The disodium salt of phosphoric acid which functions as a protein stabilizer, buffer, dispersant, and coagulation accelerator. It is milkdly alkaline with a 1 percent solution having a pH of 9.2. It is moderately soluble in water with a solubility of 12 g in 100 ml at 25°C. It is used in farina and macaroni to shorten the cooking time by making the particles swell faster and cook more thoroughly. In evaporated milk it acts as a buffer and prevents gelation, also acting as a buffer in coffee whiteners. It is an accelerator of the setting time in instant pudding. In cream sauce and whipped products it functions as a dispersant by producing a swelling of protein. It is also termed disodium monohydrogen orthophosphate; sodium phosphate, dibasic; and disodiium monophosphate.

Sodium Hesametaphosphate (NaPO3)13. A sequestrant and moisture binder that is very soluble in water but dissolves slowly. Solutions have a pH of 7.0. It permits peanuts to be salted in the shell by making it possible for the salt brine to penetrate the peanuts. In canned peas and lima beans, it functions as a tenderizer when added to the water used to soak or scald the vegetables prior to canning. It improves whipping properties in whipping proteins. It functions as a sequestrant for calcium and magnesium, having the best sequesterizing power of all the phosphates. It prevents get formation in sterilized milk. It is also termed sodium metaphosphate, sodium polyphosphate, and Graham's salt.

References

NOTE: See also reference lists at ends of entries on Flavor Enhancers and Potentiators; and Flavorings.

Amerine, M. A., Pangborn, R. M., and E. B. Roessler: "Principles of Sensory Evaluation of Foods," Academic Press, New York (1965).

Blair, J. R.: "Interface of Marketing and Sensory Evaluation in Product Development," *Food Technology*, 32 (11) 61–62 (1978).

Brandt, D. A.: "The Sensory Evaluation Laboratory," Schenley Distillers, Inc., Lawrenceburg, Indiana (1968).

Bressman, L. P., and R. W. Behling: "The Selection and Training of Judges for Discrimination Testing," *Food Technology*, 31 (11) 62–67 (1977).

Civille, G. V.: "Case Studies Demonstrating the Role of Sensory Evaluation in Product Development," *Food Technology*, 32 (11) 59–60 (1978).

Dember, W. N.: "The Psychology of Perception," Holt, Rinehart and Winston, New York (1963).

Dethmers, A. E.: "Utilizing Sensory Evaluation to Determine Product Shelf Life," *Food Technology*, 33 (9) 40–42 (1979).

Elrod, J.: "Bridging the Gap between Laboratory and Consumer Tests," *Food Technology*, 32 (11) 63 (1978).

Engen, T.: "Psychophysics 1 and 2," in *Woodworth and Schlossberg's Experimental Psychology*, (J. W. Kling and L. A. Riggs, Editors), 3rd Edition, Holt, Rinehart and Winston, New York (1971).

Erhardt, J. P.: "The Role of the Sensory Analyst in Product Development," *Food Technology*, 32 (11) 57–58 (1978).

Gacula, M. C., Jr.: "Analysis of Incomplete Block Designs with Reference Samples in Every Block," *J. of Food Science*, 43 (5) 1461–1466 (1978).

Godwin, D. R., Bargmann, R. E., and J. J. Powers: "Use of Cluster Analysis to Evaluate Sensory-Objective Relations of Processed Green Beans," *J. of Food Science*, 43 (4) 1229–1233 (1978).

Hunt, M. C., and H. B. Hedrick: "Chemical, Physical and Sensory Characteristics of Bovine Muscle from Four Quality Groups," *J. of Food Science*, 42 (3) 716–720 (1977).

Konigsbacher, K. S.: "How the Government Views Sensory Evaluation," *Food Technology*, 32 (11) 6466 (1978).

Kramer, A., and B. A. Twigg: "Quality Control for the Food Industry," 3rd Edition, Volume 1, page 10, Avi, Westport, Connecticut (1970).

Larmond, E.: "Physical Requirements for Sensory Testing," *Food Technology*, 27 (11) 28 (1973).

Nakayama, M., and C. Wessman: "Application of Sensory Evaluation to the Routine Maintenance of Product Quality," *Food Technology*, 33 (9) 38–39, 44 (1979).

Pangborn, R. M., and W. L. Dunkley: "Laboratory Procedures for Evaluating the Sensory Properties of Milk," *Dairy Science Abstracts*, 26 (2) 55 (1964).

Reece, R. N.: "A Quality Assurance Perspective of Sensory Evaluation," *Food Technology*, 33 (9) 37 (1979).

Rhyu, H. Y.: "Some Comments on the Estimation of Sensory Threshold by Kaerber and Scoville Methods," *J. of Food Science*, 43 (5) 1632–1633 (1978).

Sidel, J. L., and H. Stone: "Experimental Design and Analysis of Sensory Tests," *Food Technology*, 30 (11) 32 (1976).

Stone, H., and J. L. Sidel: "Computing Exact Probabilities in Sensory Discrimination Tests," *J. of Food Science*, 43 (3) 1028–1029 (1978).

Swartz, M. L., and T. E. Furia: "Special Sensory Panels for Screening New Synthetic Sweeteners, *Food Technology*, 31 (11) 51–55, 67 (1977).

Walsh, D. H.: "The Dynamics of the Flavor Profile," Arther D. Little, Inc., Cambridge, Massachusetts (1979).

Wolfe, K. A.: "Use of Reference Standards for Sensory Evaluation of Product Quality," *Food Technology*, 33 (9) 43–44 (1979).

Zook, K., and C. Wessman: "The Selection and Use of Judges for Descriptive Panels," *Food Technology*, 31 (11) 56–61 (1977).

SEQUESTERING AGENTS. Also called chelates or metal-ion deactivators, these substances form very stable, soluble complexes with metal ions. They are used in various aspects of food production and processing chiefly to obviate undesirable properties of metal ions without the necessity of precipitating or removing these ions from solution. The terms, *sequestering agent* and *metal-ion deactivator* are not strictly synonymous, but their meanings overlap to a large degree and the terms are often used interchangeably. Sequestering agents were first used to soften water by forming soluble complexes with calcium, magnesium, and ferrous ions, thus preventing the formation of the insoluble soaps and boilers scales which accompany the use of hard water. Metal-ion deactivation, on the other hand, implies a decrease in the catalytic activity of a metal ion. Sequestrants are used in food products and processes to keep out traces of substances like minerals that promote unwanted oxidation. Certain fertilizers have strong sequestering properties that keep impurities in solution, as well as salts of micronutrient metals that are insoluble derivatives of orthophosphoric acid—as, for example, in liquid ammonium polyphosphate (APP) fertilizers. Although micronutrients are required in soil, deficiencies soon lead to stunted and diseased crops as well as livestock. Several of these trace elements have proved quite difficult to add to the soil or plants in forms that can be assimilated readily. One way is to incorporate in fertilizers slowly soluble frits containing micronutrient compounds. Another way is to make organic chelates of metals, such as boron, cobalt, copper, iron, and zinc. Superphosphoric acid and solid or liquid polyphosphates are effective carriers for several micronutrients. See also Fertilizers.

In biological systems, chemical reactions are usually mediated by selective catalysts (enzymes). The high efficiencies and stereospecificities achieved require that enzymes have definite and characteristic geometries, whereby specific functional groups coordinated to a metal ion are held in definite spatial positions relative to each other and relative to the substances upon which they exert their catalytic effects. The incorporation of metal ions into enzymes can assist in maintaining a definite geometrical relationship between ionic and polar groups, through the geometric requirements of the coordinate bonds of the metal ion and electron donating groups of the enzyme and substrate, and through the ability of the metal ion to initiate oxidation-reduction reactions. Because of these chemical and steric effects, natural substances frequently employ coordinated metal ions in the complex compounds that catalyze biological reactions (metalloproteins).

The characteristic *coordination number* of a metal ion is the number of atoms that can combine with it by donation of an electron pair from a solvent molecule or by another molecule or anion having unshared pairs of electrons, as indicated by the reactions for metal ions of coordination number 4 and 6 shown in the accompanying diagram. When two or more donor groups are attached to the same molecule or anion, the complex compound formed is said to be a chelate compound. The chelate of glycine (formula IV) contains 3 metal chelate rings each coordinated through

Regulatory Information

Solutia food phosphates and phosphoric acid, including the components of blends, meet the specifications of the Food Chemicals Codex (FCC), as well as other codex compendia used by other countries. Solutia food phosphates and phosphoric acid are approved as Kosher (U), and confirmatory letters are available upon request. Many of the phosphates and some grades of phosphoric acid also meet specifications defined by the U.S. Pharmacopeia and the National Formulary.

Solutia food grade phosphates and phosphoric acid are approved for use by the Food and Drug Administration (FDA) in Title 21 in the Code of Federal Regulations (CFR). In Parts 182 and 184, they are identified as substances Generally Recognized As Safe (GRAS). Under Part 182, they are listed with functional groupings as follows:

- Subpart B: Multiple Purpose GRAS Food Substances
- Subpart F: Dietary Supplements
- Subpart G: Sequestrants
- Subpart I: Nutrients

(Note – Not all phosphates are identified under every classification.)

Applications in the Meat and Poultry industry are regulated by the U.S. Department of Agriculture (USDA) and are listed in Title 9 of the CFR. Specific approvals are as follows:

- Part 318.7: Use in Meat Products
- Part 381.147: Use in Poultry Products

The USDA limits the use of phosphates in these products to 0.5% by weight of the final product. The USDA specifically prohibits the use of phosphates in fresh meat and poultry products. Meat and poultry products processed with phosphates should be labeled appropriately, and the label must be approved by the USDA. Only clear solutions may be injected into meat and poultry. Letters issued by the Proprietary Mix Committee of the USDA regarding the use of Solutia food phosphates and blends are available upon request. These provide information on use and proper labeling.

Current regulations by the FDA in the U.S. limit the level of phosphates in seafoods to Good Manufacturing Practice (GMP) and must be labeled accordingly. Solutia recommends phosphate levels should not exceed 0.5% by weight of the final product. Lower levels, however, are generally sufficient for functionality. Current Compliance Guides issued by the FDA limit the amount of water that can be added to seafood products.

Non-food uses of various phosphates in USDA-inspected plants are listed in Miscellaneous Publication Number 1419, "List of Proprietary Substances and Nonfood Compounds." These include such applications as cleaners and egg washing.

Many food phosphates are also approved for use as indirect ingredients and other applications. Specific references follow:

- 21 CFR 172.892: Use of various phosphates in preparation of modified food starches
- 21 CFR 173.310: Use of phosphates and polyphosphates in boiler water
- 21 CFR 173.315: Use of phosphates in washing or to assist in lye peeling of fruits and vegetables
- 21 CFR 175: Subpart B – Substances for use only as components of adhesives; Subpart C – Substances for use as components of coatings
- 21 CFR 176: Indirect Food Additives – Paper and Paperboard Components.

Since regulation of alcoholic beverages is the responsibility of the Bureau of Alcohol, Tobacco and Firearms, the approval of ammonium phosphates for treatment of wine and alcoholic juices is listed in 27 CFR 24.246

Many phosphates are included in the Standards of Identity of many standardized foods, including processed cheese, processed cheese food, processed cheese spread, evaporated milk, baking powder, phosphated flour, self-rising flour, enriched self-rising flour, self-rising white corn meal, self-rising yellow corn meal, and bread, rolls and buns. Certain seafood products are described by a Standard of Identity as well. Limitations are set for some products. Details are listed in 21 CFR Parts 130-169.

In addition, approvals for use in pet foods and animal feeds are listed in 21 CFR Part 582.

Food products containing food phosphates must be appropriately labeled, and attention is directed to Nutrition Labeling and Education Act (NLEA) of 1990. To assist with nutritional labeling requirements, "Nutrient Data" is listed in Table G on page 32.

TABLE 2. REPRESENTATIVE FOOD APPLICATIONS FOR PHOSPHATES (cont.)

Food Product	Principal Function	Compound Usually Used	Typical Usage Level, %
POTATOES	Prevent darkening	SAPP; TSPP	2% solution dip
POULTRY	Moisture binding	STPP	0.3
PUDDINGS	Setting salts	DSP; TSPP	2.4
SEAFOODS			
Clams	Moisture binding	STPP	6-12% solution dip
Canned crab meat	Prevent crystal formation	SAPP	0.25
Fish	Moisture binding	STPP	6-12% solution dip
Lobster	Moisture binding	STPP	6-12% solution dip
Scallops	Moisture binding	STPP	6-12% solution dip
Shrimp	Moisture binding	STPP	6-12% solution dip
Canned tuna	Prevent crystal formation	SAPP	0.25
STARCH	Viscosity and stability modification	MSP; DSP; STPP	as needed
SUGAR	Clarification	H_3PO_4	as needed
TEXTURED VEGETABLE PROTEIN	Protein binding	STPP; SHMP	0.5
TOMATO JUICE, SAUCE	Thickener	SHMP	1.0
VEGETABLES			
Dried	Prevent discoloration	TSPP	as needed
Canned	Maintain texture; enhance tenderness	SHMP	0.1-0.4
YEAST	Nutrient	H_3PO_4	as needed

Source: FMC Corporation, Philadelphia, Pennsylvania.

*Special formulation furnished by manufacturer.

which aids in binding diced cured meat, fish, and poultry. It also emulsifies fat to prevent separation.

The chain length of phosphates can be increased further by melting and chilling to form a glass. Glassy sodium phosphates are generally called sodium hexametaphosphates (SHMP). SHMP has excellent sequestering power toward calcium and magnesium. It is used in meat treatment as a partial replacement for STPP to improve solubility in strong pickling brine or to prevent hardness precipitation in very hard water.

A convenient summary of the various phosphates is given in Tables 1 and 2. Phosphates are described in many entries throughout this volume, including: Acidifiers, Alkalizers, Buffers, and Neutralizers; Bread and Bakery Products; Emulsifiers, Stabilizers, and Thickeners; Fertilizers; Meat; Milk and Dairy Products; Poultry; Seafoods (Processing); Sequestering Agents. See also Appendix Table 1. Brief mention of phosphates is also made in entry on Antimicrobial Agents.

References

NOTE: Check reference lists at end of each of aforementioned entries.

Cassidy, R. D., *et al.*: "Effect of Tumbling Method, Phosphate Level and Final Cook Temperature on Histological Characteristics of Tumbled Porcine Muscle Tissue," *J. of Food Science*, 43 (5) 1514-1518 (1978).

Ellinger, R. H.: "Phosphates in Food Processing," in *Handbook of Food Additives*, (T. E. Furia, Editor), Chapter 15, CRC Press, Cleveland, Ohio (1972).

Mahoney, A. W., and D. G. Hendricks: "Some of Different Phosphate Compounds on Iron and Calcium Absorption," *J. of Food Science*, 43 (5) 1473-1475 (1978).

Ockerman, H. W., *et al.*: "Influence of Short Term Tumbling, Salt and Phosphate on Cured Canned Pork," *J. of Food Science*, 43 (3) 878-881 (1978).

Peterson, D. W.: "Effect of Polyphosphates on Tenderness of Hot Cut Chicken Breast Meat," *J. of Food Science*, 42 (1) 100-101 (1977).

Staff: "Functions of Phosphates in Foods," FMC Corporation, Philadelphia, Pennsylvania (1977).

PHOSPHINE. Fumigant; Pesticide; Raisin.

PHOSPHOGLUCONATE OXIDATIVE PATHWAY. Coenzyme; Riboflavin.

PHOSPHOGLYCERIC ACID. Amino Acid Metabolism.

PHOSPHOLIPIDS. These compounds belong to a [illegible] of fatty acid compounds sometimes referred to as "[illegible]ex lipids." The simplest are esters of fatty acids with glycerol phosphate and are called *phosphatidic acids*. Others contain the three radicals just mentioned plus nitrogen bases, such as choline and ethanolamine, the amino acid serine,

ASTARIS
Quality Products. Exceptional Response.

PRODUCT DATA SHEET

Received by OMRI
APR 27 2001

PRODUCT: Hexaphos® – Sodium Hexametaphosphate (SHMP)
Crushed (Granular)

GRADE: FCC

CODE: 208

GENERAL DESCRIPTION: Clean, white or clear, odorless, free-flowing granules.

FORMULA: $Na_{(n+2)}P_nO_{(3n+1)}$; n = 9-15

MOLECULAR WEIGHT: 978-1592

CAS NO.: 68915-31-1

DATE EFFECTIVE: December 14, 2000

CHARACTERISTICS	SPECIFICATION LIMITS	
P_2O_5, %	66.5	Minimum
pH, 1% Solution	6.8 - 7.2	
Loss on Ignition (30 minutes @ 800°C), %	1.0	Maximum
Water Insolubles, %	0.1	Maximum
Sizing, USSS:		
Retained on 8 Mesh, %	2	Maximum
Cumulative Retained on 20 Mesh, %	50	Maximum
Cumulative Retained on 100 Mesh, %	90	Minimum
Arsenic (as As), mg/kg	3	Maximum
Fluoride (as F), ppm	10	Maximum
Heavy Metals (as Pb), mg/kg	10	Maximum

Astaris FCC Grade SHMP meets the specifications of the current Food Chemicals Codex for Sodium Polyphosphate, Glassy.

NOTE: Specification Limits are subject to change from time to time. Please contact us for current data sheet.

Production Location:	Lawrence, KS; Trenton, MI
Packaging:	50 lb. multiwall bags
Labeling Requirements:	Product label
Shipping Classification:	Sodium Phosphate
Handling Precautions:	No precautionary statement required on label.

Handle in accordance with good industrial hygiene and safety practices. These include avoiding unnecessary exposure and removal of material from eyes, skin, and clothing.

This Product Data Sheet is subject to the terms and conditions on the reverse side hereof.

TABLE 2. REPRESENTATIVE FOOD APPLICATIONS FOR PHOSPHATES (cont.)

Food Product	Principal Function	Compound Usually Used	Typical Usage Level, %
CEREALS			
Dry cereals	Prevent dental caries	DSP; TSP	as needed
Quick-cooked cereals	Decrease processing time	DSP	0.2-2.0
CHEESES			
Cottage cheese	Acidulant	H_3PO_4	as needed
Imitation cheese	Emulsification	DSP; DSP$\cdot 2H_2O$	0.2-2.0
Process cheese	Emulsification	DSP; DSP$\cdot 2H_2O$	2.0
	Decrease acidity	TSP; TSP crystal	as needed
Starter media	Inhibit bacteriophage	MSP; DSP; DKP	1.5-2.5
CHIP DIPS	Prevent syneresis	STPP	0.5
COFFEE (flavored/instant)	Emulsification	DKP	as needed
DAIRY PRODUCTS (imitation)			
Nondairy creamers	Emulsification	SHMP; DKP; DSP; TSPP; SAPP	0.1-1.0
Frozen desserts	Stabilization	DSP; TSPP; SHMP	0.2
Sour cream	Prevent syneresis	STPP	as needed
Whipped toppings	Prevent syneresis	DSP; DKP; TSPP	0.2-1.0
EGGS			
Whole	Color preservation	MSP; MKP	0.5
Egg whites	Improve whipping; foam stability	SHMP	2.5
FATS AND OILS	Emulsification	STPP; TSPP SHMP; DSP	as needed
FRUIT	Mold inhibition; antioxidant	TSP; DSP	5% solution (wash)
GELATIN DESSERTS	Buffer	DSP; MSP	as needed
GUMS			
Alginate; agar	Gel strength control	DKP; TSPP	as needed
Carrageenan; others	Gel strength control	DSP; SHMP; STPP	as needed
ICE CREAM			
Hard, soft, imitation	Prevents "churning"	DSP; TSPP; SHMP	0.2
JAMS AND JELLIES	Tartness; firmness	H_3PO_4	as needed
LACTOSE (from whey)	Prevent protein precipitation	SHMP	0.1
PROTEIN (from whey)	Precipitate protein	SHMP	0.2
MEATS			
Ham	Moisture binding	STPP; SHMP	0.3
Bacon	Moisture binding	STPP; SHMP	0.3
Sausage	Cure accelerator	SAPP	0.5
Comminuted cured meats	Binding protein	STPP	0.5
Beef (frozen)	Moisture binding	STPP; SHMP	0.3
MILK PRODUCTS			
Beverages	Chelating; emulsification	DSP; TSPP	as needed
Buttermilk	Dispersing	TSPP	as needed
Cream	Stabilization	DSP; TSPP	as needed
Evaporated milk	Emulsification	DSP	0.06
PECTIN EXTRACTION	Chelation; increased yield	SHMP	1.0-2.5 (fruit weight basis)

HEXAPHOS® -- SODIUM HEXAME PHOSPHATE (SHMP), FCC GRADL RANULAR

Key Properties:

- Sequestration
- Neutral Salt
- Deflocculation
- Buffer Capacity
- Infinite Solubility in Water

Applications:

- For municipal potable water treatment, Astaris sodium hexametaphosphate conforms to the requirements of ANSI / NSF Standard 60 and meets or exceeds ANSI / AWWA Standard B502-94. Used for corrosion & scale control and sequestering.
- Generally recognized as safe under 21 CFR 182.90 (Substances migrating to food from paper and paperboard products.
- Generally recognized as safe as a sequestrant under 21 CFR 182.6760 (Sodium Hexametaphosphate).
- General recognition of safety in dietary supplements affirmed by FDA letter to trade association.
- Exempted from tolerance requirements under 21 CFR 182.99 (Adjuvants for pesticide chemicals) when used as a surfactant, emulsifier, wetting agent, suspending agent, dispersing agent or buffer in pesticide use dilutions by a grower or applicator, prior to application to the raw agricultural commodity.
- Cleared as a substance from which boiler water additives may be made under 21 CFR 173.310 (Boiler Water Additives).
- Cleared by the Meat and Poultry Inspection Division to decrease the amount of cooked-out juices in poultry, canned hams, pork shoulder picnics and loins, canned hams and pork shoulder picnics, chopped ham and bacon as follows: 5.0% phosphate in pickle at 10% pump level; 0.5% phosphate in product (only clear solutions may be injected into product).[9 CFR 381.47 and 318.7]
- Cleared by the Meat and Poultry Inspection Division as a cooling and retort water treatment agent for prevention of staining on the exterior of canned goods.
- Cleared by Meat and Poultry Inspection Division as a hog scald agent to remove hair from hog carcasses, in an amount sufficient for the purpose; must be removed by subsequent cleaning operations.
- Cleared by Meat and Poultry Inspection Division as a poultry scald agent, in an amount sufficient for the purpose in scald water; must be removed by subsequent cleaning operations (FR Oct.5, & Nov. 13, 1981).
- Cleared by the Meat and Poultry Inspection Division in potable water supply at a limit of 10 ppm to retard scale formation in pipes, from an approved feeder.
- Deemed to be generally recognized as safe by the Flavor and Extract Manufacturers' Association.

FOR MORE COMPLETE INFORMATION ON PROPERTIES AND SAFE HANDLING OF THIS MATERIAL, SEE THE ASTARIS MATERIAL SAFETY DATA SHEET (MSDS).

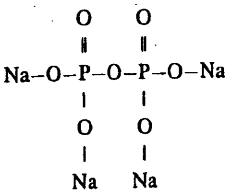
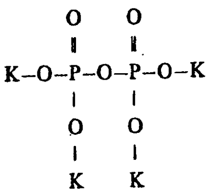
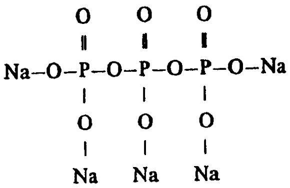
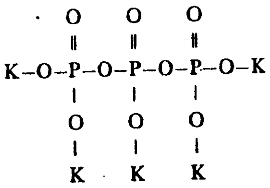
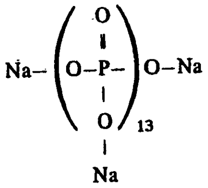
NOTICE: Although the information and recommendations set forth herein (hereinafter "Information") are presented in good faith and believed to be correct as of the date hereof, Astaris LLC makes no representations or warranties as to the completeness or accuracy thereof. Information is supplied upon the condition that the persons receiving same will make their own determination as to its suitability for their purposes prior to use. In no event will Astaris LLC be responsible for damages of any nature whatsoever resulting from the use of or reliance upon Information or the product to which Information refers. Nothing contained herein is to be construed as a recommendation to use any product, process, equipment or formulation in conflict with any patent, and Astaris LLC makes no representation or warranty, express or implied, that the use thereof will not infringe any patent. The data set forth herein are based on samples tested and are not guaranteed for all samples or applications. Such data are intended as guides and do not reflect product specifications for any particular product. NO REPRESENTATIONS OR WARRANTIES, EITHER EXPRESS OR IMPLIED, OR MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR OF ANY OTHER NATURE ARE MADE HEREUNDER WITH RESPECT TO INFORMATION OR THE PRODUCT TO WHICH INFORMATION REFERS.

Corporate Offices:

622 Emerson Road
Suite 500
P.O. Box 411160
St. Louis, Missouri 63141-1160
314-983-7500

For order assistance, please call our Customer Service Department Toll Free: 1-800-244-6169

TABLE 1. PROFILE OF PHOSPHATES USED IN FOOD PROCESSING (cont.)

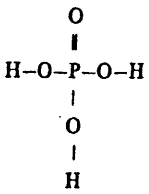
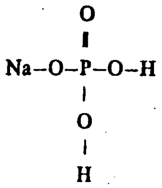
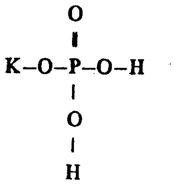
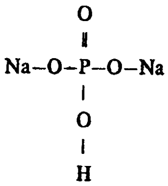
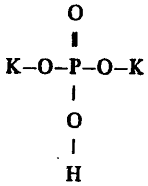
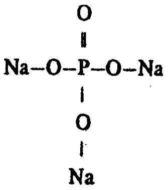
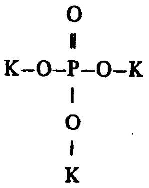
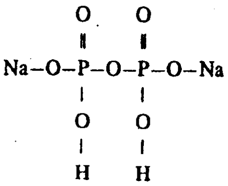
Name (Other names; abbreviation; formula)	Structural Formula	General Properties	Food-processing Functions
Tetrasodium pyrophosphate (Sodium pyrophosphate tetrabasic; Tetrasodium diphosphate; TSPP) $Na_4P_2O_7$	 $Na-O-\underset{\underset{Na}{O}}{\overset{O}{P}}-O-\underset{\underset{Na}{O}}{\overset{O}{P}}-O-Na$	Mildly alkaline, pH = 10. Moderately soluble in water. Sequestrant for iron and copper.	Buffer; emulsifier; dispersant; milk coagulant; sequestrant; antioxidant.
Tetrapotassium pyrophosphate (Potassium pyrophosphate tetrabasic; Tetrapotassium diphosphate; TKPP) $K_4P_2O_7$	 $K-O-\underset{\underset{K}{O}}{\overset{O}{P}}-O-\underset{\underset{K}{O}}{\overset{O}{P}}-O-K$	Mildly alkaline, pH = 10. Very soluble in water. Sequestrant for iron and copper.	Buffer; emulsifier; dispersant; moisture-binding in meat. Low-sodium products.
Sodium tripolyphosphate (Pentasodium triphosphate; STPP) $Na_5P_3O_{10}$	 $Na-O-\underset{\underset{Na}{O}}{\overset{O}{P}}-O-\underset{\underset{Na}{O}}{\overset{O}{P}}-O-\underset{\underset{Na}{O}}{\overset{O}{P}}-O-Na$	Mildly alkaline, pH = 10. Moderately soluble in water. Sequestrant for calcium and magnesium.	Moisture-binding in meat, poultry, and seafood. Emulsifier; sequestrant.
Potassium tripolyphosphate (Pentapotassium triphosphate; KTPP) $K_5P_3O_{10}$	 $K-O-\underset{\underset{K}{O}}{\overset{O}{P}}-O-\underset{\underset{K}{O}}{\overset{O}{P}}-O-\underset{\underset{K}{O}}{\overset{O}{P}}-O-K$	Mildly alkaline, pH = 10. Very soluble in water. Sequestrant for calcium and magnesium.	Moisture-binding in meat; emulsifier; sequestrant. Low-sodium products
Sodium hexametaphosphate (Graham's salt; Sodium phosphate glass; SHMP) $(Na_3PO_3)_{13}-Na_2O$*	 $Na-\left(O-\underset{\underset{Na}{O}}{\overset{O}{P}}-\right)_{13}O-Na$	Neutral, pH = 7.0. Very soluble in water. Sequestrant for calcium and magnesium.	Moisture-binding in meat; emulsifier; sequestrant water softener.

Source: FMC Corporation, Philadelphia, Pennsylvania.
*approximate composition

TABLE 2. REPRESENTATIVE FOOD APPLICATIONS FOR PHOSPHATES

Food Product	Principal Function	Compound Usually Used	Typical Usage Level, %
BAKERY GOODS			
Cakes	Medium-action leavening	SAPP*	1.6
Doughnuts	Fast-action leavening	SAPP*	1.6
Refrigerated dough	Slow-action leavening	SAPP*	1.6
	To prevent crystal formation	SHMP	0.05-0.1
Baking powder	Medium-action leavening	SAPP*	36-40
BEVERAGES			
Colas, root beer	Acidulant	H_3PO_4	0.1
Fruit drinks	Acidulant	H_3PO_4	as needed
Milk-based	Chelation; emulsification; buffering	DSP; TSPP	as needed
Dry mix	Acidulant	MSP	as needed

TABLE 1. PROFILE OF PHOSPHATES USED IN FOOD PROCESSING

Name (Other names; Abbreviation; formula)	Structural Formula	General Properties	Food-processing Functions
Phosphoric acid (Orthophosphoric acid; Acid phosphoric) H_3PO_4	 $\begin{array}{c}O\\ \Vert\\ H-O-P-O-H\\ \vert\\ O\\ \vert\\ H\end{array}$	Strong acid, soluble in water at all dilutions. Reacts readily with alkalis. Has no odor; is nonvolatile.	Acidulant; production of other phosphates.
Monosodium phosphate (Monosodium dihydrogen phosphate; Sodium phosphate monobasic; Sodium biphosphate; MSP) NaH_2PO_4	 $\begin{array}{c}O\\ \Vert\\ Na-O-P-O-H\\ \vert\\ O\\ \vert\\ H\end{array}$	Mildly acid, pH = 4.5; very soluble in water. Reacts readily with alkalis.	Acid buffer; emulsifier; reacts with bicarbonate to cause effervescence.
Monopotassium phosphate (Monopotassium dihydrogen phosphate; Potassium phosphate monobasic; potassium biphosphate; MKP) KH_2PO_4	 $\begin{array}{c}O\\ \Vert\\ K-O-P-O-H\\ \vert\\ O\\ \vert\\ H\end{array}$	Mildly acid, pH = 4.5. Moderately soluble in water.	Nutrient; low-sodium products.
Disodium phosphate (Disodium monohydrogen phosphate; Sodium phosphate dibasic; DSP) Na_2HPO_4	 $\begin{array}{c}O\\ \Vert\\ Na-O-P-O-Na\\ \vert\\ O\\ \vert\\ H\end{array}$	Mildly alkaline, pH = 9. Moderately soluble in water. Frequently produced as duohydrate.	Alkaline buffer—to raise pH level. Emulsifier; precipitant for calcium.
Dipotassium phosphate (Dipotassium monohydrogen phosphate; Potassium phosphate dibasic; DKP) K_2HPO_4	 $\begin{array}{c}O\\ \Vert\\ K-O-P-O-K\\ \vert\\ O\\ \vert\\ H\end{array}$	Mildly alkaline, pH = 9. Very soluble in water. Very hygroscopic.	Alkaline buffer; emulsifier. Nutrient; low-sodium products.
Trisodium phosphate (Trisodium orthophosphate; Sodium phosphate tribasic; TSP) Na_3PO_4	 $\begin{array}{c}O\\ \Vert\\ Na-O-P-O-Na\\ \vert\\ O\\ \vert\\ Na\end{array}$	Strongly alkaline, pH = 12. Moderately soluble in water. Sometimes produced as hemihydrate or dodecahydrate.	Alkalizer; emulsifier.
Tripotassium phosphate (Tripotassium orthophosphate; Potassium phosphate tribasic; TKP) K_3PO_4	 $\begin{array}{c}O\\ \Vert\\ K-O-P-O-K\\ \vert\\ O\\ \vert\\ K\end{array}$	Strongly alkaline, pH = 12. Very soluble in water. Very hygroscopic.	Alkalizer; emulsifier; Low-sodium products.
Sodium pyrophosphate (Acid sodium pyrophosphate; disodium dihydrogen diphosphate; SAPP) $Na_2H_2P_2O_7$	 $\begin{array}{c}O\quad\quad O\\ \Vert\quad\quad \Vert\\ Na-O-P-O-P-O-Na\\ \vert\quad\quad \vert\\ O\quad\quad O\\ \vert\quad\quad \vert\\ H\quad\quad H\end{array}$	Mildly acid, pH = 4.1. Moderately soluble in water. Reaction rate controlled during processing. Sequestrant for iron and copper.	Leavening acid; buffer; emulsifier; dispersant; sequestrant; antioxidant.

Regulatory Information

A. GRAS List
B. Astaris Phosphates Product Manual, Page 34

other parts of the world. The compound is available as emulsifiable concentrate (25%); and granules (10%). It is applied directly to the soil or used as a foliar spray. The residual effects provide protection up to about 3 weeks. Among the pests controlled by Phosfolan are:

aphid
armyworm
bollweevil
cotton leafworm
cutworm
fleahopper
grasshopper
hornworm
leafhopper
leaf miner
looper
lygus bug
mite
rootworm

The organic chemical name of Phosfolan is 2-(diethoxyphosphinylimino)-1,3-dithiolane.
Other designations: *Cyalane, Cylan, Cyolan, Cyolane.*
See also **Acaricide; Insecticide; Pesticide Application.**

PHOSMET ACARICIDE-INSECTICIDE. An organic phosphate contact-type pesticide that serves as an acaricide and insecticide. Developed in the United States* in the mid-1960s, Phosmet, available as a wettable powder (50%), is an effective control over a variety of insects and mites on several crops, including alfalfa, sweet potato, maize (corn), pea, nectarine, potato, and a variety of fruit crops. It is also used for insect control on livestock, but not dairy cattle. Phosmet is injurious to honeybees, fishes, and wildlife forms and thus must be used with precautions to avoid excessive usage and pollution of nearby land, lakes, and streams. The compound can be blended with most other fungicides and insecticides.

Target pests of Phosmet include:

alfalfa weevil
aphid
beetle (Colorado potato)
beetle (sweet potato)
cattle grub
codling moth
flea beetle
fruit moth (Oriental)
horn fly
leafhopper
peach twig borer
pear psylla
plum curculio
scale

The organic chemical name of Phosmet is N-(mercaptomethyl)phthalimide-S-(O,O-dimethyl phosphorodithioate).
Other designations: *Imidan, Phthalophos,* PMP, *Prolate.*
See also **Acaricide; Insecticide; Pesticide Application.**

PHOSPHAMIDON ACARICIDE-INSECTICIDE. An organic phosphate-type of pesticide that serves the function of acaricide and insecticide. Developed in Europe** in the late 1950s, Phosphamidon is effective against a variety of insects and mites. The toxicity of the compound is high and all persons using the material should wear protective clothing when in the target vicinity during and for 24 hours after application. No crop residue once treated should be fed to animals. Phosphamidon is highly injurious to honeybees. Because of this toxicity, precautions must be taken to avoid pollution of nearby fields, lakes, and streams, and any excessive use. On the positive side, the compound is comparatively harmless to wildlife and many fishes. The compound is available as an emulsifiable concentrate of several strengths. Some injury to plants [illegible] evidenced, notably cherry, plum, and peach, as [illegible] as maple trees and some varieties of sorghum. Although care must be exercised in its use, Phosphamidon is widely used on numerous crops throughout the world.

Target pests of Phosphamidon include:

aphid
beetle
beetle (Mexican bean)
bollworm
codling moth
grasshopper
leafhopper
leaf miner
mite
scale
spruce budworm
stemborer
thrip
white fly

The chemical name of Phosphamidon is (2-chloro-2-(diethylcarbamoyl)-1-methylvinyl)-dimethylphosphate.
Other designations: *Dimecron, Famfos.*
See also **Acaricide; Insecticide; Pesticide Application.**

PHOSPHATASES. Magnesium.

PHOSPHATE FERTILIZER. Fertilizer.

PHOSPHATE ROCK. Fertilizer.

PHOSPHATES. The widely diverse functionality of phosphates makes them of exceptional importance to the food technologist. Phosphoric acid finds many direct [illegible]s an acidulant. It has three available hydrogens w[illegible] can be replaced one by one with alkali metals, forming a series of **orthophosphate salts** with pH levels ranging from moderately acid (pH = 4) to strongly alkaline (pH = 12). This wide pH range makes phosphates very useful for adjusting the pH of food systems to almost any desirable level. Heating orthophosphates converts them to condensed phosphates containing 2, 3, or more phosphorus atoms per molecule. The **condensed phosphates, or polyphosphates,** have many properties which the orthophosphates do not enjoy. They are polyelectrolyes, and have dispersing or emulsifying properties. They can sequester or chelate metals, such as calcium, magnesium, iron, and copper, rendering these metals nonreactive. This functionality is useful for controlling oxidative rancidity and color formation as both are catalyzed by metal ions.

Condensed phosphates containing 2 atoms of phosporus are **pyrophosphates.** Sodium acid pyrophosphate (SAPP) is used as a leavening acid in baking, and is particularly useful because of the way it can be modified to give different rates of reaction. Pyrophosphates are good sequestrants for iron and copper, which often catalyze oxidation in fruits and vegetables. Thus, the use of a pyrophosphate effectively prevents the discoloration of such foods during preparation and storage.

Condensed phosphates containing 3 atoms of phosphorus are **tripolyphosphates,** the most important [illegible]hich is sodium tripolyphosphate (STPP). This compo[illegible]cts with the protein in meat, fish, and poultry to prevent denaturing or loss of fluids. This property is sometimes called "moisture binding." STPP also solubilizes protein

---

*Stauffer Chemical Co.
**CIBA-Geigy.

TXT	PDF	182.3798	Sodium sulfite.
TXT	PDF	182.3862	Sulfur dioxide.
TXT	PDF	182.3890	Tocopherols.
TXT	PDF	182.6085	Sodium acid phosphate.
TXT	PDF	182.6197	Calcium diacetate.
TXT	PDF	182.6203	Calcium hexametaphosphate.
TXT	PDF	182.6215	Monobasic calcium phosphate.
TXT	PDF	182.6285	Dipotassium phosphate.
TXT	PDF	182.6290	Disodium phosphate.
TXT	PDF	182.6757	Sodium gluconate.
TXT	PDF	182.6760	Sodium hexametaphosphate.
TXT	PDF	182.6769	Sodium metaphosphate.
TXT	PDF	182.6778	Sodium phosphate.
TXT	PDF	182.6787	Sodium pyrophosphate.
TXT	PDF	182.6789	Tetra sodium pyrophosphate.
TXT	PDF	182.6810	Sodium tripolyphosphate.
TXT	PDF	182.7255	Chondrus extract.
TXT	PDF	182.8013	Ascorbic acid.
TXT	PDF	182.8159	Biotin.
TXT	PDF	182.8217	Calcium phosphate.
TXT	PDF	182.8223	Calcium pyrophosphate.
TXT	PDF	182.8250	Choline bitartrate.
TXT	PDF	182.8252	Choline chloride.
TXT	PDF	182.8778	Sodium phosphate.
TXT	PDF	182.8890	Tocopherols.
TXT	PDF	182.8892	α-Tocopherol acetate.
TXT	PDF	182.8985	Zinc chloride.
TXT	PDF	182.8988	Zinc gluconate.
TXT	PDF	182.8991	Zinc oxide.
TXT	PDF	182.8994	Zinc stearate.
TXT	PDF	182.8997	Zinc sulfate.

Many emulsions are found in nature, as in the cases of milk, egg-yolk, and crude petroleum. Others are produced artificially, chiefly in the food, pharmaceutical, and cosmetic industries, by means of highspeed stirrers, colloid mills, or homogenizers. It has been found in years of experience that the stability and other properties of an artificially prepared emulsion are affected by numerous, often apparently trivial, details of operating technique. For example, the order in which ingredients are added, the speed and duration of the process, intermittent or continuous operation of the stirrer or other machine. Emulsions are sensitive to temperature and to small changes of concentration of the emulsifying agent. The production of a stable emulsion, therefore, requires patient research and longterm testing (shelf life, etc.). Instability can be determined microscopically by periodic measurement of the size-frequency distribution of the globules. An increase in average globule size, or decrease of interfacial area, shows coalescence of the disperse phase. Emulsion breaking is hastened by freezing, heating, aging, centrifuging, and the application of high-potential alternating current.

Generally, the manufacturers of food additives have conducted extensive research, not only in the development of emulsifying agents, stabilizers, and thickening agents, but also in their application engineering. Commonly, a given emulsifying agent (xanthan gum, for example) will be available in several formats and formulations for specific food product use. The physical and chemical properties of each formulation are adjusted to achieve as practically as possible the desired end-viscosity, pseudoplasticity, and other qualities as may be required for puddings, pie fillings, salad dressings, canned potato salad, canned tomato aspic, freeze-thaw stable spoonable dressing, and a host of other products.

Wide Variety of Compounds Available. Of the over-600 food chemicals listed in the "Food Chemicals Codex" (National Academy of Sciences, U.S.), emulsifiers, stabilizers, and thickeners are an important and extensive segment, comprising about 10% of the compounds described. These compounds are listed and described (formula, general characteristics, usual sources, and solubility) in Appendix Table 1:

Acacia
Acetylated monoglycerides
Agar
Alginic acid
Ammonium alginate
Calcium alginate
Calcium stearate
Calcium stearoyl-2-lactylate
Carrageenan
Cholic acid
Desoxycholic acid
Diacetyl tartaric acid esters of mono- and diglycerides
Dioctyl sodium sulfo succinate
Ethyloxylated mono- and diglycerides
Gelatin*
Gibberellic acid and gibberellic plant growth hormones*
Guar gum
Gums and mucilages*
Hydroxylated lecithin
Hydroxypropyl cellulose
Hydroxypropyl methylcellulose
Karaya gum
Lactated mono- and diglycerides
Lactylated fatty acid esters of glycerol and propylene glycol
Lactylic esters of fatty acids
Lecithin (See also entry on **Soybean Processing**)
Locust bean gum
Magnesium stearate
Methylcellulose
Methyl ethylcellulose
Mono- and diglycerides
Pectins*
Polyglycerol esters of fatty acids
Polysorbate 20, 60, 65, and 80
Potassium alginate
Potassium phosphate, tribasic
Potassium polymetaphosphate
Potassium pyrophosphate
Propylene glycol alginate
Propylene glycol monostearate
Sodium alginate
Sodium aluminum phosphate, basic
Sodium metaphosphate
Sodium phosphate, dibasic
Sodium phosphate, monobasic
Sodium phosphate, tribasic
Sodium pyrophosphate
Sodium stearoyl-2-lactylate
Sorbitan monostearate
Starches*
Succinylated monoglycerides
Tragacanth
Xanthan gum*

*Described in separate entries of same title.

References

Staff: "Additives Evaluated for Their Safety-in-Use in Food," Food Agricultural Organization/World Health Organization of the United Nations, Rome, Italy (revised periodically).
Staff: "Food Chemicals Codex," 2nd edition and later supplements, National Academy of Sciences, Washington, D.C. (1972).
Note: Also see lists of references contained in entries for items with asterisk above. Also reference lists in entries on Additives and Other Food Chemicals; and Colloid Systems.

EMULSIFICATION FUNCTIONALITY. Meat; Soybean Processing

ENCAPSULATION. Additives and Other Food Chemicals; Feedstuffs.

ENCLOSURES. Thermal (Heat) Preserving.

ENDEMIC. Foodborne Diseases.

ENDIVE. Of the family *Compositae* (composite family), endive (*Cichorium endivia*) is an annual or biennial herb having many basal leaves which in cultivated forms have become very much dissected and crisped. Mature plants are tall-stemmed and have purple, rarely white flowers, all ligulate. The plant is used either as a salad plant or as a potherb. Endive is native to India and has long been cultivated in European countries.

Endive closely resembles lettuce in its requirements for growth, except that it is less sensitive to heat. See also Lettuce. Endive may be substituted for lettuce in areas where the culture of lettuce may be impractical. In the southern United States, endive is mainly a winter crop; in the northern states, it is grown in spring, summer, and autumn. Endive is also forced in winter in northern areas. *Full Heart Batavian* and *Salad King* are popular, hardy varieties and are raised in the United States. Other endive cultivars include *Exquisite Curled* and *Green Curled*, grown in numerous areas, including the West African countries, where endive is highly regarded for its vitamin content.

Escarole or broadleaved endive is widely grown, with significant production in the United States. Total annual production in the United States averages in the range be-

TXT	PDF	182.1500	Monoammonium glutamate.
TXT	PDF	182.1516	Monopotassium glutamate.
TXT	PDF	182.1711	Silica aerogel.
TXT	PDF	182.1745	Sodium carboxymethylcellulose.
TXT	PDF	182.1748	Sodium caseinate.
TXT	PDF	182.1778	Sodium phosphate.
TXT	PDF	182.1781	Sodium aluminum phosphate.
TXT	PDF	182.1810	Sodium tripolyphosphate.
TXT	PDF	182.2122	Aluminum calcium silicate.
TXT	PDF	182.2227	Calcium silicate.
TXT	PDF	182.2437	Magnesium silicate.
TXT	PDF	182.2727	Sodium aluminosilicate.
TXT	PDF	182.2729	Sodium calcium aluminosilicate, hydrated.
TXT	PDF	182.2906	Tricalcium silicate.
TXT	PDF	182.3013	Ascorbic acid.
TXT	PDF	182.3041	Erythorbic acid.
TXT	PDF	182.3089	Sorbic acid.
TXT	PDF	182.3109	Thiodipropionic acid.
TXT	PDF	182.3149	Ascorbyl palmitate.
TXT	PDF	182.3169	Butylated hydroxyanisole.
TXT	PDF	182.3173	Butylated hydroxytoluene.
TXT	PDF	182.3189	Calcium ascorbate.
TXT	PDF	182.3225	Calcium sorbate.
TXT	PDF	182.3280	Dilauryl thiodipropionate.
TXT	PDF	182.3616	Potassium bisulfite.
TXT	PDF	182.3637	Potassium metabisulfite.
TXT	PDF	182.3640	Potassium sorbate.
TXT	PDF	182.3731	Sodium ascorbate.
TXT	PDF	182.3739	Sodium bisulfite.
TXT	PDF	182.3766	Sodium metabisulfite.
TXT	PDF	182.3795	Sodium sorbate.

EMMENTALER CHEESE. Milk and Dairy Products.

EMMER. Wheat.

EMITTER. Irrigation.

"EMPTY" CALORIE. Sweeteners.

EMULSIFIERS, STABILIZERS, AND THICKENERS. In the food processing industry, emulsifiers enable the creation of uniformly blended products (emulsions) from ingredients which, because of fundamental differences in their physical properties and as explained in the entry on **Colloid Systems**, are unmixable. Often cited as examples of two such incompatible substances are oil and water. Frequently mentioned as a successfully emulsified food product is salad dressing (oil and vinegar). In the literature, the terms emulsifier and stabilizer are sometimes used interchangeably. The term stabilizer derives from the fact that a stabilizer effectively assists in preserving an emulsion once created, with the practical result being a food product emulsion that enjoys a long shelf life. Thickeners, frequently, although not exclusively, are used in emulsified products to contribute a heavier consistency or body to the final product. Thickeners are included in this description because the majority of substances used in the food industry as emulsifiers are also classified and perform as stabilizers and thickeners. These additives may be naturally derived or synthesized and the majority are organic chemicals, but some inorganic substances also are used.

Emulsion. An emulsion is an intimate mixture of liquids, one of which (the *disperse phase*) is distributed in large or small globules throughout the other (the *continuous phase*). A third component, the *emulsifier* or *emulsifying agent*, without which the emulsion would immediately break down into layers, is always present at the interfaces between the two phases. The properties of an emulsion depend upon a complex interaction of: (1) Emulsion type, (2) concentration, (3) degree of dispersion, and (4) nature of the emulsifying agent.

Because water-and-oil emulsions are among the most thoroughly studied, the terms *water-phase* and *oil-phase* are commonly used to designate, in an emulsion of whatever composition, the phases whose relative behavior resembles that of oil and of water respectively. An emulsion in which water is the continuous phase is sometimes designated an *O/W emulsion;* an emulsion in which oil is the continuous phase is called a *W/O emulsion.* The gross properties of an emulsion are typically determined by the nature of its continuous phase. Thus, milk (a watery substance) is an O/W emulsion, whereas butter (greasy) is a W/O emulsion. Since the water-phase of any emulsion is necessarily more *hydrophilic,* or water-soluble, than the lipophilic oil-phase, the ease of dilution with water provides a convenient test to indicate whether an emulsion is O/W or W/O.

The globules in an emulsion are seldom of uniform size. Emulsions of concentration above about 70% either contain deformed polyhedral particles in close contact, or tend to *invert* into emulsions of the opposite type, containing less than 30% of the disperse phase. If inversion occurs, physical properties that vary with concentrations, such as viscosity or electrical conductivity, will show a discontinuous function through the concentration range. If inversion dc occur, the particles come in contact and are defo shape from spheres to polyhedra. Resistance to flow is caused by mutual interference, and there is a marked increase in viscosity, accompanied by a departure from Newtonian behavior, made evident by a pronounced plasticity of the emulsion. This condition was earlier termed by Ostwald as a semisolid emulsion or "liquid-liquid foam."

The stability of an emulsion depends partly on the size of the dispersed globules, and partly on the nature of their surface. The globules may range in size from a few hundred to a few micrometers. Large globules tend to rise or fall because of density difference, and may produce a concentrated "cream" or even a separated layer. The globules will coalesce if their surface is too weak to resist the forces of surface tension, tending to reduce the surface area. An emulsifying agent stabilizes the surface of each globule sufficiently to prevent coalescence.

An emulsifying agent or stabilizer may perform: (1) By supplying negatively charged ions for preferential adsorption on the globules; (2) by surrounding each globule with an adsorbed film, as of a protein; or (3) by coating each globule with a mechanically strong layer of fine solid particles (so-called armor-plated emulsion). Bancroft's rule states that for all types of emulsifying agents, the emulsifying agent is always more soluble in, or better wetted by, the continuous than by the dispersed phase. Thus, emulsions stabilized by electric charges on the surface of the globules occur almost exclusively with an aqueous continuo se. Common examples include carbon black (lipophil ich emulsifies water in oil; whereas silica (hydrophilic) emulsifies oil in water. Or, benzene can be emulsified in water by water-soluble sodium oleate; whereas water can be emulsified in benzene by oil-soluble magnesium oleate.

A surface-active emulsifying agent should be neither completely hydrophilic nor completely lipophilic. Some substances (sodium oleate, for example) while soluble in water by virtue of its polar group, has in its molecule a large organic and lipophilic group with a high surface energy in an aqueous medium. Molecules arriving at an oil-water surface arrange themselves in a low-energy orientation, with the hydrophilic group in the water and the lipophilic group in the oil. Since molecules do not migrate spontaneously from low- to high-energy positions, this surface orientation is stable. The sodium oleate molecule acts as a bridge across the oil-water interface, reducing the interfacial energy, and the negative ions thus firmly attached to the surface cause mutual repulsion of the globules of oil. Even in the absence of an electric charge, a judicious balance of the hydrophil-lipophil balance (HLB) of a molecular structure has made commercially available a large number of effective nonionic emulsifying agents. These do not have the harmful physiological effects of either the anionic or the cation-activ soaps and thus are suitable for use in foods and drugs. Since according to Bancroft's rule, an agent in which the hydrophilic character predominates will stabilize O/W emulsions and one in which the lipophilic character predor s wil stabilize W/O emulsions, an appropriate emulsit agen can be selected in advance, on the basis of its HLB, fc either type of emulsion.

FMC

Food Phosphates

Received by OMRI
APR 27 2001

chemistry,
nomenclature,
and
general functions

1982

FOODS AND FOOD PRODUCTION ENCYCLOPEDIA

DOUGLAS M. CONSIDINE, P.E.
Editor-in-Chief
(Fellow, American Association for the Advancement of Science;
Instrument Society of America; Senior Member, American
Institute of Chemical Engineers)

GLENN D. CONSIDINE
Managing Editor
(Member, American Society for Metals; Institute of Food Technologists)

VNR VAN NOSTRAND REINHOLD COMPANY
NEW YORK CINCINNATI TORONTO LONDON MELBOURNE

FMC and food phosphates

Phosphates are functional food additives with widely diverse uses.

They can be used to buffer, sequester metal ions, and increase the ionic strength of solutions. They can be used to react with proteins in a variety of ways, including emulsification enhancing in oil-water-protein systems. They can also be used as leavening acids and as nutritional supplements. In short, phosphates are essential additives in a great number of processed foods made today, including meat, poultry, seafood, dairy products, baked goods, and potato products.

Since 1948, FMC has been supplying these important additives to the food industry. We are a back-integrated producer. We mine our own phosphate shale, silica, and coal, and manufacture our own coke. Our elemental phosphorus plant is the largest in the world. From elemental phosphorus we make food grade phosphoric acid and a full line of food grade sodium, potassium, and calcium phosphates.

We produce food phosphates and phosphoric acid meeting Food Chemicals Codex quality specifications at our plants in Carteret, NJ; Buffalo, NY; Lawrence, KS; and Newark, CA. And our phosphates are available through our network of distribution centers strategically located in the major business centers of the food industry. Whenever and wherever you need them, FMC food phosphates can be delivered to you rapidly and economically.

As a complement to our manufacturing and distribution resources, our food research and development group in Princeton, NJ, is also an important resource for our customers. Our Technical Specialists with their in-depth knowledge of phosphorus chemistry can help solve customer problems in the food industry and develop new uses for phosphates in foods.

FMC's technical resources are available by contacting any Industrial Chemicals regional sales office listed at the back of this book, or by calling the Food Phosphates Research Department in Princeton, NJ, at (800) 848-3362.

Organic Materials Review Institute. 2001a. *Generic Materials List.* Eugene: OMRI.

_______. 2001b. Sodium Phosphate Technical Advisory Panel Review. http://www.omri.org/sodiumphosphates.pdf

_______. 2001c. TAP Review of Triple Superphosphate. http://www.omri.org/superphosphate.pdf

Raj, S. 1991. *The Attitudes of Processors and Distributors Towards Processing and Processing Guidelines in the Natural / Organic Foods Industry.* Syracuse, NY: Syracuse University: Unpublished Ph.D. Dissertation.

Sutton, W.J.L. 1960. Protein composition. US Patent #2,929,715. Assigned to Monsanto.

Texas Department of Agriculture (TDA) Organic Certification Program. February 2000. *TDA Organic Certification Program Materials List.*

US Environmental Protection Agency (EPA). 1995. List of Pesticide Product Inert Ingredients. Washington, DC: USEPA.

_______. 1997. The Clean Water Act: A Snapshot of Progress in Protecting America's Waters. http://www.epa.gov/owow/cwa/25report.html.

_______. 1998a. *EPCRA Section 313 Reporting Guidance for Food Processors.* Washington, DC: EPA Office of Pollution Prevention and Toxics.

_______. 1998b. *Title III List of Lists: Consolidated List of Chemicals Subject to the Emergency Planning and Community Right-to-Know Act (EPCRA) and Section 112(r) of the Clean Air Act, as Amended.* Washington, DC: EPA Office of Solid Waste and Emergency Response.

Vander, A.J. 1980. *Renal Physiology*, 2nd ed. New York: McGraw-Hill.

Washington State Department of Agriculture (WSDA) Organic Food Program. January 18, 2001. *Chapter 16-158-060 WAC* in the section titled "Minor Ingredients and Processing Aids."

Watkins, B.A. 2000. Vitamins, in G.L. Christen and J.S. Smith, *Food Chemistry: Principles and Applications.* West Sacramento, CA: STS.

Yazici, F., V.B. Alvarez, M.E. Mangino, and P.M.T. Hansen. 1997. Formulation and processing of heat stable calcium-fortified soy milk. *Journal of Food Science* 62: 535-538.

This TAP review was completed pursuant to United States Department of Agriculture Purchase Order 40-6395-0-2900.

Phosphate chemis

Phosphates are salts of phosphoric acid. The two general classes of phosphates are orthophosphates and polyphosphates. The orthophosphates contain a single phosphorus atom while the polyphosphates contain two or more phosphorus atoms.

Orthophosphates are made by partially or fully neutralizing phosphoric acid with an alkali source. This results in replacing one or more of the three available hydrogen atoms on phosphoric acid with alkali metal ions.

• • • • •

Monobasic orthophosphates have one hydrogen atom replaced with an alkali metal. **Dibasic** orthophosphates have two hydrogen atoms replaced. **Tribasic** orthophosphates have all three hydrogen atoms replaced.

Orthophosphates may be manufactured with sodium, potassium, or calcium as the element substituted for the hydrogen atom. The monobasic orthophosphates have acidic properties, while di-and tribasic orthophosphates exhibit alkaline properties.

• • • • •

Polyphosphates are made by heating mixtures of orthophosphates to high temperatures where they condense into phosphate chains.

Pyrophosphate is the simplest polyphosphate and contains two phosphorus atoms.

• • • • •

Tripolyphosphate contains three phosphorus atoms. Both pyro-and tripolyphosphate are crystalline solids, while sodium polyphosphates with chain lengths greater than three phosphorus atoms are not crystalline, but amorphous products, commonly called **"glassy" phosphates.** There are actually three commercial types of glassy phosphates which contain averages of 6, 13, and 21 phosphorus atoms per molecule. Under existing FDA regulations the official designation for the glassy phosphates for labeling purposes is "sodium polyphosphates, glassy."

The crystalline polyphosphates are fully neutralized (contain no hydrogen atoms) and behave as bases, except for the acidic form of pyrophosphate, known as sodium acid pyrophosphate, which has two hydrogen atoms remaining.

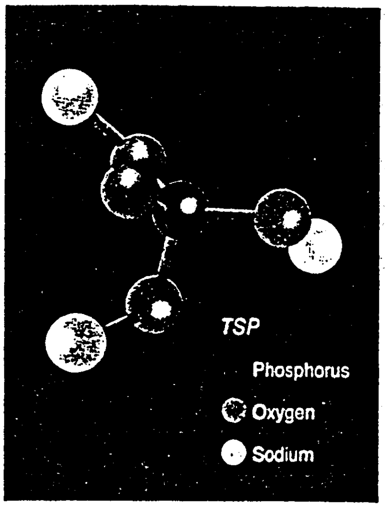
Polyphosphates are generally available only in the sodium form. However, two polyphosphates are available with potassium substituted for the sodium. These are the fully neutralized form of pyrophosphate and tripolyphosphate. Phosphates perform three basic chemical functions: they control pH by buffering; they sequester metal ions; and they provide polyvalent anions to increase the ionic strengths of solutions.

• • • • •

Buffering is the ability to maintain a constant pH even when components of a different pH are added to the system. The orthophosphates are the best buffers. Of the polyphosphates, buffering capacity is greatest for pyrophosphate, and decreases with increasing chain length.

• • • • •

Sequestering is the process of tying up metal ions in solution so that the ions cannot participate in chemical reactions. Long chain polyphosphates (particularly the glassy phosphates), are the best sequestering agents for hardness metal ions such as calcium and magnesium. Polyphosphate sequestering efficiency for calcium and magnesium increases as pH increases. Short chain polyphosphates (especially pyrophosphates) are best for sequestering heavy metal ions such as iron and copper. Sequestering efficiency of polyphosphates for heavy metal ions decreases as pH increases. Orthophosphates react with metal ions to form precipitates.



• • • • •

Polyvalent anions are ions that have more than one negative charge. All phosphates provide polyvalent anions in solution. Orthophosphates can have up to three negative charges depending on concentration and pH Polyphosphates, because they are made up of chains of phosphorus atoms, exhibit a much more pronounced polyionic character. This leads to several types of useful effects. For example, polyphosphate ions can attach one end of their chain to a positively charged site on a particle surface, and the rest of the chain can attract water molecules from the surrounding solution. This tends to maintain particles in suspension keeping them separated and surrounded by water. On the other hand, under different conditions, polyphosphates can bridge two or more positively charged sites and help bind particles together, causing precipitation.

Gard, D.R. 1996. Phosphoric acids and phosphates, in J.I. Kroschwitz (ed.), *Kirk-Othmer Encyclopedia of Chemical Technology,* (4th ed.) 18: 669-718. New York: John Wiley & Sons.

Gordon, D.T. and J.M. Klimek. 2000. Minerals, in G.L. Christen and J.S. Smith (eds.), *Food Chemistry: Principles and Applications.* West Sacramento, CA: Science Technology Systems.

Gosselin, R.E., R.P. Smith, and H.C. Hodge. 1984. *Clinical Toxicology of Commercial Products* (5th ed.) Baltimore: Williams and Wilkins.

Hall, M.W. and E.E. Thomas. 1984. Effect of selected dietary buffers upon utilization of concentrate- or roughage-based cattle diets: Laboratory studies. *Journal of Animal Science* 59: 227-236.

Harding, T.B., Jr. 2001. Materials petition for inclusion on the National List: Tetrasodium pyrophosphate. Wind Gap, PA: AgriSystems International.

_____. 2002. Letter in response to TAP Questions. June 11. Wind Gap, PA: AgriSystems International.

Heidolph, B.B. and D.R. Gard. 2000. Phosphates and food processing in F.J. Francis (ed.) *Encyclopedia of Food Science and Technology* 3: 1881-1885. New York: Wiley.

Heinonen, J.K. 2001. *Biological Role of Inorganic Pyrophosphate.* Norwell, MA: Kluwer.

Hensler, P.L. 1989. Process for manufacturing tetrasodium pyrophosphate. US Patent #4,873,068. Assigned to FMC.

_____. 1991. Preparation of a medium density, fast dissolving, tetrasodium pyrophosphate. US Patent #4,997,634.

Horvath, A.A. 1947. Process for preparing vegetable protein-polyphosphate compounds. US Patent #2,429,579. Assigned to Hall Laboratories.

International Federation of Organic Agriculture Movements (IFOAM) General Assembly 2000. IFOAM Basic Standards for Organic Production and Processing. IFOAM, Tholey-Theley, Germany.

Japan Ministry of Agriculture, Forestry and Fisheries (JMAFF). 2001. *Japanese Agricultural Standard of Organic Agricultural Products, Notification No. 59,* (Unofficial Translation). Tokyo: JMAFF.

Lindsay, R.C. 1996. Food Additives, in O.R. Fennema (ed.) *Food Chemistry*: 767-823. New York: Marcel Dekker.

Miller, D.D. 1996. Minerals, in O.R. Fennema (ed.) Food Chemistry: 617-649. New York: Marcel Dekker.

Ministry of Agriculture, Forestry and Fisheries of Japan. Japanese Agricultural Standard of Organic Agricultural Products, Notification No. 59, Unofficial Translation 2001. Ministry of Agriculture, Forestry and Fisheries, Japan.

Molins, RA. 1991. *Phosphates In Food.* Boca Raton: CRC Press.

National Toxicology Program (NTP). 2002. http://ntp-server.niehs.nih.gov/ Accessed March 27, 2002.

NOSB. 1995a. Technical Advisory Panel Review, Sodium Phosphates.

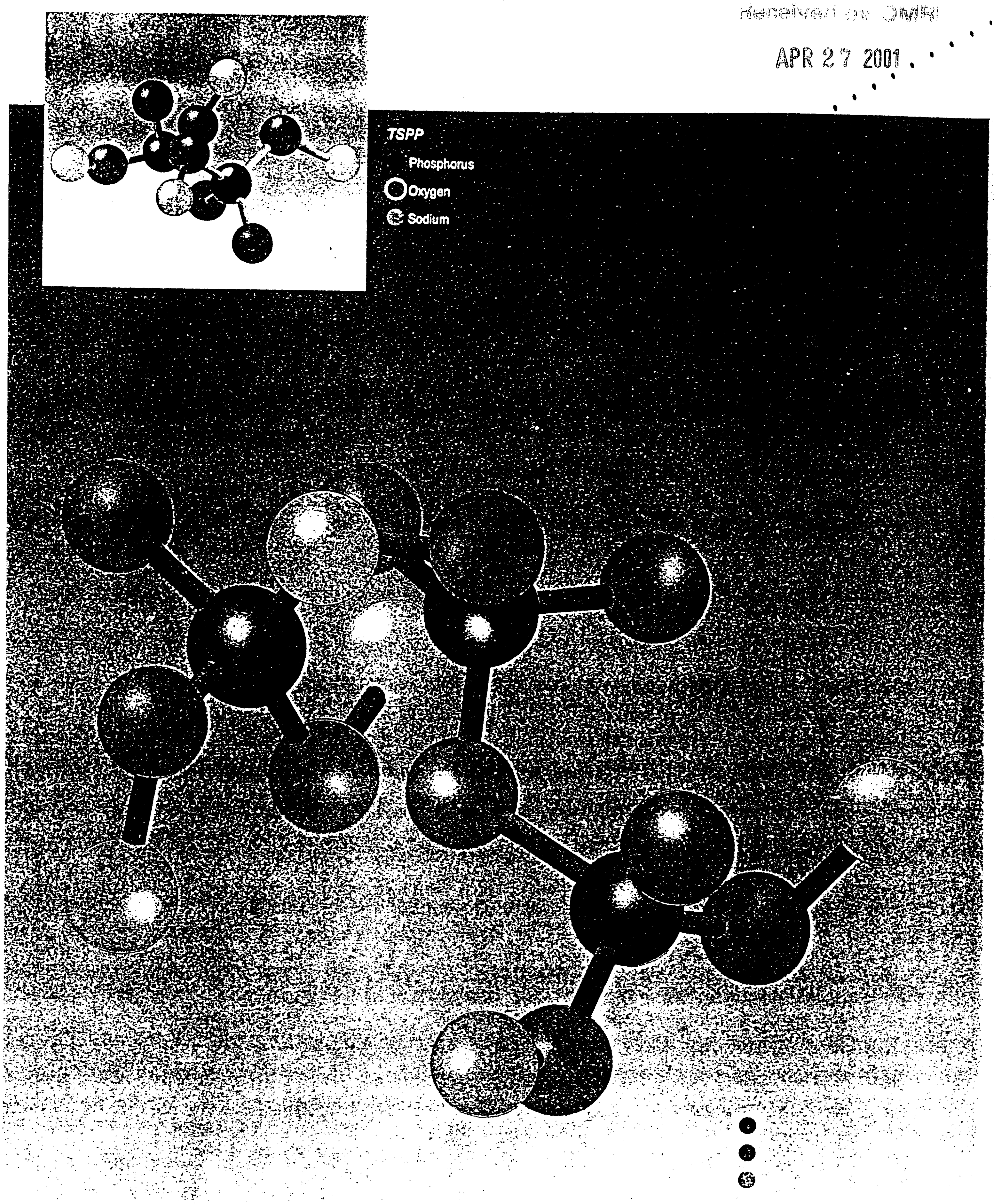
_____. 1995b. Final Minutes of the National Organic Standards Board Full Board Meeting. Austin, Texas. October 31-November 4, 1995. Vote and decision on sodium phosphates.

Nussinow, J. 2002. Seitan—the vegetarian wheat meat. Vegetarian Resource Group. www.vrg.org/recipes/vjseitan.htm.

Organic Crop Improvement Association (OCIA). July 1, 2001. *International Certification Standards.*

Oregon Tilth Certified Organic (OTCO). April 30, 1999. *Generic Materials List.*

_____. December 7, 2000. Letter from Anne Plotto to Herb Stein of Natural Flavors.


TSPP
Phosphorus
○ Oxygen
● Sodium

References

Alais, E. C. and G. Linden. 1991. *Food Biochemistry* West Sussex, UK: Ellis Horwood.

Ash, M. and I. Ash. 1995. *Handbook of Food Additives.* Brookfield, VT: Gower Publishing.

Ashford, R.D. 1994. *Ashford's Dictionary of Industrial Chemicals.* London: Wavelength Publishers, Ltd.

Astaris LLC. No date. Food phosphates. St. Louis, MO: Solutia.

Boivin, M.A. and S.R. Kahn. 1998. Symptomatic hypocalcemia from oral sodium phosphate: A report of two cases. *American Journal of Gastroenterology* 93: 2577-2579.

Branen, A.L., P.M. Davidson, S. Salminen, and J.H. Thorngate III. 2002 (eds.) *Food Additives* (2nd ed.) New York: Dekker.

Budavari, S. 1996. *Merck Index.* Whitehouse Station, NJ: Merck & Co.

California Certified Organic Farmers (CCOF). 2000. *Certification Handbook.*

Canadian General Standards Board (CGSB). 1999. *Organic Agriculture.* Ottawa: CGSB.

Cheremisinoff, N.P. 1999. *Handbook of Industrial Toxicology and Hazardous Materials.* New York: Marcel Dekker.

Considine, D.M. and G.D. Considine. 1982. *Foods and Food Production Encyclopedia.* New York: Van Nostrand Reinhold.

Cover Yur Basics. 2002. Making wheat gluten meat substitute. www.cover-yur-basics.com/wheat1.html

Datta, P.K., A.C. Frazer, M. Sharratt, and H.G. Sammons. 1962. Biological effects of food additives: II—Sodium pyrophosphate. *Journal of the Science of Food and Agriculture.* 13: 556-566.

Davidson, P.M. 2000. Antimicrobial compounds, in F.J. Francis (ed.) *Encyclopedia of Food Science and Technology* 1: 63-75. New York: Wiley.

de Man, J. (ed.) 1990. *Principles of Food Chemistry,* 2nd ed.. New York: Van Nostrand Reinhold.

de Man, J.M. and P. Melnychyn. 1971. *Phosphates in Food Processing.* Westport, CT: AVI.

Dickerson, W.H. 1927. Method of preparing pyrophosphates. US Patent #1,654,283. Assigned to Industrial Waste Products.

Ellinger, R.H. 1972. Phosphates in food processing, in T.E. Furia (ed.), *CRC Handbook of Food Additives* (2nd ed.): 617-780. Cleveland, OH: CRC Press.

European Communities. Council Regulation (EEC) No 2092/9 of 24 June 1991 on organic production of agricultural products and indications referring thereto on agricultural products and foodstuffs.

FAO/WHO Joint Standards Programme. 1999. *Codex Alimentarius Guidelines for the Production, Processing, Labelling and Marketing of Organic Processed Foods.*CAC/GL 32-1999. Rome, Italy: FAO/WHO.

FCC (Food Chemicals Codex Committee). 1996. *Food Chemicals Codex.* Washington: National Academy Press.

Fennema, O. (ed). 1985. *Principles of Food Chemistry* 2nd Ed. New York: Dekker.

FMC Corporation. no date. Food phosphates: Chemistry, nomenclature, and general functions. Philadelphia: FMC Corporation.

The three basic chemical functions of phosphates—pH buffering, sequestration, and polyvalent anionic behavior—provide many beneficial effects in food systems.

These effects are color stabilization, water binding, prevention of rancidity, prevention of coagulation, dry acid for leavening, texture improvement, emulsification, faster curing, nutritional enhancement, and easier processing.

Phosphates provide these benefits by interacting with food components and other additives. This means that the effects depend as much on the food system as upon the actual phosphate used. The following six examples will help to clarify this important concept.

1. Phosphates cannot emulsify a simple mixture of oil and water. However, process cheese which is basically an oil, water and protein mixture can be effectively emulsified by disodium phosphate (DSP). The actual emulsification is carried out by the proteins. That is, the DSP interacts with the proteins to increase their emulsifying capacity.

2. A more obvious example is a leavening system for baking. Acid phosphates are used in many leavening applications, but by themselves acid phosphates do not have any leavening effect. They must be combined with sodium bicarbonate. By neutralizing the bicarbonate the acid phosphates cause CO_2 gas to be driven off and leavening to occur.

3. Many phosphates — especially SAPP and STPP — show antioxidant effects in foods, yet phosphates are chemically unreactive toward oxygen. The antioxidant effects are brought about by the sequestering action of phosphates on iron and copper. Iron and copper ions act as oxidation catalysts, and when they are sequestered by phosphates, their catalytic abilities are lost.

4. Phosphates can be used to precipitate proteins during whey processing to allow easier filtering of the lactose solution. In this process the whey and lactose solution is acidified to near the isoelectric point of the whey protein, and a glassy phosphate is added to link the proteins together to hasten their coagulation.

5. In an opposite effect, glassy phosphates can be used to stabilize proteins and thus prevent coagulation. When pasteurized liquid egg products are made, the egg white may begin to coagulate from the heat of pasteurization. Small amounts of glassy phosphates added to the eggs before heat treatment can prevent this.

6. Phosphates such as sodium tripolyphosphate (STPP) provide increased moisture retention in meat, poultry, and seafood. The water-binding effect is brought about by specific interaction between meat proteins and phosphate. The use of STPP prevents the decrease in nutritional value by retaining the soluble proteins, minerals, and vitamins normally lost during rigor.

These examples show that phosphate applications must be considered in the context of the food systems in which they will be used. Because a phosphate exhibits a property such as emulsification in one food, it does not follow that the same phosphate can be used as an emulsifier in another food product.

It should also be kept in mind that phosphates generally provide more than one benefit. Therefore, choosing a phosphate only on the basis of one desired effect is not always the best course of action. For example, an orthophosphate may be chosen because buffering is required. However, a pyrophosphate might be almost as good a buffer, and could provide additional benefits such as oxidation protection.

Other factors to be considered are the physical properties of the phosphates. These affect the way in which phosphates can be applied. For instance, if the phosphate is to be applied as a water solution, its solubility is important, while if it is to be applied dry, its solubility in water is not as important.

This bulletin attempts to describe only the general uses of phosphates in the food industry. The unique properties of phosphates, however, lend themselves to almost unlimited applications — it would take a large book to describe them all. It is hoped that this overview will familiarize the food technologist with the fundamental properties of food phosphates and their modes of action and help guide in the selection of phosphates for use in new and improved food products. To provide specific background, FMC has published the additional bulletins on specific applications listed below:

• • • • •

Phosphates in meat and poultry

• • • • •

Phosphates in dairy products

• • • • •

Phosphates in the baking industry

• • • • •

Phosphates in the potato industry

• • • • •

Phosphates in seafood

Compatibility
Since the USDA has approved sodium orthophosphate with their inclusion in 205.605b(33) of the NOP with specific application to dairy foods, there is minimal compelling scientific justification of not including all chemical forms requested in the petition for inclusion in the NOP.

Alternatives
The class of sodium pyrophosphates under review is capable of performing specific functional properties in food systems. It must be noted that differences in solubility, moisture levels, fat levels and pH all in concert influence the activity of functional additives to enhance or stabilize food systems. For example, disodium phosphate (pyrophosphate) readily disassociates as a function of pH to bind divalent or monovalent cations which may cause beverage discoloration; phosphate anions serve as a nutrient source for Saccromycetes (yeast) in fermentation; phosphate anions react with water to form phosphoric acid in chemically leavened food products to form the acid component of the acid base chemical leavening system and phosphates contribute a high water binding capability in muscle foods enhancing their sensory value. I feel the example functional properties as cited specifically demonstrate that pyrophosphates are unique functional additives which are difficult to simulate with potential alternatives.

Conclusion
Due to the unique functional properties of tetrasodium pyrophosphate . . . in a wide range of food products and its potential use in organic vegetarian substitute foods the argument for approval is compelling.

The argument is further strengthened by previous NOSB approval of sodium orthophosphate. Therefore I am in favor of allowing its usage according to GRAS recommendations in organic food systems.

It should be noted that consistency is a very important component of the review process. Since sodium orthophosphate has been approved by the NOSB for dairy product usage only, it is very difficult to scientifically oppose the use of pyrophosphates in food systems. Overall, I feel credibility may be compromised when a product is approved for one food category.

Phosphate nomenclature

Naming of various phosphates is sometimes a confusing matter, because there are many names for each single compound (monosodium phosphate, for example, has over twenty-five alternate names) Although many of these names are considered nonstandard or obsolete, occasionally they are found in outdated literature or in translations from other languages.

The following section is designed to bring some order to the subject by allowing the reader to convert a nonstandard one used by FMC in its product line description. The following table is in alphabetical order for easy searching. To use the table, in most cases, it is necessary only to look up the given name in table to find the standard name. For example, in the table:

• • • • •

Under the **reference name** sodium acid phosphate, the **standard name** MSP is given. If there is any doubt as to the meaning of MSP, it is cross-referenced in the table as monosodium phosphate.

• • • • •

Potassium pyrophosphate tetrabasic is shown as TKPP, tetrapotassium pyrophosphate.

The list does not contain every possible name for every phosphate. To do so would make the list repetitious and several times larger. But the list does contain enough names and cross references that a little searching will usually provide a standard identification of the material. If, however, a material cannot be positively identified, it is likely that the name given is either incomplete or erroneous. For instance, the name phosphate of soda is not listed, and a search of the list will not lead to any sure identification. In this case, the name is too general, and identification cannot be made from the information given.

Some products other than standard FMC phosphates and phosphoric acid are included. This is an aid in identifying ammonium, calcium and aluminum phosphates which are sometimes the subject of inquiries by our customers. Fewer names are shown for these non-FMC products, but they can be identified by comparison with corresponding sodium phosphates.

The table contains some trademark names, FMC's and others, to aid in product identification for those customers who ask for such products or their equivalents. If there is a direct FMC equivalent, it is named in the **FMC product** column.

Several entries under FMC product are marked with an asterisk (*). This indicates that, although the product named is not an FMC product, there may be an alternate FMC product that will satisfy the customer's requirements. Specific inquiries about generic or non-FMC products should be referred to Phosphorus Marketing or a Technical Representative for alternate products available from FMC.

Reference name	Standard name or abbreviation	FMC product
Acid orthophosphoric	Phosphoric acid	Yes
Acid phosphoric	Phosphoric acid	Yes
Acid polyphosphoric	PPA	Yes
Acid pyrophosporic	Pyrophosphoric acid	No*
Acid sodium pyrophosphate	SAPP	Yes
Acid superphosphoric	SPA	Yes
Actif-8[1]	SALP/MCP blend (for leavening)	No
Ammonium phosphate monobasic	MAP	No
Ammonium phosphate dibasic	DAP	No
Anhydrous monocalcium phosphate	MCP-Anhydrous	No
BL-60[1]	SALP/Ammonium Sulfate blend (for leavening)	No
B.P. PYRO[1]	SAPP	Yes
Basic potassium pyrophosphate	TKPP	Yes
Basic sodium pyrophosphate	TSPP	Yes
Brifisol[2] D510	STPP/SHMP	Yes
Brifisol[2] 512	Instantized STPP/Poly Glassy blend	No*
Brifisol[2] 414	Pyro/Poly Glassy blend	No*
Calcium acid phosphate	MCP	Yes
Calcium biphosphate	MCP	Yes
Calcium phosphate dibasic	DCP	Yes
Calcium phosphate monobasic	MCP	Yes

[1] Trademark – Rhône-Poulenc

[2] Trademark – Joh. A Benckiser GmbH

Regarding the overall impact on the organic food choices and the nutritional value of organic foods provided to the consumer, the benefits of allowing TSPP into organic food processing systems is questionable, in the opinion of this reviewer. The intention to create "fake" meats or similar products could, over the course of time and the spectrum of manufacturing possibilities, result in an array of products on the market that are increasingly further departures from the original agricultural foods used as starting ingredients. Allowing the use of a synthetic agent such as TSPP could result in the creation of protein isolates or otherwise potentially nutritionally unbalanced food products. Limiting such processed products to those which are produced using only nonsynthetic ingredients and traditional food preparation methods (such as are used to produce wheat gluten in Asian cuisines) is a closer approximation to organic production practices and principles, and is perhaps more harmonious with the evolutionary development of the human diet. The advantages of ease and speed of processing stated by the petitioner may be desirable, but these concerns should not outweigh these other principles.

While it is entirely possible to have a complete vegetarian diet, such a diet generally implies that the eater consumes a wide enough variety of foods to get complete nutrition. Meats are generally high in nutrients, but fake meat is not the same thing, and it might be inadvisable for the consumer to equate one with the other – yet this is what the manufacturers of such products might want imply, and what some uneducated consumers believe. Therefore, it does not seem appropriate to allow TSPP for foods labeled as "made with organic *[specified ingredients]*" either. Unless there are more strict guidelines on how said organic ingredients would be labeled – particularly in the case of isolates created in the process using TSPP – the consumer might easily be misled by such label declarations, thinking they were buying a product with the whole organic food or natural part of said food, as opposed to an isolate created using a synthetic agent. For example, such products labeled as "made with organic wheat" might not necessarily be as accurate as a product "made with proteins isolated from organic wheat."

Alternatives

Nonsynthetic methods have long been used to produce plant-based protein concentrates. Numerous cookbooks and simple food processing manuals give recipes and procedures for producing seitan and other wheat gluten products. Production of such foods is entirely possible without the use of synthetic agents. (Wheat gluten is traditionally produced using only water as a processing aid.) Defatted soy flour - made without the use of synthetic agents - is also readily available on the market as a "meat substitute."

Conclusion

Among the benefits put forward by the petitioner of allowing TSPP in organic systems is that it would provide alternatives to meats to the organic consumer, and would thereby increase the market demand of certain organic grains produced by farmers. These are worthy goals. However, in this case the end does not justify the means. The allowance of a synthetic agent to create a food product that has unknown, inconclusive, or questionable nutritional effects, or results in the creation of food products far removed from their natural substrates, is generally not compatible with organic production principles. Natural alternatives exist in a variety of aspects, as mentioned in the TAP database and this review. Consumers who do not wish to eat meat generally have ability to learn and prepare a wide variety of well-established vegetarian *[dishes]* from various world cuisines.

The petitioner's request, while specific to their intended food products, are not the only product formulations that will be affected by the decision on TSPP, and a long-range view should be taken. Allowance of this synthetic material for the types of purposes intended by the petitioner could be a significant precedent.

Reviewer 3 *[West Coast--Ph.D., Food Science and Nutrition professor with inspection and certification experience]*

It should be noted that sodium pyrophosphate is also called sodium diphosphate and the listing of chemical forms of phosphate should be specifically listed to avoid potential co-mingling of the forms of phosphate considered during the review process.

Nutritional Quality

Additional dietary phosphate may contribute to phosphorylation reactions in vivo contributing to the formation of high-energy nucleotides such as adenosine triphosphate and therefore contribute to oxidative phosphorylation. The net effect would be maintenance of body's energy metabolism.

Primary Purpose

The . . . two phosphate atoms linked through a shared oxygenation is also used in the fermentation industry as a yeast nutrient for alcoholic fermentation of beer and wine.

Reference name	Standard name or abbreviation	FMC product
Calcium phosphate tribasic	TCP	Yes
Calcium pyrophosphate	Calcium pyrophosphate	No
Calgon[6]	SHMP	Hexaphos[4]
Crystalline disodium phosphate	DSP duohydrate	Yes
Crystalline trisodium phosphate	TSPX	Yes
Curacel[3]	SAPP (for sausage)	Yes
Curafos[1]	STPP	Yes
Curafos[1] Formula 11-2, 22-4	STPP/SHMP blend	Yes
Curavis[1] Formula 250, Formula 350	STPP/SHMP/SAPP blend	No*
Diammonium phosphate	DAP	No
Dibasic potassium phosphate	DKP	Yes
Dibasic sodium phosphate	DSP	Yes
Dibasic sodium pyrophosphate	SAPP	Yes
Dicalcium phosphate	DCP	Yes
Dipotassium hydrogen phosphate	DKP	Yes
Dipotassium phosphate	DKP	Yes
Disodium dihydrogen pyrophosphate	SAPP	Yes
Disodium hydrogen phosphate	DSP	Yes
Disodium phosphate	DSP	Yes
Disodium phosphate duohydrate	DSP duohydrate	Yes
Disodium pyrophosphate	SAPP	Yes
Donut Pyro[1]	SAPP	Yes
Fish-Plus[2]	Polyphosphate/ Potassium Sorbate/ Citric Acid blend	No
FOS-6[3]	STPP/SHMP blend (for meat)	Yes
Freez-Gard[1] Formula FP-19	STPP	Yes
Freez-Gard[1] Formula FP-88E	SHMP/NaCl/Sodium Erythorbate blend	No
Glass H[4]	SHMP-long chain	Yes
Glassy sodium phosphate	SHMP	Yes
Graham's salt	SHMP	Yes
Hexaphos[4]	SHMP – Medium chain	Yes
IMP	Insoluble sodium metaphosphate	No
KTPP	Potassium tripolyphosphate	Yes
Kasal	SALP	No
Kena[1] Formula FP-28	STPP/SHMP Blend	Yes
Levair[1]	SALP	No
Levn-Lite[5]	SALP	No
MAP	Monoammonium phosphate	No
MCP	Monocalcium phosphate	Yes
MKP	Monopotassium phosphate	Yes
MSP	Monosodium phosphate	Yes
Maddrell's salt	Insoluble sodium metaphosphate	No
Monoammonium phosphate	MAP	No
Monobasic potassium phosphate	MKP	Yes
Monobasic sodium phosphate	MSP	Yes
Monocalcium phosphate	MCP	Yes
Monopotassium dihydrogen phosphate	MKP	Yes
Monopotassium phosphate	MKP	Yes
Monosodium dihydrogen phosphate	MSP	Yes
Monosodium phosphate	MSP	Yes
Monosodium phosphate crystalline	MSP monohydrate	Yes
Monosodium phosphate hydrate	MSP monohydrate	Yes
90/10 Blend	STPP/SHMP blend	Yes
Nutrifos[5]	STPP	Yes
Nutrifos[5] B-90	STPP/SHMP blend	Yes
Orthophosphoric acid	Phosphoric acid	Yes
Pan-O-Lite[5]	SALP	No
Perfection[1]	SAPP	Yes*
Phosphoric acid	Phosphoric acid	Yes
Potassium dihydrogen phosphate	MKP	Yes
Potassium diphosphate	TKPP	Yes
Potassium monohydrogen phosphate	DKP	Yes
Potassium phosphate dibasic	DKP	Yes
Potassium phosphate monobasic	MKP	Yes
Potassium phosphate tribasic	TKP	Yes

[1] Trademark – Rhône-Poulenc

[2] Trademark – Benckiser-Knapsack GmbH

[3] Trademark – Griffith Laboratories, U.S.A., Inc.

[4] Trademark – FMC Corporation

[5] Trademark – Monsanto Company

[6] Trademark – Merck & Co.

Primary Purpose

The petition indicates that TSPP complexes metals and inhibits rancidity and fat oxidation.

Compatibility

The use of TSPP has not been established as necessary for the processing of an organic food. The nutritional impact of TSPP on protein quality has not been evaluated.

Conclusion

Tetra Sodium Pyrophosphate should NOT BE ADDED TO THE NATIONAL LIST as an ingredient allowable in a product labeled 95% organic or in a product made with organic ingredients (i.e, it should be PROHIBITED), because no use has been established as necessary for the processing of an organic food and because the nutritional impact of TSPP on protein quality has not been evaluated.

Reviewer 2 [West coast--Consultant to organic certifiers, extensive experience in processing]

Both phosphorous and sodium, while necessary and important components of human biochemistry, are readily available from a wide variety of nonsynthetic sources, both agricultural and non-agricultural. The literature is not conclusive one way or the other as to whether the addition of TSPP to the diet contributes adversely to human health. There is no compelling reason to believe, however, that the addition of synthetic TSPP to human foods is necessary in the diet or would in and of itself contribute positively to human health.

Nutritional Quality

The interaction of sodium and phosphorous in the body is intimately linked with metabolism of other ions as well, perhaps most notably calcium. Calcium levels in the body are suggested to be especially important when considering its effects on healthy bone maintenance. Uncertainty arises from several factors, among which are: (i) The interactions of phosphates and calcium in the body is not completely understood. Balance of the two is also dependent on a variety of other physiological factors, including hormone and vitamin levels (Vander, 1980). Much of the interactions on a cellular and wider physiological level are simply not adequately known. (ii) Individual human metabolism varies considerably from one person to another, based on genetics, body type, diet, lifestyle, and environmental exposure. (iii) Patterns of osteoporosis and other bone-related diseases in the human population have not been well discerned to date.

Elevated sodium intake is widely known to contribute adversely to a number of circulatory and other diseases in humans, but the amounts afforded by the proposed use of TSPP is not deemed by this reviewer to constitute a significant added threat, especially if normal food labeling guidelines are followed by the manufacturer, whereby sodium content of the food product would be noted. Furthermore, concerns about sodium content in the human diet should not be based solely on one type of food product. Overall dietary consumption of sodium is part of a larger regimen; those persons concerned with excessive sodium intake should simply avoid foods made with extra sodium, and many alternatives exist, even if TSPP was allowed in organic systems as proposed by the petitioner.

Primary Use

The petitioner states that one of the main reasons to use TSPP is "for the texturization of the proteins which is also critical to the quality characteristics of the end-use products." This is essentially a desire to create or improve textures not normally found in the organic agricultural ingredients under handling practices that do not use the synthetic agent, and as such fails the criterion.

The petitioner also states that the sequestrate action of TSPP inhibits rancidity of the textured final products. This implies two things: (i) TSPP is acting as a preservative; and (ii) TSPP effects a chemical interaction with the organic agricultural ingredients, from which one might thus conclude that the final product is synthetic in itself. In these regards TSPP again fails the criterion.

Compatibility

Organic systems are in principle conceived to be as close a mimic to nature as possible. The removal of parts of the whole food during processing should therefore be considered carefully, as should the reaction of organic ingredients with synthetic ingredients. The creation of isolates or chemically altered foods as significant components of the human diet is a departure from the principles of organic production (although this might be considered a matter of degree, in some cases). Until chemistry can explain biology – which at this point in time it cannot adequately do – a precautionary approach is advisable when considering the inclusion of synthetic components on food production systems and consumer food products.

Reference name	Standard name or abbreviation	FMC product
Potassium pyrophosphate tetrabasic	TKPP	Yes
Potassium tripolyphosphate	KTPP	Yes
Py-ran[5]	MCP-Anhydrous	No
RD-1	SAPP 22	Yes
Regent 12xx[1]	MCP	Yes
SALP	Sodium aluminium phosphate	No
SAPP	Sodium acid pyrophosphate	Yes
SHMP	Sodium hexametaphosphate	Yes
STPP	Sodium tripolyphosphate	Yes
Sodaphos[4]	SHMP-Short Chain	Yes
Sodium acid phosphate	MSP	Yes
Sodium acid pyrophosphate	SAPP	Yes
Sodium aluminium phosphate	SALP	No
Sodium dihydrogen phosphate	MSP	Yes
Sodium diphosphate	TSPP	Yes
Sodium hexametaphosphate	SHMP	Yes
Sodium monohydrogen phosphate	DSP	Yes
Sodium phosphate dibasic	DSP	Yes
Sodium phosphate glass	SHMP	Yes
Sodium phosphate monobasic	MSP	Yes
Sodium phosphate tribasic	TSP	Yes
Sodium polyphosphate, glassy	SHMP	Yes
Sodium pyrophosphate tetrabasic	TSPP	Yes
Sodium tetrametaphosphate	Sodium tetrametaphosphate	Sodaphos[4]
Sodium triphosphate	STPP	Yes
Sodium tripolyphosphate	STPP	Yes
SQ Phosphate	SHMP	Sodaphos[4]
Stabil-9[5]	SALP/MCP Blend (for leavening)	No
TCP	Tricalcium phosphate	Yes
TKP	Tripotassium phosphate	Yes
TKPP	Tetrapotassium pyrophosphate	Yes
TMP-65	Sodium polyphosphate (for bacon)	Yes
TSP	Trisodium phosphate	Yes
TSPP	Tetrasodium pyrophosphate	Yes
Taterfos[1]	SAPP	Yes
Tetrapotassium pyrophosphate	TKPP	Yes
Tetrasodium pyrophosphate	TSPP	Yes
Tribasic potassium phosphate	TKP	Yes
Tribasic sodium phosphate	TSP	Yes
Tricalcium phosphate	TCP	Yes
Tripotassium phosphate	TKP	Yes
Trisodium phosphate	TSP	Yes
Trisodium phosphate crystals	TSPX	Yes
Trisodium phosphate dodecahydrate	TSPX	Yes
V-90[1]	MCP-Anhydrous	No
Victor Cream[1]	SAPP	Yes*
Vitafos	SHMP	Hexaphos[4]

[1] Trademark – Rhône-Poulenc

[4] Trademark – FMC Corporation

[5] Trademark – Monsanto Company

particular, do any of you have good references for the making of seitan or other gluten-based high protein meat substitutes?

Reviewer 1: It is important to distinguish between food labeling questions and food processing questions. "Imitation" is a term used in labeling and advertising, regulated by the Food and Drug Administration and the Federal Trade Commission, respectively. These other agencies are charged with enforcing true and non-misleading labeling and advertising, respectively, with regard to foods. So-called "imitation meat" is true food made from gluten-containing grains. Traditionally this food is called "seitan."

The questions at hand are (1) whether the production of "seitan" requires use of the synthetic substance TSPP and (2) whether such production is compatible with the requirements of the OFPA and its attendant regulations. Neither of these questions have been answered by the petition, the petitioner or the accompanying references.

Q4. What are the vegan or vegetarian alternatives to muscle meat and can they be organic?

Reviewer 1. "Seitan" [gluten dough washed free of carbohydrate] is claimed as a vegetarian substitute for meat. See various websites for preparation methods and recipes for its use.

Q5. How can "seitan" ("gluten meat") be produced?

Reviewer 1The modern method requires instant gluten flour; also known as pure gluten flour or vital wheat gluten. (Gluten flour is **not** the same as high-gluten bread flour.) Pure gluten flour has had its starch (and bran) removed, and doesn't act like ordinary flour at all. When mixed with water, it doesn't make dough, but instead makes something that looks like wet rubber. In fact, this rubbery stuff is raw gluten.

The traditional way to make seitan is to combine flour and water to make a dough and then rinse the dough in water to remove the starch. [information taken from http://home.teleport.com/]

Q6. Can "seitan" be produced without tetrasodium pyrophosphate?

Reviewer 1: According to Internet websites, Arrowhead Mills produces a "Seitan Quick Mix." Also, some health food stores sell 'wet' seitan in the refrigerated section. These products apparently do not contain TSPP. Thus, it appears that "seitan" can be prepared without TSPP.

Reviewer 2: As stated in my review, numerous cookbooks state how to do this very simply using water only. Probably can find a similar description in an industrial food process textbook...

Reviewer 3: Review of reference *Foods and Food Production Encyclopedia* (1982) . . . indicates that phosphates are used in production of texturized vegetable protein to enhance water binding. TVP (texturized vegetable proteins) are the basis of meat analogues used for the production of meat substitutes. Sources of vegetable proteins routinely are wheat gluten or soy protein. Therefore, it would seem reasonable that use of sodium pyrophosphate due to its high affinity to bind water molecules at low concentrations is a unique functional property that appears not to [affect] the hydrophilic/hydrophobic balance of the food system allowing TVP and phosphate to work in concert in binding water, flavor and other components of the meat analogue system.

Reviewer Comments

<u>*Reviewer 1*</u> *[East Coast--Ph.D. in biochemistry with food industry experience]*

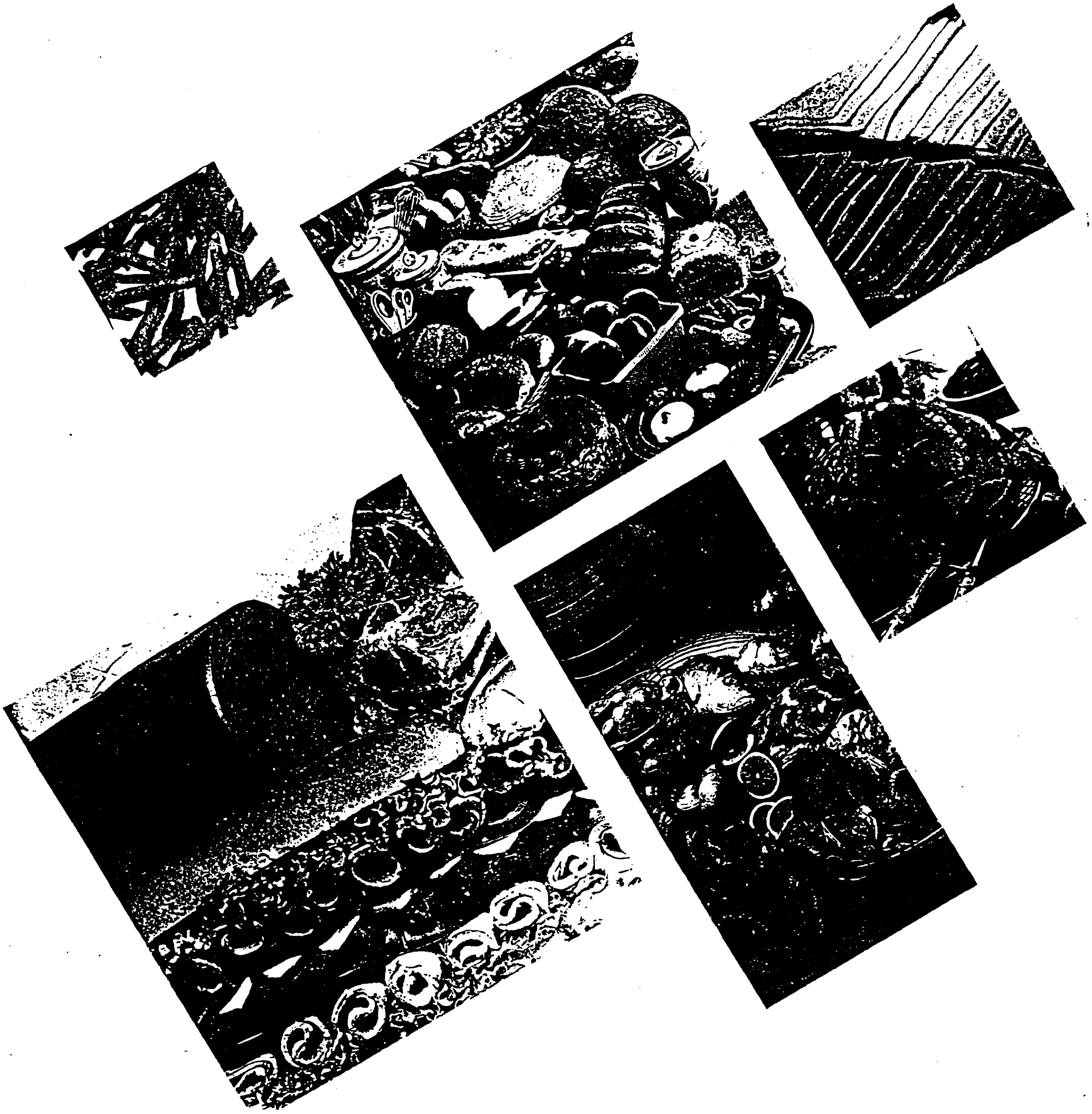
It is extremely difficult to evaluate the adequacy of the TSPP TAP Review because the petition is not clear on the particulars of use of TSPP or on the effect of not using it in the desired application. The petition (page 4 of 5, submitted September 2001) indicates that "... as a result of our internal proprietary research and process development, we have yet to find a material(s) equal to TSPP in overall functionality and process flow, at such minor amounts . ." but provides no details of this research that permit of an evaluation against point 7 of the Criteria established by the NOSB on February 10, 1999. Maintaining such information as a trade secret is inconsistent with the transparency required for a TAP Review.

Organic Ingredients as Substitutes

The application is very poorly described in the petition so it is virtually impossible to determine if an organic ingredient can substitute for TSPP.

MC

Corporation
Phosphates Marketing
Market Street
elphia PA 19103



TAP Reviewer Discussion[2]

The TAP Reviewers were asked the following questions:

Q1.Is there any documentation on tetrasodium phosphate in organic processing?

Reviewer 1: No. A search of the internet found that TSPP is an ingredient of JELL-O brand instant pudding but no indication that organic foods contain TSPP.

Reviewer 2: I have never come across this material being used before for direct contact with organic foods, in my direct work with over half a dozen certifiers and indirect work with dozens more.

Reviewer 3: An additional computer search did not reveal any literature documenting the use of tetrasodium phosphate in organic products or in process operations.

Q2 . . . [Are there a]ny references to add in the discussion of the compatibility of imitation v. real products in organic?

Reviewer 1: A fundamental principle of processing organic food with a synthetic substance as an ingredient is that a determination has been made that no nonsynthetic substance is able to be used successfully in the processing. The petition and the accompanying documentation provide no evidence of the essentiality of TSPP in the application and also provide no evidence of an evaluation of any nonsynthetic materials in the application.

The application is stated to be the use of TSPP as a buffering agent and a dough conditioner for milled and processed grain products. "Dough conditioners" allowed by FDA in foods include diverse substances: sodium stearoyl lactylate, datem, ammonium sulfate, calcium sulfate, l-cysteine hydrochloride, ascorbic acid, potassium iodate, azodicarbonamide, l-cysteine, and enzymes; at least some of these may be compatible with organic. "Buffering agents" allowed in organic foods include sodium citrate and sodium bicarbonate. There are no data presented to indicate that these materials have been tested in the application.

The petition does not clearly identify the food product(s) in which TSPP is used. The petition refers to "good textured wheat gluten proteins" and "milled and processed grain products which are used as ingredients for organic meat alternative products." The letter of June 11, 2002, refers to an "extrusion process." An example of product packaging would be useful, as would a flow diagram of how the product(s) is made.

Another principle of processing organic food is "minimal processing." The temperatures and pressures generated during an extrusion process may be sufficient to create complexes of protein and phosphates with diminished digestibility and bioavailability. Protein quality should be evaluated.

Reviewer 2: I looked for references like this, but was not able to come up with any that satisfied me.

Reviewer 3: Overall I do not feel any synthetic additive is compatible with the principle of organic food products except for one exception. For issues of food safety only would a synthetic be considered. However, the review process has allowed the use of synthetic additives for a host of technical issues. Therefore, the review process is a critical pathway to conduct a careful technical review so that the individual merits of each review can be evaluated. For example, the NOSB has approved the use of sodium orthophosphate. On a purely scientific basis it is difficult to argue against using tetrasodium phosphate, sodium diphosphate, or sodium pyrophosphate. It is critical to the review process that consistency is maintained and sound science be used for the basis of the review process. This is the baseline of judgment that I feel should be employed in the assessment of compatibility issues.

Q3. . . By definition, meat products are similar. However, there is a segment of consumers that demand organic vegan/vegetarian substitutes for meat products. How is this best explored and explained? In

---

[2] *OMRI's information is enclosed is square brackets in italics. Where a reviewer corrected a technical point (e.g., the word should be "intravenous" rather than "subcutaneous"), these corrections were made in this document and are not listed here in the Reviewer Comments. The rest of the TAP Reviewer's comments are edited for any identifying comments, redundant statements, and typographical errors. Text removed is identified by ellipses [...]. Statements expressed by reviewers are their own and do not reflect the opinions of any other individual or organizations.*

FMC

Phosphates Help Make Dairy Products Better

Table 1
FDA References to Tetrasodium Pyrophosphate and Pyrophosphates

21 CFR	Section Heading	Notes / Limitations
133.169	Pasteurized process cheese	Optional ingredient as an emulsifier, not to exceed 3% by weight of the product.
133.173	Pasteurized process cheese food	Optional ingredient as an emulsifier, not to exceed 3% by weight of the product.
133.179	Pasteurized process cheese spread	Optional ingredient as an emulsifier, not to exceed 3% by weight of the product.
173.310	Boiler water additive	The amount of additive is not in excess of that required for its functional purpose, and the amount of steam in contact with food does not exceed that required to produce the intended effect in or on the food.
175.210	Acrylate ester copolymer coating	Not to exceed the amount required as a preservative in emulsion defoamer.
175.300	Resinous and polymeric coatings	Miscellaneous material.
181.29	Stabilizers	Sodium pyrophosphate classified as a stabilizer, when migrating from food-packaging material.
182.70	Substances migrating from cotton and cotton fabrics used in dry food packaging	Tetrasodium pyrophosphate is GRAS as a substance migrating to food from cotton and cotton fabrics used in dry food packaging.
182.6787	Sodium pyrophosphate	GRAS when used in accordance with GMPs.
182.6789	Tetra sodium pyrophosphate	GRAS when used in accordance with GMPs.

Source: EAFUS (2002)

6. Its use is compatible with the principles of organic handling.
Additives used for stabilization and prolonging shelf life have generally not been considered compatible with principles of organic processing (Raj, 1991). Principles of organic handling adopted by NOSB in October, 2001 include the statement "Organic processors and handlers implement organic good manufacturing and handling practices in order to maintain the integrity and quality of organic products through all stages of processing, handling, transport, and storage." The NOSB considered a petition for the general use of sodium phosphates in 1995, and restricted that use to dairy products. The 2001 review of sodium phosphates made it clear that the only substances considered in the 1995 and 2001 petitions were the three sodium orthosphosphates, mono-, di-, and tri-.

7. There is no other way to produce a similar product without its use and it is used in the minimum quantity required to achieve the process.
The petition refers to internal proprietary research and process development, but does not provide any data to support the case. The investigator is unable to evaluate the claims made in the petition without more information. There is also no information to determine the quantity needed.

In general, various alginates, lecithin, and sodium citrate, can be used to substitute for emulsification; calcium carbonate, calcium citrate, potassium carbonate, potassium citrate, sodium carbonate, and sodium bicarbonate can be used as pH buffers; and citric acid and sodium citrate can be used as sequestrants (Lindsay, 1996).

FMC and food phosphates

Phosphates are functional food additives with a wide range of applications. They can be used to buffer, to sequester metal ions, and to increase the ionic strength of a solution.

They enhance emulsification of oil/water/protein suspensions, and react with proteins in a variety of ways that may help to stabilize or accelerate a given process. They add to the shelf life and attractiveness of processed foods, and are themselves essential additives in a great number of processed foods, including meat, poultry, seafood, dairy products, baked goods, and potato products.

Manufacturing

FMC has been supplying these important additives to the food industry since 1948. We are a back-integrated producer: we mine our own phosphate shale, silica, and coal, and manufacture our own coke. Our elemental phosphorus plant is the largest in the world. From elemental phosphorus we make food-grade phosphoric acid and a full line of sodium, potassium, and calcium phosphates.

Our plants in Buffalo NY, Carteret NJ, Lawrence KS, and Newark CA produce food phosphates meeting or exceeding the Food Chemicals Codex quality specifications. With our network of distribution centers located in the major business centers of the food industry, we can deliver FMC phosphates to you whenever and wherever you need them.

Technical Service

As a complement to our manufacturing and distribution resources, our research and development group in Princeton NJ provides additional services to our customers.

Our technical specialists apply their in-depth understanding of phosphorus chemistry to solving customer problems with phosphate formulations and processes. In addition, they are

A primary environmental concern of sodium phosphates is their release into water. Phosphate detergents caused algal blooms and eutrophication of the Great Lakes. This was remedied by the development of low-phosphate detergents and bans on high-phosphate detergents in the states that drain into the Great Lakes (US EPA, 1997). This is primarily related to trisodium phosphate used as a detergent or cleaner, and is generally not related to use as a food additive.

3. If the nutritional quality of the food is maintained and the material itself or its breakdown products do not have adverse effects on human health as defined by applicable Federal regulations.
The process of extrusion creates high temperature and pressures. High-temperature treatment of proteins with polyphosphates (pyrophosphate is the simplest polyphosphate) creates stable complexes resistant to the action of microorganisms, acids and alkalis (Ellinger, 1972). If a protein-phosphate complex is this stable, it is foreseeable that the protein is less bioavailable than untreated protein. The biological quality of the processed protein needs to be assessed to determine if there has been a significant loss in protein quality.

The use of tetrasodium pyrophosphate raises nutritional concerns related to the formation of bone tissue because its addition raises both sodium and phosphorous levels in the food. Calcium and phosphorous are metabolically linked by their common absorptive mechanism through Vitamin D. Vitamin D_3 stimulates absorption of calcium in the intestine. This maintains the homeostasis of calcium and phosphorus in bone formation from those two minerals (Watkins, 2000). The distribution of phosphorous in foods is so wide that deficiencies do not seem to exist. It is always linked to calcium in skeletal mass and exists as a phosphate salt in bone as phospho proteins, phospho lipids and nucleic acids in the cell (Alais and Linden, 1991).

4. Its primary purpose is not as a preservative or used only to recreate/improve flavors, colors, textures, or nutritive value lost during processing except in the latter case as required by law.
Sodium phosphates possess antimicrobial properties. In particular, TSPP inhibits *Bacillus subtilis Enterococcus faecalis, Clostridium sporogenes, C. bifermentans,* and *Staphylococcus aureus* (Davidson, 2000). Phosphates stabilize proteins during processing so they improve finished product texture (Yazici, et al., 1997). It is also used as a nutritional supplement to replace or enhance phosphate levels. Pyrophosphates are often be used to prevent discoloration of foods during preparation and storage (Considine and Considine, 1982).

5. Is Generally Recognized As Safe (GRAS) by FDA when used in accordance with Good Manufacturing Practices (GMP), and contains no residues of heavy metals or other contaminants in excess of FDA tolerances.
The Food Chemicals Codex (1996) specifications for sodium pyrophosphate are as follows:

Assay: Not less than 95.0% and not more than 100.5% of $Na_4P_2O_7$, calculated on an ignited basis.
Arsenic: Not more than 3 mg/kg
Fluoride: Not more than 0.005%
Heavy metals (as Pb) Not more than 10 mg/kg
Insoluble substances: Not more than 0.2%
Loss on ignition: $Na_4P_2O_7$ (anhydrous): Not more than 0.5%; $Na_4P_2O_7 \bullet 10H_2O$ (decahydrate): between 38.0% and 42.0%.

actively researching new applications of phosphates in the food industry.

Product information and availability may be obtained by contacting any Chemical Products Group sales office listed at the back of this book. The Technical Service toll-free number is 1-800-848-3362.

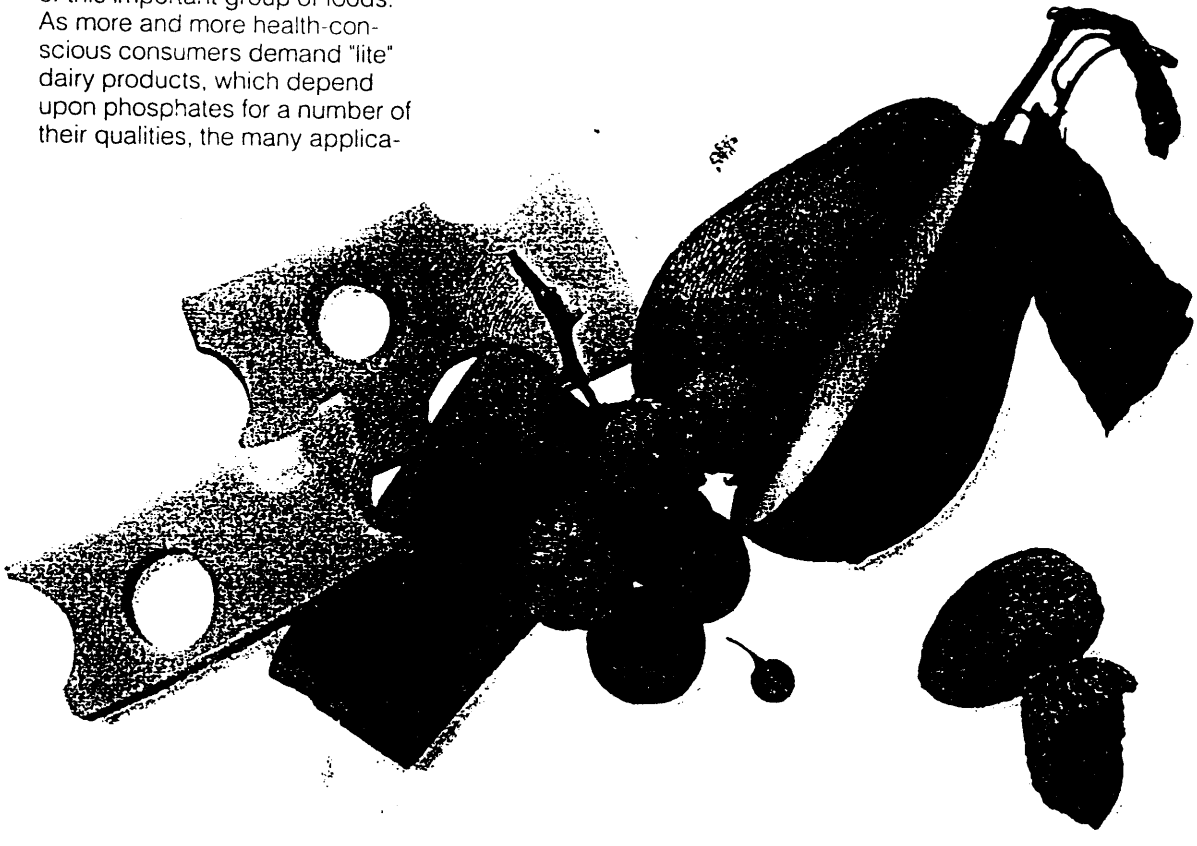
Product Application

Today hundreds of different products are produced from milk, and dairy analogues comprise a similarly large and growing industry. Food phosphates play an important role in dairy foods processing by making better products more economically. Food phosphates can be used to thicken, buffer, stabilize, and improve texture, as well as to control coagulation and gelling. From process cheese to instant puddings, phosphates enhance the taste, shelf life, and diversity of this important group of foods. As more and more health-conscious consumers demand "lite" dairy products, which depend upon phosphates for a number of their qualities, the many applications of food phosphates in the dairy industry will continue to diversify.

Nomenclature

The phosphates commonly used as food additives are sodium, potassium, and calcium salts of phosphoric acid. The two general classes of phosphates are orthophosphates and polyphosphates. The orthophosphates contain a single phosphorus atom while the polyphosphates contain two or more phosphorus atoms. The orthophosphates are termed monobasic, dibasic, or tribasic (as in monosodium phosphate, disodium phosphate, and trisodium phosphate). Pyrophosphate is the simplest polyphosphate unit, with two phosphorus atoms, while tripolyphosphate contains three phosphorus atoms. Longer-chain polyphosphates, known collectively as sodium hexametaphosphate, have average chain lengths of 6, 13, and 21. The corresponding FMC products are known as Sodaphos®, Hexaphos®, and Glass H®. FMC manufactures a complete line of sodium, potassium, and calcium salts for the many applications of food phosphates in dairy products.

FMC has been supplying food phosphates since 1948



diarrhea (Chermishinoff, 2000). Emits toxic fumes of PO_x and Na_2O (Ash and Ash, 1995). Also see criterion 4 and processing criterion 3, below.

3. The probability of environmental contamination during manufacture, use, misuse, or disposal of the substance.
See processing criterion 2, below.

4. The effects of the substance on human health.
As noted above (criterion 2), sodium pyrophosphate has been linked to kidney damage. Extrapolation from rat models may overestimate kidney damage from sodium pyrophosphate as a food additive, but overall phosphate consumption may be more relevant because sodium pyrophosphate readily converts to orthophosphate (Datta, et al., 1962). Actual consumption data is scarce, and phosphate additives may be over- or under-estimated (Molins, 1991).

Inhalation of heavy dust may irritate nose and throat. Ingestion may injure mouth, throat, and gastrointestinal tract, resulting in nausea, vomiting, cramps, and diarrhea; pain and burning in the mouth may occur. Contact with eyes produces local irritation, and may lead to chronic damage. Contact with skin produces local irritation; repeated or prolonged contact can lead to dermititis (Cheremisinoff, 1999)

Most of the human health references are related to its medical, rather than food, use. A number of the adverse health effects are related to the use of phosphates purgatives. In a number of cases, bowel cleansers were not used according to label instructions or were given to patients with reduced renal function where the use of phosphate purgatives is medically contraindicated.

Because phosphates react slowly, systemic reactions are unlikely. Low calcium (hypocalcemia) has been reported in certain susceptible individuals (Gosselin, et al., 1984; Boivin and Kahn, 1998). Continuous contact may cause skin irritation and can be minimally to moderately irritating to unwashed eyes.

5. The effects of the substance on biological and chemical interactions in the agroecosystem, including the physiological effects of the substance on soil organisms (including the salt index and solubility of the soil), crops and livestock.
This is a processing material that is not applied to soil. TSPP used as a buffer in cattle diets increased the microbial alpha-amino N (microbial protein synthesis) more than any other buffer—nearly twice the control (Hall and Thomas, 1984). TSPP inhibits *Bacillus subtilis* and other organisms commonly found in soils (Davidson, 2000).

6. The alternatives to using the substance in terms of practices or other available materials.
See processing criteria 1 and 7, below.

7. Its compatibility with a system of sustainable agriculture.
See processing criterion 6, below.

Criteria From the February 10, 1999 NOSB Meeting

A PROCESSING AID OR ADJUVANT may be used if:

1. It cannot be produced from a natural source and has no organic ingredients as substitutes.
Alkali pyrophosphates are naturally produced in plants, animals, and microorganisms (Heinonen, 2001). No documentation could be found of natural sources of food grade tetrasodium pyrophosphate. Various nonsynthetic items that already appear on the National List could be possible substitutes as pH buffers, including calcium carbonate, calcium phosphates, and sodium orthophosphates. Sodium chloride (salt) is also used as a buffer. Lecithin from organic soybeans is a possible substitute for certain applications as an emulsifier. Sodium alginate was found to be a more effective stabilizer for whipped cream than TSPP (Rothwell, cited in Ellinger, 1972). Dairy cultures can be used to make buttermilk instead of TSPP. The process using TSPP takes 1-5 hours, while the dairy culture process takes 15-48 hours (van Wazer, cited in Ellinger, 1972).

2. Its manufacture, use, and disposal do not have adverse effects on the environment and are done in a manner compatible with organic handling as described in section 6513 of the OFPA.
Because it is manufactured from sodium orthophosphates, and is used and disposed of in much the same manner, the impacts on the environment are similar. The manufacturing processes for sodium orthophosphates, sodium carbonate, and sodium hydroxide (see "How Made" section, above) are covered in previous TAP reviews for these materials. Sodium hydroxide and sodium carbonate were reviewed by the NOSB and added to the National List. Manufacture of food-grade phosphoric acid involves the removal of heavy metals and radioactive waste. The environmental impact of mining calcium phosphate is covered in the TAP review for triple superphosphate (OMRI, 2001c).

Functions

Phosphates influence the properties of dairy products through three basic mechanisms:
(1) calcium complexing,
(2) pH modification, and
(3) direct interaction with casein, the principal protein of milk. A particular phosphate might perform all three functions, interacting both with the dairy formulation and with other phosphate additives.

> ***Phosphates can influence the properties of dairy products by calcium complexing, pH modification, and direct interaction with casein.***

Although the chemistry of phosphate additives is thus quite complex, a few general principles can be stated.

- The dibasic and tribasic phosphates are most often used as alkaline buffers, while monobasic phosphate provides acidity.
- Sodium hexametaphosphate (SHMP) is used to inhibit coagulation.
- Tetrasodium pyrophosphate (TSPP) promotes coagulation.
- Disodium phosphate (DSP) interacts with milk protein to promote emulsification. At room temperature it accelerates coagulation; at high temperatures it prevents coagulation.
- Monocalcium phosphate (MCP) adds firmness to gels by contributing calcium.
- Polyphosphates (SHMP) have a polyionic character, which can aid in maintaining a suspension or can accelerate precipitation.

Calcium Complexing

The affinity of phosphates for calcium directly influences the emulsification, coagulation, and heat stabilization properties of dairy products. These properties are affected by the solubility of the calcium phosphate complex, which is dependent on the chain length of the phosphate. Sodium and potassium orthophosphates and pyrophosphates generally form insoluble calcium phosphate-protein complexes. As a result, these phosphates generally destabilize the liquid phase and accelerate coagulation. Milk coagulates almost instantly when TSPP is added. In contrast, polyphosphates, such as SHMP, form soluble calcium phosphate-protein complexes. This action helps stabilize protein dispersions.

pH Modification

A wide range of phosphates are available to increase, decrease, or buffer the pH of dairy systems.

Orthophosphates are used to buffer the pH of heat-processed products such as coffee whiteners, ultra-high temperature (UHT) beverages and shelf-stable beverages. Acidic orthophosphates such as monosodium phosphate (MSP) effectively emulsify and acidify cheese sauces. Alkaline orthophosphates increase the pH in process cheese, providing a smooth, meltable product. The pH values of the phosphates most commonly used in the dairy industry are shown in Table 1.

Protein Interaction

Direct interaction with milk proteins is the most important mechanism by which phosphates influence dairy systems. In milk and milk products, the fat and the casein proteins are present as a colloidal suspension. In process cheese manufacturing, phosphates solubilize casein proteins to enhance their emulsification properties. Phosphates also play an important role in protein dispersion and stabilization of imitation dairy products made with soy proteins or sodium caseinate.

Regulatory:
See Table 1, below, for FDA references to tetrasodium pyrophosphate.

EPA/NIEHS/Other Sources:
EPA -Inert ingredients List 4B (US EPA, 1995).

NIEHS - No listing in the National Toxicology Program database (NTP, 2002).

Status Among U.S. Certifiers:
No certifier lists tetrasodium pyrophosphate as allowed, but several list sodium phosphates. Although the NOSB clarified that the recommendation was only for sodium (mono-, di-, and tri) orthophosphates and only for dairy products, some certifiers may have considered this sufficient to allow sodium pyrophosphates and sodium polyphosphates. Tetrasodium pyrophosphates do not appear on the Organic Materials Review Institute (OMRI) *Generic Materials List* (OMRI, 2001a).

California Certified Organic Farmers (CCOF) Certification Handbook (2000), Section 8.3.3 Processing and Handling Materials, "Sodium phosphates - Allowed Non-Organic, Use as an ingredient restricted to dairy foods." The listing does not distinguish between ortho-, pyro-, and polyphosphates.

Oregon Tilth Certified Organic (OTCO) - The most recent available Standards Manual prior to the NOS Final Rule (1998) lists only "Sodium Phosphates" as an allowed synthetic in organic processing, and does not list ortho-, pyro-, or polyphosphates separately. The annotation accompanying sodium phosphates states "...for use only in dairy foods."

Organic Crop Improvement Association International (OCIA) International Certification Standards (2001) Section 9.4.3, regulated for use in the NOI (non-organic ingredient) class with specifications "use as an ingredients restricted to dairy foods." The listing does not distinguish between ortho-, pyro-, and polyphosphates.

Quality Assurance International (QAI) - No reference.

Texas Department of Agriculture (TDA) Organic Certification Program - TDA Organic Certification Program Materials List (February 2000), restricted for use in processing with comments, "Use as a non-organic ingredient is restricted to dairy foods." The listing does not distinguish between ortho-, pyro-, and polyphosphates.

Washington State Department of Agriculture (WSDA) Organic Food Program - Chapter 16-158-060 WAC (rev. January 18, 2001), listed in the section "Minor Ingredients and Processing Aids" as "sodium phosphate—for dairy processing only." The listing does not distinguish between ortho-, pyro-, and polyphosphates.

International
CODEX - Not listed.
EU 2092/91 - Not listed.
Japan Ministry of Agriculture, Forestry and Fisheries (JMAFF, 2001) - Not listed.
IFOAM - Not listed.
Canada - Not listed.
Other International Certifiers - Could not find any that allow any sodium phosphates for any purpose.

Section 2119 OFPA U.S.C. 6518(m)(1-7) Criteria

1. The potential of the substance for detrimental chemical interactions with other materials used in organic farming systems.
The substance is used in processing and therefore would not interact directly with other materials used in organic farming systems.

2. The toxicity and mode of action of the substance and of its breakdown products or any contaminants, and their persistence and areas of concentration in the environment.
One study reported that sodium pyrophosphate has a rat intraperitoneal LD_{50} of 233 mg/kg and an oral LD_{50} of greater than 4 g/kg (Datta, et al., 1962). As such, sodium pyrophosphate is less toxic than the orthophosphates, but has similar deleterious subacute effects. TSPP depressed weight gains, decreased hemoglobin concentration, and reduced liver iron values the greatest among several food additive phosphates tested on rats (Molins, 1991). A number of feeding studies that involved rodent models showed kidney damage and calcium deposits in test animals (Ellinger, 1972). The toxicity of sodium phosphates is generally related to the sequestration of calcium and the subsequent reduction of ionized calcium (Gosselin, et al., 1984). Ingestion may injure the mouth, throat, and gastrointestinal tract, resulting in nausea, vomiting, cramps, and

Applications

Process Cheese

Process cheese products are produced from natural cheeses, salt, water, and emulsifying salts. They are classified into three categories based on U.S. Food and Drug Administration Standards of Identity: pasteurized process cheese, pasteurized process cheese foods, and pasteurized process cheese spreads (Table 2). These products differ in their fat and moisture contents, but for our purposes they may be considered to be similar.

Phosphates are the most widely used and the most cost-effective emulsifying salts. Although Federal Standards allow a maximum of 3% emulsifying salts in process cheese, phosphates provide optimal benefits at the 2% level.

The most commonly used salts are disodium phosphate duohydrate (DSP DUO) and trisodium phosphate dodecahydrate (TSPX, typically known as trisodium phosphate crystals). These alkaline orthophosphate salts have a weak affinity for calcium and produce soft, meltable cheese. They are used to produce slices, loaves and cheese foods.

Polyphosphates such as TSPP, sodium tripolyphosphate (STPP), and SHMP bind calcium more strongly, resulting in cheeses that are firmer and nonmelting. These phosphates are preferred for cheese spreads.

In the manufacturing of cheese powder, a slurry containing cheese, water, coloring, and phosphate is pasteurized, homogenized, and spray-dried. Disodium phosphate (DSP) is dissolved in the water prior to forming the slurry. Typical levels are 1.5–2.5% of the weight of the cheese, depending on the age and variety.

> *Phosphates can emulsify process cheeses, set instant puddings, stabilize heat-processed dairy products, and aid in the formulation of low-fat products*

Instant Puddings

Instant pudding mixes contain starch, sugar, flavoring, and phosphates. When added to cold milk, the phosphates in the mix cause the milk protein to precipitate and produce a firm gel.

The preferred setting system is a combination of TSPP and DSP. The pyrophosphate TSPP reacts with the milk calcium to form a gel, while the orthophosphate DSP accelerates the rate of setting. Typically, the level of phosphates in the dry mix ranges from 2.5–3.0%.

Phosphates can also be used as setting salts for instant cheesecake fillings. TSPP and monocalcium phosphate monohydrate (MCPM) are recommended to produce a firm-bodied cheesecake with a creamy texture. The additional calcium from MCPM increases the firmness of the gel. The level of phosphates in the dry mix is about 1.5% by weight.

Milk Products

Phosphates are used to buffer and stabilize milk proteins, which undergo heat treatment during processing. DSP and the SHMPs (Sodaphos, Hexaphos, and Glass H) at levels between 0.1–0.5% prevent precipitation and gelation in UHT beverages. Products in this category include

Characterization

Composition:
$Na_4P_2O_7$

Properties:
White crystalline solid (Ashford, 1994). Solubility in water at 0°C., 0.316 g/l (Budavari, 1996); Solubility in water at 25°C, 6.7 g/l (Ashford, 1994). The pH of a 1% solution is 10.2. Insoluble in alcohol (Budavari, 1996).

How Made:
TSPP can be prepared by molecular dehydration of dibasic sodium phosphate at 500°C. (Budavari, 1996). Sodium phosphates are generally prepared by the partial or total neutralization of phosphoric acid using sodium carbonate or sodium hydroxide (Ashford, 1994). Crystals of a specific hydrate can then be obtained by evaporation of the resultant solution within the temperature range over which the hydrate is stable (Gard, 1996). Another way to prepare TSPP involves the calcination of sodium tripolyphosphate and a sodium salt (Hensler, 1989). The manufacture of the precursors is described in the review of triple superphosphate (OMRI, 2001c).

Specific Uses:
The specific use petitioned is as a pH buffer and dough conditioner for use in organic meat alternative products (Harding, 2002). Cereal and baked goods account for the greatest food use of phosphate additives (Branen, et al., 2002). The principal food uses for tetrasodium pyrophosphate are as an emulsifier, buffer, nutrient, dietary supplement, sequestrant, and texturizer (Astaris; FCC, 1996; Heidolph, et al., 2000). TSPP is also used in cleaning compounds, oil well drilling, rust removal, ink erasers, and in electrodeposition on metals (Budavari, 1996).

Action:
Phosphates in general interact with proteins, such as casein, to function as emulsifiers and prevent the separation of both fat and water in cheese (Gard, 1996). Casein is precipitated by pyrophosphates to form thick gels (Ellinger, 1972). This is believed to be the result of the negative ionic charge of pyrophosphate anions reacting with the positively charged cations in casein (Zittle, cited in Ellinger, 1972). Pyrophosphates are good sequestrants for copper and iron, which often catalyze oxidation in fruits and vegetables (Considine and Considine, 1982). One source notes considerable debate about the mechanisms of phosphate functionality, with reference to water holding capacity of meat and fish (Miller, 1996). The addition of phosphates to muscle food homogenates, raw and cooked meats, in sausages, hams, poultry, and seafood will decrease the amount of drip loss, enhance waterbinding and water holding capacity resulting in enhanced sensory characteristics (Fennema, 1985).

Combinations:
Tetrasodium pyrophosphate is combined with calcium phosphates as leavening agents (Ellinger, 1972; FMC, no date). TSPP has a synergistic effect on various foaming agents, such as alkyl polycarboxylates and triethyl citrate (Sutton, 1960). Other salts, such as sodium chloride, can have a synergistic effect on water-holding capacity of sodium phosphates (Gordon and Klimek, 2000).

Status

Historic Use:
The interaction of shorter chain polyphosphates—including pyrophosphates—with proteins was first known in 1916 (Ellinger, 1972). Industrial manufacturing of pyrophosphates occurred as early as the 1920s (Dickerson, 1927). Commercial application of polyphosphates for preparing vegetable protein-polyphosphate compounds in food processing appears to date back to the late 1940s (Reviewed in Ellinger, 1972. See, for example, Horvath, 1947).

OFPA, USDA Final Rule:
The NOSB has previously reviewed sodium orthophosphates (NOSB, 1995a) and the USDA added them to section 205.605(b)(33) of the NOP National List of "Non-agricultural (nonorganic) ingredients allowed for use in organic processed products . . .Sodium phosphates—for use only in dairy foods." The NOSB reviewed sodium phosphates again in October, 2001 (see the TAP review at OMRI, 2001b) and declined a petition to expand the permitted uses to include soy products. The NOSB determined that pyrophosphates and other polyphosphates require separate TAP reviews.

microwavable gourmet coffees, fruit- and chocolate-flavored milk drinks, and flavored coffee creamers. DSP at the 0.02–0.1% level is added to evaporated and condensed milk to prevent gelation during storage. In the production of low-fat dry milk powder, the use of 2% DSP (based on solids) ensures a uniform dispersion when the milk is reconstituted. DSP minimizes the denaturation of casein that may occur during drying.

Imitation Dairy Products

Imitation dairy products contain vegetable oils and soy, whey, or casein proteins. Demand for these products is growing because of their low cholesterol content.

Coffee whiteners made with vegetable oils and milk proteins contain dipotassium phosphate (DKP) or DSP to prevent oil droplets from coalescing and protein from curdling in hot coffee. Phosphate levels in powdered whiteners range from 1.0–2.0%; liquid products contain 0.1–1.0%.

Phosphates perform a similar function in imitation process cheeses as they do in their dairy counterparts. The levels of DSP DUO and TSPX may vary, depending on the raw materials in the formulation.

In whipped toppings, phosphates enable the protein to form a stable foam, thus providing stiffening and preventing syneresis (weeping). The phosphates used in these products are DSP, DKP, and TSPP.

Low-Sodium Products

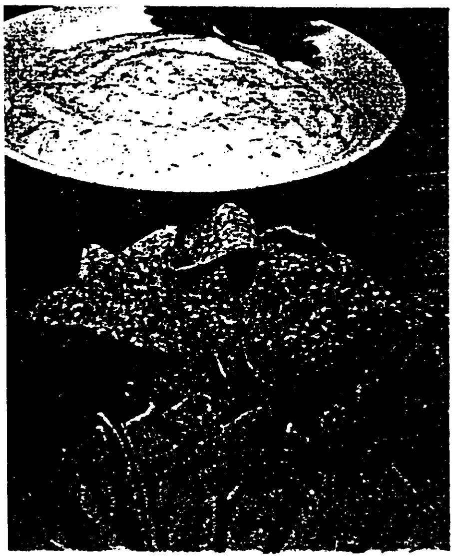
Reduction of sodium content can be achieved by partial substitution of sodium chloride with potassium chloride and the use of potassium phosphates instead of sodium phosphates. FMC produces a complete line of potassium phosphates for formulating a wide variety of low-sodium products.

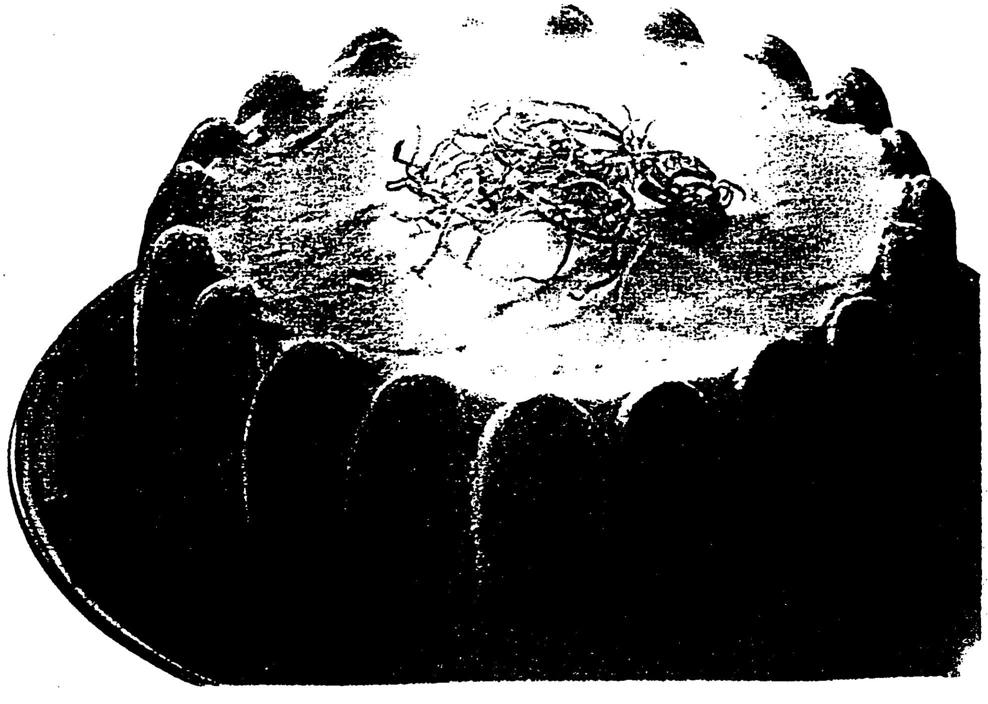
Low-Fat, Low-Cholesterol Products

In certain products, milk and vegetable proteins are used to partially replace the fat. Phosphates aid in maintaining the proper dispersion and stability of these ingredients.

FMC Food Ingredients

In addition to our versatile food phosphates, FMC produces many other food ingredients for the dairy industry. Marine Colloids Division produces carrageenan and konjac flour products. Food and Pharmaceutical Products Division offers the family of Avicel® cellulose gel products for fat replacement and stabilization. Peroxygen Division produces calcium peroxide and Durox® food-grade hydrogen peroxide, while our Alkali Division manufactures and markets sodium carbonate and sodium bicarbonate to the food industry. For more information on any of these products, just call your local sales office.





Tetrasodium Pyrophosphate

Processing

Executive Summary

The NOSB received a petition to consider tetrasodium pyrophosphate (TSPP) as a pH buffer and dough conditioner for use in organic meat alternative products. The principal food uses for tetrasodium pyrophosphate are as an emulsifier, buffer, nutrient, dietary supplement, sequestrant, and texturizer in bread and cereal products. It may be prepared from processes involving neutralization of phosphoric acid using sodium carbonate or sodium hydroxide to produce dibasic sodium phosphate, which is further dehydrated molecularly to produce TSPP.

TSPP has not previously been reviewed by the NOSB. Sodium phosphates, a precursor, were reviewed in 1995 and again in 2001. The restriction on use established by the 1995 review—for use only in dairy products—was not extended to include other uses as petitioned in the 2001 review.

All reviewers agreed that Tetrasodium pyrophosphate is a synthetically produced food additive. A majority of reviewers agreed that the substance should not be added to the National List.

Identification

Chemical Name:
tetrasodium pyrophosphate

Other Names:
TSPP, pyro, sodium pyrophosphate, tetrasodium diphosphate; Diphosphoric acid, tetrasodium salt

Trade Names: Albrite TSPP Food Grade; Solutia TSPP; Nutrifos L-50 (with sodium tripolyphosphate); Wakal A601 (Ash and Ash, 1995).

CAS Numbers:
7722-88-5

International Numbering System (INS) Numbers:
452(i)

Other:
NIOSH Registry Number:
ACX #X10000138-0
RTECS UX735000

Summary of TAP Reviewer Analyses [1]

95% organic

Synthetic / Nonsynthetic:	Allowed or Prohibited:	Suggested Annotation:
Synthetic (3-0)	*Allowed (1)* *Prohibited (2)*	*None (3)*

Made with organic

Synthetic / Nonsynthetic:	Allowed or Prohibited:	Suggested Annotation:
Synthetic (3-0)	*Allowed (1)* *Prohibited (2)*	*None (3)*

---

[1] *This Technical Advisory Panel (TAP) review is based on the information available as of the date of this review. This review addresses the requirements of the Organic Foods Production Act to the best of the investigator's ability, and has been reviewed by experts on the TAP. The substance is evaluated against the criteria found in section 2119(m) of the OFPA [7 USC 6517(m)]. The information and advice presented to the NOSB is based on the technical evaluation against that criteria, and does not incorporate commercial availability, socio-economic impact or other factors that the NOSB and the USDA may want to consider in making decisions.*

Table 1

pH Values of Phosphates Commonly Used for Dairy Products

Product name	Abbreviation	pH of a 1% solution
Monosodium phosphate	MSP	4.6
Monopotassium phosphate	MKP	4.6
Disodium phosphate	DSP	9.2
Disodium phosphate duohydrate	DSP DUO	9.1
Dipotassium phosphate	DKP	9.3
Trisodium phosphate crystals	TSPX	12.4
Tripotassium phosphate	TKP	12.4
Sodium acid pyrophosphate	SAPP	4.3
Tetrasodium pyrophosphate	TSPP	10.3
Tetrapotassium pyrophosphate	TKPP	10.5
Sodaphos®	SHMP	7.7
Hexaphos®	SHMP	6.9
Glass H®	SHMP	6.3
Sodium tripolyphosphate	STPP	9.7
Potassium tripolyphosphate	KTPP	9.6
Monocalcium phosphate monohydrate	MCPM	3.8 *
Dicalcium phosphate dihydrate	DCPD	7.4 *
Tricalcium phosphate	TCP	7.4 *

*pH, 1% slurry

Ash & Ash 1995 Handbook of Food Addit.
Aldershot UK: Gower

1A

s alcohol; m.w. 304.50; m.p. 232-

ted to decomp., emits acrid toxic

ng material (Japan)
), 176.200, 176.210, 177.1200,
as indirect food additive; Japan

lmitic acid sodium salt; Sodium

oard for food pkg.
), 176.210, 177.1200, 177.2600,

n.w. 288.30
stion, inh., skin contact, IV, IP,
heated to decomp., emits toxic

l pkg.
ily), 181.30

dens. 2.400

decomp., emits toxic fumes of SO_x

biphenyl-2-yl oxide; (1,1′-Biphen-

Empirical: $C_{12}H_9O \cdot Na$
Formula: $C_6H_4(C_6H_5)ONa \cdot 4HOH$
Properties: White flakes; sol./100 g solvent: 122 g water, 156 g acetone, 138 g methanol, 28 g propylene glycol; pract. insol. in petrol. fractions, pine oil; m.w. 192.20
Toxicology: Moderately toxic by ingestion; human skin irritant
Uses: Preservative, antimicrobial, mold inhibitor for apples, etc.
Usage level: 0.05-0.5%; ADI 0-0.02 mg/kg (EEC)
Regulatory: FDA 21CFR §175.105, 175.300, 176.170, 176.210, 177.1210, 178.3120; USA not restricted; Europe listed; Japan approved (0.01 g/kg residual)
Manuf./Distrib.: Ashland

Sodium o-phenylphenolate. *See* Sodium o-phenylphenate
Sodium o-phenylphenol. *See* Sodium o-phenylphenate

Sodium phosphate
CAS 7558-80-7 (anhyd.), 13472-35-0 (dihydrate); EINECS 231-449-2; EEC E339
Synonyms: MSP; Sodium phosphate monobasic; Sodium acid phosphate; Monobasic sodium phosphate; Monosodium dihydrogen phosphate; Monosodium dihydrogen orthophosphate; Sodium biphosphate; Sodium phosphate primary
Classification: Inorganic salt
Empirical: H_2NaO_4P
Formula: NaH_2PO_4
Properties: Wh. cryst. powd., gran., odorless; hygroscopic; sol. 87 g/100 g water; insol. in alcohol; m.w. 119.98
Toxicology: LD50 (oral, rat) 8290 mg/kg; poison by intramuscular route; mildly toxic by ingestion; eye irritant; heated to decomp., emits toxic fumes of PO_x and Na_2O
Uses: Nutrient, dietary supplement, buffer, emulsifier, sequestrant, preservative; acid ingred. in effervescent powds. and laxatives; prod. of caramel; boiler water additive; poultry scald agent
Usage level: Limitation 5% (in pickling meat prods.), 0.5% (meat prods.), 0.5% (total poultry prod.)
Regulatory: FDA 21CFR §133, 150, 160, 163.123, 163.130, 163.135, 163.140, 163.145, 163.150, 163.153, 163.155, 172.892, 173.310, 182.1778, 182.5778, 182.6085, 182.6778, 182.8778, GRAS; USDA 9CFR §318.7, 381.147
Regulatory: Japan approved
Manuf./Distrib.: Albright & Wilson Am.; Browning; FMC; Lohmann; Rhone-Poulenc Food Ingreds.
Trade names: Albrite MSP Food Grade
Trade names containing: Medium KL

Sodium phosphate dibasic
CAS 7558-79-4 (anhyd.); 7782-85-6; 10039-32-4 (dodecahydrate); 10140-65-5; EINECS 231-448-7; EEC E339b
Synonyms: DSP-O; Disodium phosphate; Dibasic sodium phosphate; Disodium hydrogen phosphate; Disodium monohydrogen orthophosphate; Disodium orthophosphate
Classification: Inorganic salt
Definition: Phosphoric acid, disodium salt
Empirical: $HO_4P \cdot 2Na$
Formula: Na_2HPO_4
Properties: Colorless translucent cryst. or wh. powd., saline taste; sol. in water; very sol. in alcohol; m.w. 141.97; dens. 1.5235; m.p. 35 C, loses water at 92.5 C
Toxicology: LD50 (oral, rat) 17 g/kg; skin and eye irritant; poison by intravenous route, moderately toxic by intraperitoneal, subcutaneous route; mildly toxic by ingestion; when heated to decomp., emits toxic fumes of PO_x and Na_2O
Uses: Buffer, dietary supplement, emulsifier, hog/poultry scald agent, nutrient, sequestrant, stabilizer, texturizer in foods (evaporated milk, process cheese, cereals, meat prods.); water treatment in food processing; stabilizer migrating from food pkg.
Regulatory: FDA 21CFR §133.169, 133.173, 133.179, 135.110, 137.305, 139.110, 139.115, 139.117, 139.135, 150.141, 150.161, 173.310, 175.210, 175.300, 181.22, 181.29, 182.1778, 182.5778, 182.6290, 182.6778, 182.8778, 182.8890, GRAS; USDA 9CFR 318.7, 381.147
Regulatory: Japan approved
Manuf./Distrib.: Albright & Wilson Am.; FMC; Lohmann; Monsanto; Rhone-Poulenc Food Ingreds.

Sodium phosphate dibasic dihydrate. *See* Disodium phosphate, dihydrate
Sodium phosphate glass. *See* Sodium hexametaphosphate
Sodium phosphate monobasic. *See* Sodium phosphate
Sodium phosphate primary. *See* Sodium phosphate
Sodium phosphate tertiary dodecahydrate. *See* Sodium phosphate tribasic dodecahydrate

ASTARIS™

Quality Products. Exceptional Response.

Material Safety Data Sheet

Responsible Care®
A Public Commitment

Received by OMRI

APR 27 2001

1. CHEMICAL PRODUCT AND COMPANY IDENTIFICATION

PRODUCT NAME: DISODIUM PHOSPHATE ANHYDROUS

MSDS Number: 007558794 Date: 09/17/97

Chemical Name: phosphoric acid, disodium salt

Synonyms: DSP; sodium phosphate, dibasic.

SOLUTIA INC., 10300 OLIVE BOULEVARD, P.O. BOX 66760, ST. LOUIS, MO
63166-6760

FOR CHEMICAL EMERGENCY, SPILL LEAK, FIRE, EXPOSURE, OR ACCIDENT Call CHEMTREC - Day or Night - 1-800-424-9300 Toll free in the continental U.S., Hawaii, Puerto Rico, Canada, Alaska, or Virgin Islands. For calls originating elsewhere: 703-527-3887 (collect calls accepted)

For additional non-emergency information, call: 314-674-6661

2. COMPOSITION/INFORMATION ON INGREDIENTS

Component	CAS No.	% by weight
disodium phosphate anhydrous	7558-79-4	100

3. HAZARDS IDENTIFICATION

EMERGENCY OVERVIEW

Appearance and Odor: white granules or powder with no odor

WARNING STATEMENTS

NO SIGNIFICANT HAZARDS ASSOCIATED WITH THIS MATERIAL

Sodium phosphate tribasic
CAS 7601-54-9; EINECS 231-509-8
Synonyms: TSP-O; Trisodium phosphate; Trisodium orthophosphate; Phosphoric acid trisodium salt
Classification: Inorganic salt
Empirical: Na_3PO_4
Formula: $H_3O_4P \cdot 3Na$
Properties: Wh. cryst., cryst. powd., gran., odorless; sol. 14 g/100 g water; insol. in alcohol; m.w. 163.97
Precaution: Strong caustic material
Toxicology: Moderately toxic by intravenous route; mutagenic data; heated to decomp., emits toxic fumes of Na_2O and PO_x
Uses: Dietary supplement, nutrient; sequestrant; buffer, pH control agent in food systems; emulsifier and alkalizer for process cheese; boiler water additive; denuding agent; fat rendering aid; hog/poultry scald agent
Regulatory: FDA 21CFR §133.169, 133.173, 133.179, 150.141, 150.161, 173.310, 182.1778, 182.5778, 182.6778, 182.8778, GRAS; USDA 9CFR §318.7, 381.147; Japan approved
Manuf./Distrib.: Browning; FMC

Sodium phosphate tribasic dodecahydrate
CAS 10101-89-0 (dodecahydrate); EINECS 231-509-8
Synonyms: TSP-12; Trisodium phosphate dodecahydrate; Tribasic sodium phosphate dodecahydrate; Sodium phosphate tertiary dodecahydrate
Classification: Sodium phosphate
Empirical: $Na_3PO_4 \cdot 12H_2O$
Properties: m.w. 380.14
Uses: Emulsifier for processed cheese; buffer for processed foods
Manuf./Distrib.: Albright & Wilson Am.; Lohmann; Rhone-Poulenc Food Ingreds.

Sodium phosphinate. *See* Sodium hypophosphite

Sodium phosphoaluminate
Properties: Wh. powd.
Uses: Migrating to foods from paper/paperboard
Regulatory: FDA 21CFR §182.90, GRAS

Sodium polignate. *See* Sodium lignosulfonate

Sodium polyacrylate
CAS 9003-04-7
Synonyms: Polyacrylic acid, sodium salt
Empirical: $(C_3H_4O_2)_x \cdot xNa$
Properties: m.w. 2000-2300
Toxicology: Eye irritant; heated to decomp., emits toxic fumes of Na_2O
Uses: Controls mineral scale during beet or cane sugar processing; boiler water additive; stabilizer and thickener in defoaming agents containing dimethicone
Usage level: 3.6 ppm max. of raw juice
Regulatory: FDA 21CFR §173.73, 173.310, 173.340; Japan approved (0.2% max.)
Manuf./Distrib.: Allchem Industries

Sodium polyacrylate-acrylamide resin
Definition: Produced by polymerization and subsequent hydrolysis of acrylonitrile in a sodium silicate-sodium hydroxide aq. sol'n.
Uses: Controls organic and mineral scale in beet sugar juice/liquor or cane sugar juice/liquor
Regulatory: FDA 21CFR §173.5, limitation 2.5 ppm

Sodium polyaluminate. *See* Sodium aluminate
Sodium polymannuronate. *See* Algin

Sodium polymethacrylate
CAS 25086-62-8; 54193-36-1
Synonyms: 2-Propenoic acid, 2-methyl-, homopolymer, sodium salt
Classification: Polymer
Empirical: $(C_4H_6O_2)_x \cdot xNa$
Formula: $[CH_3CHCHCOONa]_x$
Uses: Boiler water additive for food contact
Regulatory: FDA 21CFR §173.310, 175.105

Sodium polynapthalene methane sulfonate. *See* Sodium methylnaphthalenesulfonate
Sodium polyphosphates glassy. *See* Sodium hexametaphosphate

ISODIUM PHOSPHATE, ANHYD US (DSPa), FCC GRADE, POWDER

Astaris Disodium Phosphate, Anhydrous is a white, powdered product which complies with the specifications of the current Food Chemicals Codex for Sodium Phosphate, Dibasic (anhydrous).

Received by OMRI
APR 27 2001

Key Properties:

- Alkalinity
- Buffering agent
- Protein modifier
- Stabilizer
- Emulsifying agent
- 24 month Shelf-life

Applications:

- Cereal and Pasta Products: DSP is added to adjust the pH of these products to maintain quality color in final product and as it also accelerates the cook time is especially useful in quick cooking cereals.
- Spray Dried Milk Products: DSP is commonly used during production of spray dried cheese and nonfat milk powders. DSP protects the milk proteins from heat dehydration allowing the proteins to remain dispersed during the spray drying process, which assists in the solubility of the powders upon reconstitution with water. DSP also stabilizes the emulsion to enhance flavor, body, and appearance of the final product.
- Fluid Milk Products: DSP prevents heat coagulation in condensed and evaporated milk/cream, sterilized milk/cream/soups, and UHT processed milk products. Storage life is maximized due to retardation of age gelation of the milk proteins.
- Process Cheese Products: DSP helps to buffer the pH of the processed cheese and interacts with milk proteins to promote emulsification.
- Instant Pudding and No-Bake Cheesecake: The addition of DSP, when used in conjunction with a gel inducer, will accelerate the set of the gel at room temperature.
- Disodium phosphate (DSP) is listed as a sequestrant in 21 CFR 182.6290.
- Disodium hydrogen phosphate (DSP) is specifically approved as an adhesive and/or coating component for food packaging in 21 CFR 175.105 and 175.300. It is also classified as a stabilizer when migrating from food-packaging materials under 21 CFR 181.29.
- Sodium Phosphate (mono-, di-, and tribasic; MSP, DSP and TSP) is approved as GRAS (generally recognized as safe) as a multiple purpose food substance, dietary supplement and nutrient by the FDA under 21 CFR 182.1778, 182.5778 and 182.8778. Food Grade Sodium Phosphate is generally recognized as safe when used in accordance with good manufacturing practice.
- Sodium Phosphate (mono-, di-, tri-) has approval as a boiler water additive in 21 CFR 173.310.
- Potable Water Treatment: Astaris disodium phosphate conforms to the requirements of ANSI / NSF Standard 60 and meets or exceeds ANSI / AWWA Standard B505-88. Used for corrosion & scale control. Maximum Use Level 15 mg/L.

FOR MORE COMPLETE INFORMATION ON PROPERTIES AND SAFE HANDLING OF THIS MATERIAL, SEE THE ASTARIS MATERIAL SAFETY DATA SHEET (MSDS).

NOTICE: Although the information and recommendations set forth herein (hereinafter "Information") are presented in good faith and believed to be correct as of the date hereof, Astaris LLC makes no representations or warranties as to the completeness or accuracy thereof. Information is supplied upon the condition that the persons receiving same will make their own determination as to its suitability for their purposes prior to use. In no event will Astaris LLC be responsible for damages of any nature whatsoever resulting from the use of or reliance upon Information or the product to which Information refers. Nothing contained herein is to be construed as a recommendation to use any product, process, equipment or formulation in conflict with any patent, and Astaris LLC makes no representation or warranty, express or implied, that the use thereof will not infringe any patent. The data set forth herein are based on samples tested and are not guaranteed for all samples or applications. Such data are intended as guides and do not reflect product specifications for any particular product. NO REPRESENTATIONS OR WARRANTIES, EITHER EXPRESS OR IMPLIED, OR MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR OF ANY OTHER NATURE ARE MADE HEREUNDER WITH RESPECT TO INFORMATION OR THE PRODUCT TO WHICH INFORMATION REFERS.

Corporate Offices:

622 Emerson Road
Suite 500
P.O. Box 411160
St. Louis, Missouri 63141-1160
314-983-7500

For order assistance, please call our Customer Service Department Toll Free: 1-800-244-6169

Blank

ASTARIS
Quality Products. Exceptional Response.

PRODUCT DATA SHEET

NSF

Received by OMRI
APR 27 2001

PRODUCT: Disodium Phosphate, Anhydrous (DSPa)
Granular & Powder

GRADE: FCC

CODE: 108 (Granular)
118 (Powder)

GENERAL DESCRIPTION: White, odorless, free flowing powder.

FORMULA: Na_2HPO_4

MOLECULAR WEIGHT: 141.98

CAS NO.: 7558-79-4

DATE EFFECTIVE: January 8, 2001

CHARACTERISTICS	SPECIFICATION LIMITS	
Assay, Na_2HPO_4, %	98	Minimum
Pyrophosphate, %	2.0	Maximum
pH, 1% Solution	8.7 - 9.6	
Loss on Drying, %	5	Maximum
Insoluble Substances, %	0.2	Maximum
Arsenic (as As), mg/kg	3	Maximum
Fluoride (as F), ppm	50	Maximum
Heavy Metals (as Pb), mg/kg	10	Maximum

Sizing, USSS:	Granular	Powder
Thru 20 Mesh, %	95 Minimum	99 Minimum
Thru 100 Mesh, %	25 Maximum	90 Minimum

NOTE: Specification Limits are subject to change from time to time. Please contact us for current data sheet.

Production Location:	Lawrence, KS
Packaging:	50 lb. multiwall bags, super sacks
Labeling Requirements:	Product label required by law.
Shipping Classification:	Sodium Phosphate
Handling Precautions:	No precautionary statement required on label.

Handle in accordance with good industrial hygiene and safety practices. These include avoiding unnecessary exposure and removal of material from eyes, skin, and clothing.

This Product Data Sheet is subject to the terms and conditions on the reverse side hereof.

2

CHAPTER 15

Phosphates in Food Processing

R. H. Ellinger, Ph.D.

Manager, Regulatory Compliance
Kraft Foods Company
Division of Kraftco Corporation
Chicago, Illinois

IL

T.E. Furia (ed) CRC Handbook of
Food Additives (2nd ed): 617-780
Cleveland, OH: CRC Press

Introduction

Phosphorus is an essential element to all life, animal and vegetable, single-celled as well as multi-celled organisms. With few exceptions it is utilized only as the phosphate anion. There is no living organism known that can synthesize the phosphate anion.[1] The element, therefore, is absorbed through the food supply as the phosphate anion by all living organisms.[1,2] Very few natural compounds in living organisms contain phosphorus in any form other than that of the phosphate anion.[3]

Release of 5000 or more of this product into the environment in a 24 hour period requires notification to the National Response Center (800-424-8802 or 202-426-2675). Since local, state, and federal laws vary, consult your attorney or appropriate regulatory officials for information relating to spill reporting.

Refer to Section 11 for OSHA Hazardous Chemical(s) and Section 13 for RCRA classification.

This product has been classified in accordance with the hazard criteria of the Canadian Controlled Products Regulation and the MSDS contains all the information required by the Canadian Controlled Products Regulation.

16. OTHER INFORMATION

	Health	Fire	Reactivity	Additional Information
Suggested NFPA Rating	3	0	0	
Suggested HMIS Rating	3	0	0	G

Reason for revision: New Company

Supersedes MSDS dated: Not Applicable

Product Use: Industrial and household cleaners, water conditioner, photo developer bath ingredient, paint remover, denture cleaners, emulsifier and pH control agent for foods. May be used to treat drinking water up to 17.3 mg/L.

Astaris™ is a trademark of Astaris LLC
Responsible Care® is a registered trademark of the Chemical Manufacturers Association

AST10064.600.doc

The ability of the phosphate anion to form polymers is vital to many life processes. The transfer of one phosphate unit from the tripolyphosphate portion of ATP (adenosine triphosphate) is the means of energy transfer in most essential processes. These facts are so well established in the scientific literature that it is unnecessary to review them here.

The polyphosphates have played a vital role in the origin of life.[4-6] Studies have shown that polyphosphates exist in, and are vital to, living tissues, including single-celled and higher forms of life.[7-18] It has also been demonstrated repeatedly that enzymatic systems in present living organisms are capable of synthesizing and hydrolyzing polyphosphates, even those with a very long chain.[8,17-19] The vital role of the phosphate and pyrophosphate anions in metabolism has been completely accepted, as demonstrated, for example, in the chart of biological pathways in the *Handbook of Biochemistry*.[20]

Phosphorus in the form of the phosphate anion is a constituent of nearly every type of food consumed by living organisms. Sherman[21] has published a compilation of the phosphorus content of many natural foods, some of which are shown in Table 1.

TABLE 1
Phosphorus Content of the Edible Portion of Some Typical Foods

Type of Food	*Phosphorus Content, mg/100 g*	*Type of Food*	*Phosphorus Content, mg/100 g*
Roots, Tubers, and Bulbs		**Cereal Products**	
Beets	41 ± 1.1	Corn, sweet	120 ± 1.8
Carrots	40 ± 1.2	Oats (oatmeal)	395 ± 14.9
Potatoes	56 ± 0.8	Wheat flour	101 ± 2.1
Onions	33 ± 1.1	White bread	97 ± 2.0
Edible Leaves and Buds		**Animal Products**	
Broccoli	72 ± 2.3	Beef, lean	204 ± 2.5
Cabbage	30 ± 0.6	Cheese, cheddar	524 ± 18.0
Lettuce	28 ± 0.9	Eggs	224 ± 1.4
Fruits and Juices		Milk	93 ± 0.3
Apples	11 ± 0.17		
Orange juice	17 ± 0.4		
Oranges	21 ± 0.5		
Peaches	18 ± 0.55		

Source: Table based on data in Sherman, H. C., 1947. *Calcium and Phosphorus in Foods and Nutrition*, Columbia University Press, pp. 91–103.

As the volume of literature describing the applications of phosphates in food processing is enormous, only a small portion can be reviewed here. Further information can be obtained from a study of the numerous reviews of phosphate applications in food processing,[22-30] many of which were used in the preparation of this chapter.

13. DISPOSAL CONSIDERATIONS

This material when discarded is not a hazardous waste as that term is defined by the Resource, Conservation and Recovery Act (RCRA), 40 CFR 261. Dry material may be landfilled or recycled in accordance with local, state and federal regulations. Consult your attorney or appropriate regulatory officials for information on such disposal.

14. TRANSPORT INFORMATION

The data provided in this section is for information only. Please apply the appropriate regulations to properly classify your shipment for transportation.

US DOT

Proper Shipping Name:	Environmentally hazardous substance, solid, n.o.s. *(contains sodium phosphate, tribasic),
Hazard Class	9
Hazard Identification Number:	UN3077
Packing Group:	Packing Group III
Transport Label:	Class 9

Canadian TDG

Proper Shipping Name:	Sodium Phosphate Tribasic *
Hazard Class	9.2
Hazard Identification Number:	NA9148
Packing Group:	Packing Group III

US DOT RQ: 5000 lbs sodium phosphate tribasic
Package size containing reportable amount: 5000 lbs

Canadian TDG RL: 230 kg sodium phosphate tribasic
Package size containing reportable amount: 230 kg

* Applies ONLY to containers which contain an RQ or RL.

15. REGULATORY INFORMATION

TSCA Inventory:	Listed
DSL Inventory:	Listed
WHMIS Classification:	D2(B) - Materials Causing Other Toxic Effects

SARA Hazard Notification

Hazard Categories Under Title III Rules (40 CFR 370):	Immediate
Section 302 Extremely Hazardous Substances:	Not Applicable
Section 313 Toxic Chemical(s):	Not Applicable

CERCLA Reportable Quantity:

Nomenclature, Classification, and Chemistry of Food Phosphates

A study of the food-science literature demonstrates that the nomenclature and classification of the phosphates, particularly the polyphosphates, are confusing to many food scientists. It is often impossible to determine from the description of a phosphate which specific one was used in a study. Many studies also seem to consider the polyphosphates as a class of pure compounds. Molecular weights are often assigned to these compounds, such as to sodium hexametaphosphate; yet the compounds are such mixtures of polymeric phosphates that a molecular weight is meaningless.

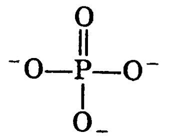
A thorough discussion of the nomenclature, structure, classification, and chemistry of the food phosphates is beyond the scope of this chapter. Anyone desiring further information on phosphate chemistry can find numerous references in the literature. Excellent reviews for food scientists have recently been published by Van Wazer[29,30] and by Bell.[29]

A detailed study of some of the chemical characteristics of the various phosphates specifically used in food applications has been published by Ellinger[28]; more detailed discussions of the various characteristics of all phosphates have been published by Van Wazer[30] and by others.[29-38]

Table 2 summarizes the nomenclature, structures, common names, formulas, pH values of solutions or slurries, and solubilities of the commonly used food phosphates. Further discussions of important characteristics of individual phosphates will appear in subsequent paragraphs; the reader also is referred to reviews by Van Wazer[29] and by Bell.[29]

The Orthophosphates

The orthophosphate anion is the simplest structure and the basic unit for all phosphates. Its structure is as follows:



$$^{-}O-\overset{\overset{\displaystyle O}{\|}}{\underset{\underset{\displaystyle O_{-}}{|}}{P}}-O^{-}$$

As the structure indicates, the anion is tribasic, and its three valences can be satisfied by hydrogen, metal ions, or combinations of the two. It also can form straight-chain and cyclic polymers, as will be discussed later.

Orthophosphoric Acid Orthophosphoric acid (H_3PO_4), commonly called phosphoric acid, is a natural constituent of many fruits and their juices. It is a strong acid, classified as tribasic because it has three replaceable hydrogens. It has been found to be an excellent acidifying agent in food applications. It is available commercially as a viscous, colorless, syrupy liquid, and it is usually sold according to its P_2O_5 (phosphoric anhydride) content. Commercial phosphoric acid, containing 68.8% or less of P_2O_5, is composed only of the monomeric phosphoric acid, H_3PO_4. Those commercial compositions containing more than 68.8% P_2O_5 contain increasing quantities of the polymers of phosphoric acid. Pyrophosphoric acid ($H_4P_2O_7$) and higher polymers increase

Solubility in Water (g/100 g H2O):	5.4 @ 0 degrees C 14.5 @ 25 degrees C 23.3 @ 40 degrees C 54.3 @ 60 degrees C 94.6 @ 100 degrees C

NOTE: These physical data are typical values based on material tested but may vary from sample to sample. Typical values should not be construed as a guaranteed analysis of any specific lot or as specifications for the product.

10. STABILITY AND REACTIVITY

STABILITY: Product is stable under normal conditions of storage and handling.

MATERIALS TO AVOID: This material could be corrosive to aluminum surfaces because of high pH.

HAZARDOUS DECOMPOSITION PRODUCTS: None known

HAZARDOUS POLYMERIZATION: Will not occur

11. TOXICOLOGICAL INFORMATION

This material has been defined as a hazardous chemical under the criteria of the OSHA Hazard Communication Standard (29 CFR 1910.1200).

Due to the high pH, skin contact with this material may result in irritation.

Data from laboratory studies conducted by Astaris and from the scientific literature with this material are summarized below.

Oral - rat LD50 - 4,150 mg/kg; slightly toxic
Dermal - rabbit LD50 - > 7,940 mg/kg; practically nontoxic
Eye Irritation - rabbit - (4-hr exp.); corrosive
Skin Irritation - rabbit: - 2.2/8.0; slightly irritating

This material produced no mutagenic effects in standard assays using fruit flies.

12. ECOLOGICAL INFORMATION

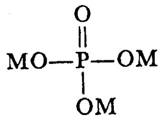
The following data have been classified using the criteria adopted by the European Economic Community (EEC) for aquatic organism toxicity.

Invertebrate: 50-hr EC50 Daphnia magna: 177 mg/L; Practically Nontoxic
Warmwater fish: 96-hr LC50 Bluegill sunfish: 220 mg/L; Practically Nontoxic
Coldwater fish: 96-hr LC50 Rainbow trout: 120 mg/L; Practically Nontoxic

No definitive algal data was available for this material.

No definitive biodegradation data was available for this material.

TABLE 2
Nomenclature, Structure, and Some Characteristics of Phosphate Acids and Salts Commonly Used in Foods[a]

Class of Phosphate	*Number P Atoms per Molecule*	*General Structure*[b]	*Common Names*	*Formulas*[c]	*pH*[d]	*Solubility*[e]
Orthophosphates (monomer)	One	 $MO{-}\overset{\overset{\displaystyle O}{\|}}{\underset{\underset{\displaystyle OM}{\mid}}{P}}{-}OM$	Phosphoric acid	H_3PO_4	2.0–2.2	High
			Monoammonium phosphate	$NH_4H_2PO_4$	4.5	28
			Diammonium phosphate	$(NH_4)_2HPO_4$	8.0	41
			Monocalcium phosphate	$Ca(H_2PO_4)_2$	4.5	Disprop[f]
			Dicalcium phosphate	$CaHPO_4$	7.5	Insol
			Tricalcium phosphate	$Ca_5(PO_4)_3(OH)$[g]	7.2	Insol
			Ferric orthophosphate	$FePO_4$[g]	3.8–4.4	Insol
			Monopotassium phosphate	KH_2PO_4	4.4	20
			Dipotassium phosphate	K_2HPO_4	8.8	63
			Tripotassium phosphate	K_3PO_4	11.9	51
			Hemisodium phosphate	$NaH_2PO_4 \cdot H_3PO_4$	2.2	High
			Monosodium phosphate	NaH_2PO_4	4.4	48
			Disodium phosphate	Na_2HPO_4	8.8	11
			Trisodium phosphate	Na_3PO_4	11.8	13
			Sodium aluminum phosphate, acidic	$NaAl_3H_{14}(PO_4)_8$	2.4–2.5	Slight
			Sodium aluminum phosphate, acidic	$Na_3Al_2H_{15}(PO_4)_8$	2.6	Slight
			Sodium aluminum phosphate, alkaline	$Na_{15}Al_{2.8}(PO_4)_8$[g]	9.2–9.4	Slight

HANDLING:
Do not get in eyes, on skin, or on clothing
Avoid breathing dust
Keep container closed
Use only with adequate ventilation
Wash thoroughly after handling
Do not taste or swallow

Emptied container retains product residue. Observe all labeled safeguards until container is cleaned, reconditioned, or destroyed. The reuse of this material's container for non-industrial purposes is prohibited and any reuse must be in consideration of the data provided in this MSDS.

STORAGE: Store in a cool, dry place to maintain product performance. Sealed containers should be kept free of water because of its corrosivity when wet.

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

EYE PROTECTION: Where there is potential for eye contact, wear goggles and have eye flushing equipment immediately available.

SKIN PROTECTION: Wear appropriate protective clothing and chemical resistant gloves to prevent skin contact. Consult the glove/clothing manufacturer to determine the appropriate type glove/clothing for a given application. Wash immediately if skin is contaminated. Launder contaminated clothing and clean protective equipment before reuse. Provide a safety shower at any location where skin contact can occur. Wash thoroughly after handling.

RESPIRATORY PROTECTION: Avoid breathing dust. Use NIOSH/MSHA approved respiratory protection equipment when airborne exposure is excessive. Consult the respirator manufacturer to determine appropriate type equipment for a given application. Observe respirator use limitations specified by NIOSH/MSHA or the manufacturer. Respiratory protection programs must comply with 29 C.F.R. 1910.134.

VENTILATION: Provide natural or mechanical ventilation to minimize exposure. The use of local mechanical exhaust ventilation is preferred at sources of air contamination such as open process equipment. Consult NFPA Standard 91 for design of exhaust systems.

AIRBORNE EXPOSURE LIMITS: OSHA and ACGIH have not established specific exposure limits for this material. However, OSHA and ACGIH have established limits for particulates not otherwise classified (PNOC) which are the least stringent exposure limits applicable to dusts.

OSHA PEL	ACGIH TLV
15 mg/m3 (total dust) 8-hr TWA	10 mg/m3 (inhalable) 8-hr TWA
5 mg/m3 (respirable) 8-hr TWA	3 mg/m3 (respirable) 8-hr TWA

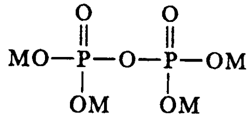
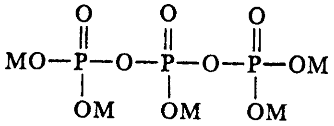
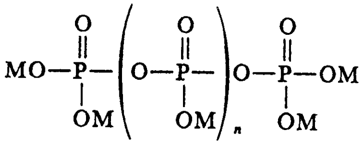
Components referred to herein may be regulated by specific Canadian provincial legislation. Please refer to exposure limits legislated for the province in which the substance will be used.

9. PHYSICAL AND CHEMICAL PROPERTIES

Chemical Formula:	Na_3PO_4
Appearance:	White, free-flowing granular product
Odor:	None
pH:	11.5 - 12.0 (as a 1% solution @ 25 degrees C)
Bulk Density:	49-63 lbs./cu. ft.

TABLE 2

Nomenclature, Structure, and Some Characteristics of Phosphate Acids and Salts Commonly Used in Foods[a] (Continued)

Class of Phosphate	*Number P Atoms per Molecule*	*General Structure*[b]	*Common Names*	*Formulas*[c]	*pH*[d]	*Solubility*[e]
Linear or straight-chain polyphosphates (polymer)	Two (dimer)	 $\mathrm{MO{-}\underset{OM}{\overset{O}{P}}{-}O{-}\underset{OM}{\overset{O}{P}}{-}OM}$	Pyrophosphoric acid	$H_4P_2O_7$	V. acid	High
			Calcium pyrophosphate	$Ca_2P_2O_7$	6.0	Insol
			Tetrapotassium pyrophosphate	$K_4P_2O_7$	10.2	61
			Ferric pyrophosphate	$Fe_4(P_2O_7)_3$[g]	—	Insol
			Sodium acid pyrophosphate	$Na_2H_2P_2O_7$	4.2	13
			Tetrasodium pyrophosphate	$Na_4P_2O_7$	10.2	6
			Sodium iron pyrophosphate	$Na_8Fe_4(P_2O_7)_5$[g]	7.0–7.7	Insol
	Three (trimer)	 $\mathrm{MO{-}\underset{OM}{\overset{O}{P}}{-}O{-}\underset{OM}{\overset{O}{P}}{-}O{-}\underset{OM}{\overset{O}{P}}{-}OM}$	Tripolyphosphoric acid	$H_5P_3O_{10}$	V. acid	High
			Potassium tripolyphosphate	$K_5P_3O_{10}$	9.8	65
			Sodium tripolyphosphate	$Na_5P_3O_{10}$	9.8	13+
			Polyphosphoric acids	$(HPO_3)_n$	V. acid	High
			Potassium metaphosphates (Kurrol's salt)	$(KPO_3)_n$ $n = 400–20\,000$	4–8	Insol[h]
	4–10[5]	 $\mathrm{MO{-}\underset{OM}{\overset{O}{P}}{-}\left(O{-}\underset{OM}{\overset{O}{P}}{-}\right)_n O{-}\underset{OM}{\overset{O}{P}}{-}OM}$ $M_{(n+2)}P_nO_{(3n+1)}$	Sodium tetrapolyphosphate	$(NaPO_3)_n$ $n = 4–10$	7–8	High
			Sodium hexametaphosphate (Graham's salt)	$(NaPO_3)_n$ $n = 10–15$	7.0	High
			Soluble sodium metaphosphate (Graham's salt)	$(NaPO_3)_n$ $n = 50–100$	6.2	High
			Insoluble sodium metaphosphate (Kurrol's salt)	$(NaPO_3)_n$ $n = 100–500$	5.5	Insol[k]

POTENTIAL HEALTH EFFECTS

Likely Routes of Exposure: Skin contact and inhalation

EYE CONTACT: This product causes eye burns based on toxicity studies. Injury may be permanent.

SKIN CONTACT: This product may cause pain, redness, swelling, and blisters based on physical properties. No more than slightly toxic based on toxicity studies.

INHALATION: Inhalation of the dust may cause coughing and sneezing.

INGESTION: This product may cause severe nausea, vomiting, abdominal discomfort, and burning sensation based on toxicity studies.

Refer to Section 11 for toxicological information.

---

4. FIRST AID MEASURES

IF IN EYES, immediately flush with plenty of water for at least 15 minutes. If easy to do, remove any contact lenses. Get medical attention. Remove material from eyes, skin and clothing.

IF ON SKIN, immediate first aid is not likely to be required. However, this material can be removed with water. Wash heavily contaminated clothing before reuse.

IF INHALED, remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen.

IF SWALLOWED, do not induce vomiting. Rinse mouth with water. Get medical attention. Contact a Poison Control Center. NEVER GIVE ANYTHING BY MOUTH TO AN UNCONSCIOUS PERSON.

5. FIRE FIGHTING MEASURES

FLASH POINT: Not combustible

HAZARDOUS PRODUCTS OF COMBUSTION: Not applicable

EXTINGUISHING MEDIA: Not applicable

UNUSUAL FIRE AND EXPLOSION HAZARDS: None known

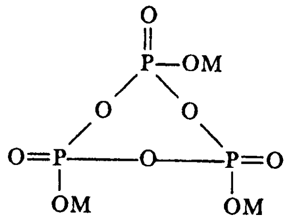
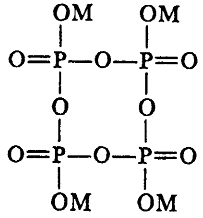
6. ACCIDENTAL RELEASE MEASURES

In case of spill, sweep, scoop or vacuum and remove. Flush residual spill area with water.

Refer to Section 13 for disposal information and Sections 14 & 15 for reportable quantity information.

7. HANDLING AND STORAGE

TABLE 2
Nomenclature, Structure, and Some Characteristics of Phosphate Acids and Salts Commonly Used in Foods[a] (Continued)

Class of Phosphate	*Number P Atoms per Molecule*	*General Structure*[b]	*Common Names*	*Formulas*[c]	*pH*[d]	*Solubility*[e]
Cyclic polyphosphates	Three		Sodium trimetaphosphate	$(NaPO_3)_3$	6.7	23
	Four		Sodium tetrametaphosphate	$(NaPO_3)_4$	6.2	18

---

[a] The information in this table was compiled from references 22. 30–32, 35, and 36.
[b] The letter M in these structures can be hydrogen or a metal ion in the compounds used as food additives.
[c] Only the formulas for the anhydrous compounds are given. The hydrates that are important as food additives are described in subsequent sections.
[d] The pH of soluble phosphates was determined in a 1% solution and in 10–50% slurries of insoluble compounds.
[e] Solubility values represent g/100 g of saturated solutions at 25°C.
[f] Monocalcium phosphate dissolves incongruently, or disproportionates to form insoluble dicalcium phosphate and phosphoric acid. However, it is commonly called soluble calcium phosphate, as it appears to be very soluble.
[g] These formulas are the molecular ratios shown by analysis. The iron compounds also contain water of hydration.
[h] Some long-chain potassium polyphosphates are made soluble by the presence of sodium ions.
[k] Some long-chain sodium polyphosphates are made soluble by the presence of potassium ions.

Received by OMRI

APR 27 2001

ASTARIS
Quality Products. Exceptional Response.

Material Safety Data Sheet

Responsible Care®
A Public Commitment

1. CHEMICAL PRODUCT AND COMPANY IDENTIFICATION

Product Name: TRISODIUM PHOSPHATE ANHYDROUS

Reference Number: AST10064 Date: April 17, 2000

Chemical Family: Phosphate Salts

Chemical Name: Phosphoric Acid, Trisodium Salt

Synonyms: TSP, TSPA; Trisodium Orthophosphate; Sodium Phosphate, Tribasic

Company Information:

ASTARIS LLC
622 Emerson Road - Suite 500
St. Louis, Missouri 63141

Emergency telephone: In USA call CHEMTREC: 1-800-424-9300
In Canada call CANUTEC: 1-613-996-6666

General Information: 1-800-244-6169

2. COMPOSITION/INFORMATION ON INGREDIENTS

Component	CAS No.	% by weight
Trisodium Phosphate Anhydrous	7601-54-9	97

3. HAZARDS IDENTIFICATION

EMERGENCY OVERVIEW

Appearance and Odor: White, free-flowing granular product with no odor

WARNING STATEMENTS

DANGER!
CAUSES EYE IRRITATION
MAY CAUSE RESPIRATORY TRACT IRRITATION

that the rat kidney is capable of a higher degree of concentration of salts than that of other species; they questioned the validity of relating the effects of rat-feeding studies of mineral salts with effects in humans.

Polyphosphates Hodge[70] fed rats diets containing 0.2, 2.0, and 10% STP, then compared the results with rats fed diets containing 10% sodium chloride and others a diet containing 5% DSP. Although no rats died, those fed diets containing 10% sodium chloride and 10% STP were found to have decreased growth rate, increased kidney weights, and significant kidney damage. Kidney damage also was apparent for all the rats, except those fed the diet containing 0.2% polyphosphate, which caused no changes at all. Hahn and co-workers[64,68,69] found that feeding rats 3% and 5% STP or SHMP resulted in severe kidney damage, while feeding 1.8% of either phosphate caused no observable physiological damage. The authors found the level of kidney damage to be equivalent to that found when similar levels of DSP had been fed in the diets. They postulated that the polyphosphates are hydrolyzed to orthophosphate prior to absorption through the intestinal walls, thus giving the same effect as orthophosphate.

Hodge[70] found that dogs tolerated 0.1 g/kg day of either STP or SHMP without any evidence of adverse effects. However, when dogs were fed increasing dosages of either phosphate, beginning at 1.0 g/kg day and increasing to 4.0 g/kg day for the last month of a 5-month feeding period, the dogs fed SHMP began to lose weight when the daily dose reached 2.5 g/kg day; those fed STP began to lose weight when the level in the diet reached 4.0 g/kg day. Gassner and co-workers[74] studied the absorption of potassium Kurrol's salt when rats were fed 750 mg of the salt for 6 days. Paper chromatography demonstrated that approximately 25% of the daily intake of the polyphosphate appeared in the urine as orthophosphate. No condensed phosphate was found in the urine for the first 2 days, but after that an average of about 4% of the daily dose was found, of which 20% was tripolyphosphate or pyrophosphate, and 80% had an average chain length of four to five. A few samples contained the cyclic trimetaphosphate in quantities below 0.2%.

Cyclic Polyphosphates The cyclic polyphosphates were found by Hodge[70,73] to have fewer physiological effects on rats than either orthophosphates or polyphosphates. Diets containing 0.2, 2.0, and 10% sodium trimetaphosphate and similar diets containing the same quantities of sodium tetrametaphosphate were used in the studies. Only the highest levels were found to have adverse effects on kidneys; none of the lower levels had any adverse effects. When dogs were fed increasing doses of the cyclic phosphates, adverse effects began to appear only after the daily dose had reached 4 g/kg day. A further study of 100 rats fed diets containing 0.1, 1.0, and 10% sodium trimetaphosphate resulted in retarded growth for all of the rats when the diets contained 10% and a reduction in growth rate for those male rats receiving 1%.[73] Histological studies and studies of reproduction through two generations showed no further abnormalities. The cyclic polyphosphates, therefore, appear to be considerably less toxic than the straight-chain polyphosphates.

Biochemical Aspects of Phosphate Toxicity

Although the phosphate anion is essential to metabolism in all living organisms, no organism is known to synthesize this anion; therefore, it must be

RISODIUM PHOSPHATE, ANHYDROUS (TSPa), FCC GRADE, GRANULAR or POWDER

Astaris FCC Grade Trisodium Phosphate, Anhydrous complies with the specifications of the current Food Chemicals Codex for Sodium Phosphate, Tribasic. Trisodium Phosphate Anhydrous (TSPa) and Trisodium Phosphate Crystalline (TSPc) are generally interchangeable in their applications if allowance is made for the differences in contained water. TSPa offers high concentration and low bulk since one pound of TSPa is equivalent to approximately 2.33 pounds of TSPc.

Key Properties:

- Strongly alkaline salt
- Emulsifying agent.
- Protein modifier
- Buffer capacity

Applications:

- Process Cheese and Cheese Products: TSP is used to make a soft process cheese that melts & flows easily at 75-80°C. The TSP sequesters the calcium from the cheese protein causing the protein to dissolve and emulsify the system.
- Quick Cooking Cereals: The high alkalinity of TSP is advantageous when quicker cooking rates are desirable in cooked breakfast cereals. Increased pH also makes the product more creamy or yellow in color giving a richer appearance.
- Generally Recognized As Safe (GRAS) when added directly to human food under 21 CFR 182.1778, 182.6778, and 182.8778. Food Grade Sodium Phosphate (mono-, di-, tri-) is generally recognized as safe when used in accordance with good manufacturing practice.
- Approved for use as a boiler water additive under 21 CFR 173.310. Steam from boiler water treated with TSP is allowed to contact edible products in official meat, poultry, and food processing establishments under USDA jurisdiction.
- USDA approved as a general cleaning agent, or for use with steam cleaning or recirculating devices in all departments of official meat, poultry and food processing establishments under USDA jurisdiction. Before using this compound, food products and packaging materials must be removed from the room or carefully protected. After using this compound, equipment and utensils must be thoroughly rinsed with potable water.
- USDA approved for use in meat, poultry and food processing plants under USDA jurisdiction as a water conditioning compound for entire potable water systems; dosage not to exceed 20 ppm calculated as PO_4.
- USDA approved as a hog scalding and tripe denuding agent in official meat processing establishments. Treatment must be followed by thorough rinsing with potable water to remove the added substance.
- Potable Water Treatment: Astaris trisodium phosphate anhydrous conforms to the requirements of ANSI / NSF Standard 60 and meets or exceeds ANSI / AWWA Standard B505-88. Used for corrosion & scale control. Maximum Use Level = 17 mg/L.

FOR MORE COMPLETE INFORMATION ON PROPERTIES AND SAFE HANDLING OF THIS MATERIAL, SEE THE ASTARIS MATERIAL SAFETY DATA SHEET (MSDS).

NOTICE: Although the information and recommendations set forth herein (hereinafter "Information") are presented in good faith and believed to be correct as of the date hereof, Astaris LLC makes no representations or warranties as to the completeness or accuracy thereof. Information is supplied upon the condition that the persons receiving same will make their own determination as to its suitability for their purposes prior to use. In no event will Astaris LLC be responsible for damages of any nature whatsoever resulting from the use of or reliance upon Information or the product to which Information refers. Nothing contained herein is to be construed as a recommendation to use any product, process, equipment or formulation in conflict with any patent, and Astaris LLC makes no representation or warranty, express or implied, that the use thereof will not infringe any patent. The data set forth herein are based on samples tested and are not guaranteed for all samples or applications. Such data are intended as guides and do not reflect product specifications for any particular product. NO REPRESENTATIONS OR WARRANTIES, EITHER EXPRESS OR IMPLIED, OR MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR OF ANY OTHER NATURE ARE MADE HEREUNDER WITH RESPECT TO INFORMATION OR THE PRODUCT TO WHICH INFORMATION REFERS.

Corporate Offices:

622 Emerson Road
Suite 500
P.O. Box 411160
St. Louis, Missouri 63141-1160
314-983-7500

For order assistance, please call our Customer Service Department Toll Free: 1-800-244-6169

affected when 0.25 g/day of the dilute acid was administered, and adults tolerated as high as 26 g/day without adverse effects. Feeding studies with dogs demonstrated that they would tolerate as high as 13 g/day of the dilute acid before signs of enteritis appeared. Other studies of the results of feeding phosphoric acid to dogs and rabbits also have been reviewed by this author. Based on these studies Nazario calculated that a 70 kg man could tolerate 17 g of 100% phosphoric acid and that approximately 22 g of the acid would be lethal.

Bonting[62] fed three generations of rats 0.75% H_3PO_4 in their diets. Studies of their blood, tissues, mineral balance, nitrogen retention, and acidic conditions in their digestive tracts indicated that the young and adult rats suffered no adverse effects. However, extensive pathological damage, particularly to the kidneys of rats, occurred when MacKay and Oliver[63] fed 2.94% H_3PO_4 and 3.93–7.86% sodium or potassium orthophosphates to rats. Hahn and co-workers[64] studied the effects of diets containing 1.8, 3.0, and 5.0% DSP to rats. The lowest level produced only slight physiological effects, such as minor increases in kidney weight and renal calcification, but extensive physiological damage was done at the 3.0 and 5.0% levels. Levels of phosphorus, copper, iron, and calcium in the blood and organs were found to have undergone no significant changes.

Dymsza and co-workers[65] could find no histological or chemical signs of adverse physiological effects, and no changes in absorption or utilization of calcium, phosphorus, or iron when rats were fed diets containing 0.87 and 5.1% DKP for 150 days. McFarlane[57] found that only the lower level of oral administration produced no adverse effects in rats when they were fed 0.34–1.2 g/100 g body weight. All other levels and methods of administration produced renal damage in the rat kidneys. Three generations of rats were fed diets containing 0.5–5.0% of a mixture of MSP and DSP by van Esch and co-workers.[58] A level of 0.5% produced no discernible damage. However, rats receiving diets containing 1% or more of the mixture were found to have renal damage and tissue calcification. Growth was impaired, fertility was reduced, and life spans were shortened in the animals receiving 5% phosphate. Hogan and co-workers[66,67] found that the levels of magnesium and potassium in the diets of guinea pigs determined whether physiological effects were adverse or not. Diets containing 0.9% calcium, 1.7% phosphorus, 0.04% magnesium, and 0.41% potassium resulted in severe reductions in weight gain, increased stiffness of leg joints, and numerous visible deposits of calcium phosphates in the guinea-pig footpads. These symptoms were significantly reduced or eliminated when the diet was altered so that it contained 0.35% magnesium and 1.5% potassium with the same levels of calcium and phosphorus. These reports may be highly significant in explaining the discrepancies in the numerous studies of the effects of phosphates in the diets of test animals. As far as could be determined in reviewing the literature, Hogan and his co-workers are the only ones who reported the levels of magnesium and potassium in the diet and related physiological damage to the presence or absence of these two minerals.

Pyrophosphates Hahn and Seifen,[68] Hahn,[64,69] Datta *et al.*,[59] and van Esch *et al.*[58] fed diets containing 0.5–5.0% pyrophosphate to rats. All diets containing 1% or more of the pyrophosphate produced physiologically adverse effects, principally kidney damage and calcification. Datta and co-workers[59] observed

ASTARIS
Quality Products: Exceptional Response.

Received by OMRI
APR 27 2001

PRODUCT DATA SHEET

NSF

PRODUCT: Trisodium Phosphate Anhydrous (TSPa)
Granular & Powder

GRADE: FCC

CODE: 208 (granular)
218 (powder)

GENERAL DESCRIPTION: White, free-flowing, granular product

FORMULA: Na_3PO_4

MOLECULAR WEIGHT: 164.0

CAS NO.: 7601-54-9

DATE EFFECTIVE: February 7, 2001

CHARACTERISTICS	SPECIFICATION LIMITS
Assay, % (ignited basis)	97.0 Minimum
P_2O_5, % (ignited basis)	42.0 Minimum
Alkalinity, % Na_2O	36.0 - 39.0
Loss on ignition, %	2 Maximum
Insolubles, %	0.2 Maximum
Arsenic (as As), mg/kg	3 Maximum
Fluoride, mg/kg	50 Maximum
Heavy metals (as Pb), mg/kg	10 Maximum

	Granular	Powder
Sizing, USSS:		
Thru 20 mesh, %	90 Min.	100 Min.
Thru 100 mesh, %	25 Max.	90 Min.
Bulk Density, lb/ft^3	37 - 47	65 (Typical)
g/cc	0.6 - 0.75	1.0 (Typical)

NOTE: Specification Limits are subject to change from time to time. Please contact us for current data sheet.

Production Location:	Lawrence, KS
Packaging:	50 lb. multiwall bags; 2000 lb. super sacks
Labeling Requirements:	Product label required by law.
Shipping Classification:	Trisodium Phosphate
Handling Precautions:	

DANGER! CAUSES EYE BURNS. CAUSES SKIN IRRITATION. Do not get in eyes, on skin, or clothing. Avoid breathing dust. Keep container closed. Use with adequate ventilation. Wash thoroughly after handling. FIRST AID: IF IN EYES, immediately flush with plenty of water for at least 15 minutes. Call a physician. IF ON SKIN, immediately flush with plenty of water. Remove contaminated clothing. Wash clothing before reuse.

This Product Data Sheet is subject to the terms and conditions on the reverse side hereof.

TABLE 7
Dietary Levels of Phosphates Producing No Adverse Effects (Continued)

Phosphate	*Test Animal*	*Length of Test*[a]	*Maximum Level Tolerated*	*Effect of Excess Phosphate*	*Reference*
Pyrophosphates					
TSPP	Rat	6 mo	$>1.8\%, <3.0\%$	Kidney damage	64, 68, 69
TSPP	Rat	16 wk	$<1\%$	Kidney damage	59
SAPP + TSPP + $(KPO_3)_n$	Rat	3 gen	$>0.5\%, <1\%$	Kidney damage	58
Tripolyphosphates					
STP	Rat	6 mo	$>1.8\%, <3.0\%$	Kidney damage	64, 68, 69
STP	Rat	1 mo	$>0.2\%, <2\%$	Kidney damage	70
STP	Rat	2 yr	$>0.5\%, <5\%$	Kidney damage	71
STP	Dog	1 mo	>0.1 g/kg d	No adverse effects	70
STP	Dog	5 mo	<4.0 g/kg d	Kidney, heart damage	70
Polyphosphates					
SHMP	Rat	150 d	$>0.9\%, <3.5\%$	Slight growth reduction	65
SHMP	Rat	1 mo	$>0.2\%, <2\%$	Kidney damage	70
SHMP	Rat	3 gen	$>0.5\%, <5\%$	Kidney damage	72
SHMP	Dog	1 mo	>0.1 g/kg d	No adverse effects	70
SHMP	Dog	5 mo	<2.5 g/kg d	Kidney, heart damage	70
Graham's salt	Rat	6 mo	$>1.8\%, <3\%$	Kidney damage	64, 68, 69
$(KPO_3)_n$ + SAPP + TSPP	Rat	3 gen	$>0.5\%, <1\%$	Kidney damage	58
Cyclic phosphates					
$(NaPO_3)_3$	Rat	1 mo	$>2\%, <10\%$	Kidney damage	70
$(NaPO_3)_3$	Rat	2 yr	$>0.1\%, <1\%$	Retarded growth of males	73
$(NaPO_3)_3$	Rat	3 gen	$>0.05\%$	No adverse effects	73
$(NaPO_3)_3$	Dog	1 mo	>0.1 g/kg d	No adverse effects	70
$(NaPO_3)_3$	Dog	5 mo	<4 g/kg d	Kidney, heart damage	70
$(NaPO_3)_4$	Rat	1 mo	$>2\%, <10\%$	Kidney, heart damage	70
$(NaPO_3)_4$	Dog	1 mo	>0.1 g/kg d	No adverse effects	70
$(NaPO_3)_4$	Dog	5 mo	<4 g/kg d	Kidney, heart damage	70

---

[a] Some reports did not give definite time periods.

[b] "No adverse effects" = no physiological damage noticeable at any level of phosphate tested.

[c] Guinea pigs tolerated higher levels of phosphate only when increased levels of Mg^{++} and K^+ were present in their diets.

The Orthophosphates According to Nazario,[1] a 36.4% solution of phosphoric acid has frequently been administered to humans, both babies and adults, in the treatment of hypoacid diathesis. Babies were not adversely

MATERIAL SAFETY DATA SHEET

Sodium Hexametaphosphate

ASTARIS

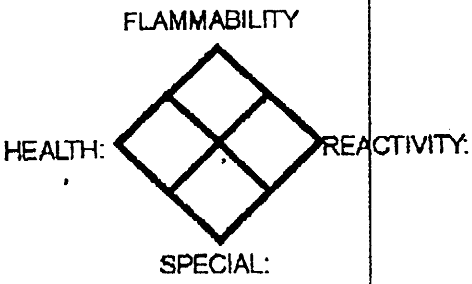
Page: 7 of 7
MSDS Ref. No: AST10053
Date Approved: 07/11/2000
Version: US/Canada
Revision No: New MSDS

HMIS RATING

HEALTH:	1
FLAMMABILITY	0
REACTIVITY:	0
PROTECTION:	F

Key
4 = Severe
3 = Serious
2 = Moderate
1 = Slight
0 = Minimal

NFPA RATING



Reason for Revision: New Company

Supersedes MSDS dated: Not applicable

Astaris™ is a trademark of Astaris LLC

Although the information and recommendations set forth herein (hereinafter "Information") are presented in good faith and believed to be correct as of the date hereof, Astaris LLC makes no representations as to the completeness or accuracy thereof. Information is supplied upon the condition that the persons receiving same will make their own determination as to its suitability for their purposes prior to use. In no event will Astaris LLC be responsible for damages of any nature whatsoever resulting from the use of or reliance upon information. NO REPRESENTATIONS OR WARRANTIES, EITHER EXPRESS OR IMPLIED, OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR OF ANY OTHER NATURE ARE MADE HEREUNDER WITH RESPECT TO INFORMATION OR THE PRODUCT TO WHICH INFORMATION REFERS.

affected when 0.25 g/day of the dilute acid was administered, and adults tolerated as high as 26 g/day without adverse effects. Feeding studies with dogs demonstrated that they would tolerate as high as 13 g/day of the dilute acid before signs of enteritis appeared. Other studies of the results of feeding phosphoric acid to dogs and rabbits also have been reviewed by this author. Based on these studies Nazario calculated that a 70 kg man could tolerate 17 g of 100% phosphoric acid and that approximately 22 g of the acid would be lethal.

Bonting[62] fed three generations of rats 0.75% H_3PO_4 in their diets. Studies of their blood, tissues, mineral balance, nitrogen retention, and acidic conditions in their digestive tracts indicated that the young and adult rats suffered no adverse effects. However, extensive pathological damage, particularly to the kidneys of rats, occurred when MacKay and Oliver[63] fed 2.94% H_3PO_4 and 3.93–7.86% sodium or potassium orthophosphates to rats. Hahn and co-workers[64] studied the effects of diets containing 1.8, 3.0, and 5.0% DSP to rats. The lowest level produced only slight physiological effects, such as minor increases in kidney weight and renal calcification, but extensive physiological damage was done at the 3.0 and 5.0% levels. Levels of phosphorus, copper, iron, and calcium in the blood and organs were found to have undergone no significant changes.

Dymsza and co-workers[65] could find no histological or chemical signs of adverse physiological effects, and no changes in absorption or utilization of calcium, phosphorus, or iron when rats were fed diets containing 0.87 and 5.1% DKP for 150 days. McFarlane[57] found that only the lower level of oral administration produced no adverse effects in rats when they were fed 0.34–1.2 g/100 g body weight. All other levels and methods of administration produced renal damage in the rat kidneys. Three generations of rats were fed diets containing 0.5–5.0% of a mixture of MSP and DSP by van Esch and co-workers.[58] A level of 0.5% produced no discernible damage. However, rats receiving diets containing 1% or more of the mixture were found to have renal damage and tissue calcification. Growth was impaired, fertility was reduced, and life spans were shortened in the animals receiving 5% phosphate. Hogan and co-workers[66,67] found that the levels of magnesium and potassium in the diets of guinea pigs determined whether physiological effects were adverse or not. Diets containing 0.9% calcium, 1.7% phosphorus, 0.04% magnesium, and 0.41% potassium resulted in severe reductions in weight gain, increased stiffness of leg joints, and numerous visible deposits of calcium phosphates in the guinea-pig footpads. These symptoms were significantly reduced or eliminated when the diet was altered so that it contained 0.35% magnesium and 1.5% potassium with the same levels of calcium and phosphorus. These reports may be highly significant in explaining the discrepancies in the numerous studies of the effects of phosphates in the diets of test animals. As far as could be determined in reviewing the literature, Hogan and his co-workers are the only ones who reported the levels of magnesium and potassium in the diet and related physiological damage to the presence or absence of these two minerals.

Pyrophosphates Hahn and Seifen,[68] Hahn,[64,69] Datta *et al.*,[59] and van Esch *et al.*[58] fed diets containing 0.5–5.0% pyrophosphate to rats. All diets containing 1% or more of the pyrophosphate produced physiologically adverse effects, principally kidney damage and calcification. Datta and co-workers[59] observed

MATERIAL SAFETY DATA SHEET

Sodium Hexametaphosphate

ASTARIS

COMMENTS:
The data provided in this section is for information only. Please apply the appropriate regulations to properly classify your shipment for transportation.

15. REGULATORY INFORMATION

UNITED STATES

SARA TITLE III (SUPERFUND AMENDMENTS AND REAUTHORIZATION ACT)
SARA TITLE III SECTION 302 EXTREMELY HAZARDOUS SUBSTANCES (40 CFR 355):
Not listed

SECTION 311 HAZARD CATEGORY (40 CFR 370): Not applicable

SECTION 313 REPORTABLE INGREDIENTS (40 CFR 372): Not listed

CERCLA (COMPREHENSIVE ENVIRONMENTAL RESPONSE COMPENSATION AND LIABILITY ACT)
CERCLA RQ: Not applicable

TSCA (TOXIC SUBSTANCE CONTROL ACT)
TSCA STATUS (40 CFR 710): Listed

CANADA

WHMIS (WORKPLACE HAZARDOUS MATERIALS INFORMATION SYSTEM):
Hazard Classification: Not controlled
Domestic Substance List: Listed

COMMENTS:
This product has been classified in accordance with the hazard criteria of the Canadian Controlled Products Regulation and the MSDS contains all the information required by the Canadian Controlled Products Regulation.

Refer to Section 11 for OSHA/HPA Hazardous Chemical(s) and Section 13 for RCRA classification.

16. OTHER INFORMATION

TABLE 7
Dietary Levels of Phosphates Producing No Adverse Effects (Continued)

Phosphate	*Test Animal*	*Length of Test*[a]	*Maximum Level Tolerated*	*Effect of Excess Phosphate*	*Reference*
Pyrophosphates					
TSPP	Rat	6 mo	>1.8%, <3.0%	Kidney damage	64, 68, 69
TSPP	Rat	16 wk	<1%	Kidney damage	59
SAPP + TSPP + $(KPO_3)_n$	Rat	3 gen	>0.5%, <1%	Kidney damage	58
Tripolyphosphates					
STP	Rat	6 mo	>1.8%, <3.0%	Kidney damage	64, 68, 69
STP	Rat	1 mo	>0.2%, <2%	Kidney damage	70
STP	Rat	2 yr	>0.5%, <5%	Kidney damage	71
STP	Dog	1 mo	>0.1 g/kg d	No adverse effects	70
STP	Dog	5 mo	<4.0 g/kg d	Kidney, heart damage	70
Polyphosphates					
SHMP	Rat	150 d	>0.9%, <3.5%	Slight growth reduction	65
SHMP	Rat	1 mo	>0.2%, <2%	Kidney damage	70
SHMP	Rat	3 gen	>0.5%, <5%	Kidney damage	72
SHMP	Dog	1 mo	>0.1 g/kg d	No adverse effects	70
SHMP	Dog	5 mo	<2.5 g/kg d	Kidney, heart damage	70
Graham's salt	Rat	6 mo	>1.8%, <3%	Kidney damage	64, 68, 69
$(KPO_3)_n$ + SAPP + TSPP	Rat	3 gen	>0.5%, <1%	Kidney damage	58
Cyclic phosphates					
$(NaPO_3)_3$	Rat	1 mo	>2%, <10%	Kidney damage	70
$(NaPO_3)_3$	Rat	2 yr	>0.1%, <1%	Retarded growth of males	73
$(NaPO_3)_3$	Rat	3 gen	>0.05%	No adverse effects	73
$(NaPO_3)_3$	Dog	1 mo	>0.1 g/kg d	No adverse effects	70
$(NaPO_3)_3$	Dog	5 mo	<4 g/kg d	Kidney, heart damage	70
$(NaPO_3)_4$	Rat	1 mo	>2%, <10%	Kidney, heart damage	70
$(NaPO_3)_4$	Dog	1 mo	>0.1 g/kg d	No adverse effects	70
$(NaPO_3)_4$	Dog	5 mo	<4 g/kg d	Kidney, heart damage	70

[a] Some reports did not give definite time periods.

[b] "No adverse effects" = no physiological damage noticeable at any level of phosphate tested.

[c] Guinea pigs tolerated higher levels of phosphate only when increased levels of Mg^{++} and K^{+} were present in their diets.

The Orthophosphates According to Nazario,[1] a 36.4% solution of phosphoric acid has frequently been administered to humans, both babies and adults, in the treatment of hypoacid diathesis. Babies were not adversely

ACUTE EFFECTS FROM OVEREXPOSURE:
The dry material may cause foreign body irritation in some individuals. Excessive inhalation of dust may be annoying and can mechanically impede respiration. Prolonged contact with the dry powder may cause drying or chapping of the skin.

Rats fed this material in their diet for one month showed decreased growth, increased kidney, lung and spleen weight, and kidney damage.

CHRONIC EFFECTS FROM OVEREXPOSURE:
Rats fed this material for two years showed decreased weight gain, increased kidney weight, and kidney changes. No increase in tumors was reported.

REPRODUCTIVE EFFECTS:
No adverse effects in reproductive capacity were reported in a multigeneration study using rats fed this material.

COMMENTS:
Data from Astaris single-dose (acute) animal studies with this material are given above.

12. ECOLOGICAL INFORMATION

ECOTOXICOLOGICAL INFORMATION:
Astaris has not conducted environmental toxicity or biodegradation studies with this product.

Astaris has not conducted biodegradation studies with this product since when dissolved/hydrolyzed in water it yields completely mineralized materials.

13. DISPOSAL CONSIDERATIONS

DISPOSAL METHOD:
This material, when discarded, is not a hazardous waste as that term is defined by the Resource, Conservation and Recovery Act (RCRA), 40 CFR 261. Dry material may be landfilled or recycled in accordance with local, state and federal regulations. Consult your attorney or appropriate regulatory officials for information on such disposal.

14. TRANSPORT INFORMATION

U.S. DOT (DEPARTMENT OF TRANSPORTATION)
PROPER SHIPPING NAME: Not regulated for transportation

CANADA TRANSPORT OF DANGEROUS GOODS
PROPER SHIPPING NAME: Not regulated for transportation

As shown by the data in Table 6, the phosphates are somewhat more toxic than sodium chloride when given orally; the toxicity of phosphates decreases with increasing chain length. The phosphates also appear to be more toxic than sodium chloride when introduced into the body in a manner that circumvents the digestive system. The LD_{50} levels of the various phosphates, including the longer-chain polyphosphates, change little when introduced directly into the body through intravenous or intraperitoneal injection. This is probably due to their rapid enzymatic hydrolysis to orthophosphates.

Although the phosphates are much more toxic when introduced directly into the body, their toxicity upon oral administration is of greater importance here, since this is the manner in which they will be introduced through their applications in food processing. All food applications introduce low but constant levels of phosphates into the diet. Therefore, the chronic toxicity studies are of more concern in studying the safety of phosphates in the human diet.

Chronic Toxicity of Phosphates in Diets

Table 7 summarizes data found in the literature on the chronic toxicity of phosphates administered orally to humans and animals. Many investigations included studies of phosphates of several chain lengths. The data have been separated into categories according to the phosphate chain length for presentation in Table 7, in order to demonstrate the effect of chain length on the degree of toxicity. The chronic toxicity of the phosphates grouped according to their chain lengths will be discussed in the following paragraphs.

TABLE 7
Dietary Levels of Phosphates Producing No Adverse Effects

Abbreviations:

d = day
g = gram
gen = generation
kg = kilogram
mo = month
wk = week
yr = year
% = per cent phosphate in diet (often calculated from % P)

Phosphate	*Test Animal*	*Length of Test*[a]	*Maximum Level Tolerated*	*Effect of Excess Phosphate*	*Reference*
Orthophosphates					
H_3PO_4 (36.4%)	Human	Variable	17–26 g/d	No adverse effects[b]	1
H_3PO_4 (36.4%)	Rat	>12 mo	>0.75%	No adverse effects[b]	62
H_3PO_4 (36.4%)	Rat	44 d	<2.94%	Kidney damage	63
Na and K orthophosphates	Rat	44 d	<3.93%	Kidney damage	63
MSP	Human	Variable	5–7 g/d	No adverse effects	37
MSP	Rat	42 d	>3.4 g/kg d	Kidney damage	57
MSP	Guinea pig	200 d	>2.2%, < 4.0%	Ca deposits, reduced growth	66
MSP	Guinea pig	12–32 wk	4–8%[c]	Ca deposits, reduced growth	67
MSP + DSP	Rat	3 gen	>0.5%, <1%	Kidney damage	58
DSP	Rat	6 mo	>1.8%, <3.0%	Kidney damage	64, 68, 69
DSP	Rat	1 mo	<5%	Kidney damage	70
DKP	Rat	150 d	>5.1%	No adverse effects	65

MATERIAL SAFETY DATA SHEET

Sodium Hexametaphosphate

9. PHYSICAL AND CHEMICAL PROPERTIES

ODOR: None
APPEARANCE: White powder, granules, or glass plates
pH: (as a 1% solution): SHMP: 7.0; SHMP Long chain: 5.6 - 6.8
MELTING POINT: 628°C (1162°F)
SOLUBILITY IN WATER: Infinitely soluble, but dissolves slowly
DENSITY: (Bulk) (lb./cu. ft.): Powder: 78 - 84; Granular (crushed): 77 - 81

COMMENTS:
NOTE: These physical data are typical values based on material tested but may vary from sample to sample. Typical values should not be construed as a guaranteed analysis of any specific lot or as specifications for the product.

10. STABILITY AND REACTIVITY

STABILITY:
Solutions of this product will hydrolyze to form orthophosphate and other shorter chain phosphates. Dissolution is impacted by temperature and pH of the system.

POLYMERIZATION:
Will not occur

HAZARDOUS DECOMPOSITION PRODUCTS:
None known

INCOMPATIBLE MATERIALS:
None known

11. TOXICOLOGICAL INFORMATION

SKIN EFFECTS:
Skin Irritation (rabbit - 24 hr. exposure): 0.0/8.0; non-irritating

EYES:
Eye Irritation - rabbit: 1.3/110.0; slightly irritating

DERMAL LD_{50}:
>7940 mg/kg (rabbit); practically non-toxic

ORAL LD_{50}:
6600 mg/kg (rat); practically non-toxic

TABLE 6
Acute Toxicity Levels of Phosphates in Animals (Continued)

Phosphate	*Animal*	*Route*	*LD_{50}, mg/kg body weight*	*Approx Lethal Dose, mg/kg body weight*	*Reference*
$NaH_2PO_4 + Na_2HPO_4$	Rat	IV	>500		58
$Na_2H_2P_2O_7$	Mouse	O	2 650		60
$Na_2H_2P_2O_7$	Mouse	SC	480		60
$Na_2H_2P_2O_7$	Mouse	IV	59		60
$Na_2H_2P_2O_7$	Rat	O	>4 000		59
$Na_4P_2O_7$	Rat	IP	233		59
$Na_4P_2O_7$	Rat	IV	100–500		58
$Na_4P_2O_7$	Mouse	IP		ca 40	55
$Na_4P_2O_7$	Mouse	O	2 980		60
$Na_4P_2O_7$	Mouse	SC	400		60
$Na_4P_2O_7$	Mouse	IV	69		60
$Na_4P_2O_7$	Rabbit	IV		ca 50	55
$Na_5P_3O_{10}$	Mouse	O		>100	55
$Na_5P_3O_{10}$	Mouse	O	3 210		60
$Na_5P_3O_{10}$	Mouse	SC	900		60
$Na_5P_3O_{10}$	Mouse	IV	71		60
$Na_5P_3O_{10}$	Rat	IP	134		61
$Na_6P_4O_{13}$	Rat	O	3 920		60
$Na_6P_4O_{13}$	Rat	SC	875		60
$(KPO_3)_n$ + Pyro	Rat	O	4 000		58
$(KPO_3)_n$ + Pyro	Rat	IV	ca 18		58
Hexametaphosphate[a]	Rabbit	IV		ca 140	55
Hexametaphosphate[a]	Mouse	O		>100	55
Hexametaphosphate[a]	Mouse	O	7 250		60
Hexametaphosphate[a]	Mouse	SC	1 300		60
Hexametaphosphate[a]	Mouse	IV	62		60
$(NaPO_3)_{\bar{n}=6}$[b]	Rat	IP	192		61
$(NaPO_3)_{\bar{n}=11}$	Rat	IP	200		61
$(NaPO_3)_{\bar{n}=27}$	Rat	IP	326		61
$(NaPO_3)_{\bar{n}=47}$	Rat	IP	70		61
$(NaPO_3)_{\bar{n}=65}$	Rat	IP	40		61
$(NaPO_3)_3$ cyclic	Mouse	O	10 300		60
$(NaPO_3)_3$ cyclic	Mouse	SC	5 940		60
$(NaPO_3)_3$ cyclic	Mouse	IV	1 165		60
NaCl (table salt)	Mouse	O	5 890		60
NaCl (table salt)	Mouse	SC	3 000		60
NaCl (table salt)	Mouse	IV	645		60

[a] Average chain lengths are not given.

[b] Polyphosphate preparations for which the $\bar{n}$ was determined.

7. HANDLING AND STORAGE

HANDLING:
HANDLE IN ACCORDANCE WITH GOOD INDUSTRIAL HYGIENE AND SAFETY PRACTICES. THESE PRACTICES INCLUDE AVOIDING UNNECESSARY EXPOSURE AND REMOVAL OF MATERIAL FROM EYES, SKIN, AND CLOTHING.

STORAGE:
Store in a cool, dry place to maintain product performance.

8. EXPOSURE CONTROLS / PERSONAL PROTECTION

PERSONAL PROTECTIVE EQUIPMENT

EYES AND FACE:
This product does not cause significant eye irritation or eye toxicity requiring special protection. Use good industrial practice to avoid eye contact.

SKIN:
Although this product does not present a significant skin concern, minimize skin contamination by following good industrial practice. Wearing protective gloves is recommended. Wash hands and contaminated skin thoroughly after handling.

RESPIRATORY:
Avoid breathing dust. Use NIOSH/MSHA approved respiratory protection equipment when airborne exposure limits are exceeded (see below). Consult the respirator manufacturer to determine the appropriate type of equipment for a given application. Observe respirator use limitations specified by NIOSH/MSHA or the manufacturer. Respiratory protection programs must comply with 29 C.F.R. 1910.134.

VENTILATION:
Provide natural or mechanical ventilation to control exposure levels below airborne exposure limits (see below). The use of local mechanical exhaust ventilation is preferred at sources of air contamination such as open process equipment.

AIRBORNE EXPOSURE LIMITS:
OSHA and ACGIH have not established specific exposure limits for this material. However, OSHA and ACGIH have established limits for particulates not otherwise classified (PNOC) which are the least stringent exposure limits applicable to dusts.

OSHA PEL: 15 mg/m^3 (total dust) 8 hr. TWA; 5 mg/m^3 (respirable) 8 hr. TWA.
ACGIH TLV: 10 mg/m^3 (Inhalable) 8 hr. TWA; 3 mg/m^3 (respirable) 8 hr. TWA

Components referred to herein may be regulated by specific Canadian provincial legislation. Please refer to exposure limits legislated for the province in which the substance will be used.

straight-chain compound, and eventually hydrolyzes to orthophosphate. Pyrophosphates hydrolyze directly to orthophosphate.

The influence of chemical characteristics of the various phosphates on their interactions with food constituents will be discussed in subsequent sections.

Toxicology of the Food Phosphates

Many investigators have published the results of their studies on the toxicity of phosphates that have been added to foods during processing. Phosphates, in common with all inorganic salts, are toxic to any organism ingesting excess quantities of the salts. Excess ingestion of any inorganic salt may upset mineral balance in the body, adversely affect the osmotic pressure of body fluids, and prevent absorption or utilization of necessary mineral nutrients.

A brief but excellent review and discussion of the toxicology of the food phosphates has been published in the report of the seventh meeting of the FAO/WHO Expert Committee on Food Additives held in 1963.[37] The literature review was published in support of the committee's recommendations for acceptable daily intakes of phosphates in human diets.

Acute Toxicity

A summary of the data found in the literature describing the acute toxicity levels of phosphates is found in Table 6.[37-44] The table contains the published LD_{50} and lethal-dose quantities for ortho- and polyphosphates, as well as similar data for sodium chloride when administered orally in the diet and by intraperitoneal or intravenous injection.

TABLE 6
Acute Toxicity Levels of Phosphates in Animals

Abbreviations:
IP—intraperitoneal
IV—intravenous
O—oral; in diet, stomach tube, etc.
SC—subcutaneous

Phosphate	*Animal*	*Route*	*LD_{50}, mg/kg body weight*	*Approx Lethal Dose, mg/kg body weight*	*Reference*
H_3PO_4	Rabbit	IV		1 010	54
NaH_2PO_4	Mouse	O		>100	55
NaH_2PO_4	Guinea pig	O		$>2\,000$	56
NaH_2PO_4	Rat	IP		>36	57
Na_2HPO_4	Rabbit	IV		>985, $\leq 1\,075$	56

INGESTION: Not toxic if swallowed based on toxicity studies. No significant adverse health effects are expected to develop if only small amounts (less than a mouthful) are swallowed.

Refer to Section 11 for toxicological information.

4. FIRST AID MEASURES

EYES:
Immediate first aid is not likely to be required. However, this material can be removed with water. Remove material from eyes.

SKIN:
Immediate first aid is not likely to be required. However, this material can be removed with water. Remove material from skin and clothing. Wash heavily contaminated clothing before reuse.

INGESTION:
Immediate first aid is not likely to be required. A physician or Poison Control Center can be contacted for advice.

INHALATION:
Immediate first aid is not likely to be required. However, if symptoms occur, remove to fresh air.

5. FIRE FIGHTING MEASURES

EXTINGUISHING MEDIA:
Not applicable

HAZARDOUS COMBUSTION PRODUCTS:
Not applicable

FIRE / EXPLOSION HAZARDS:
None known

FLASH POINT:
Non-combustible

6. ACCIDENTAL RELEASE MEASURES

RELEASE NOTES:
In case of spill; sweep, scoop or vacuum and remove. Flush residual spill area with water.

Refer to Section 13 for disposal information and Sections 14 & 15 for reportable quantity information.

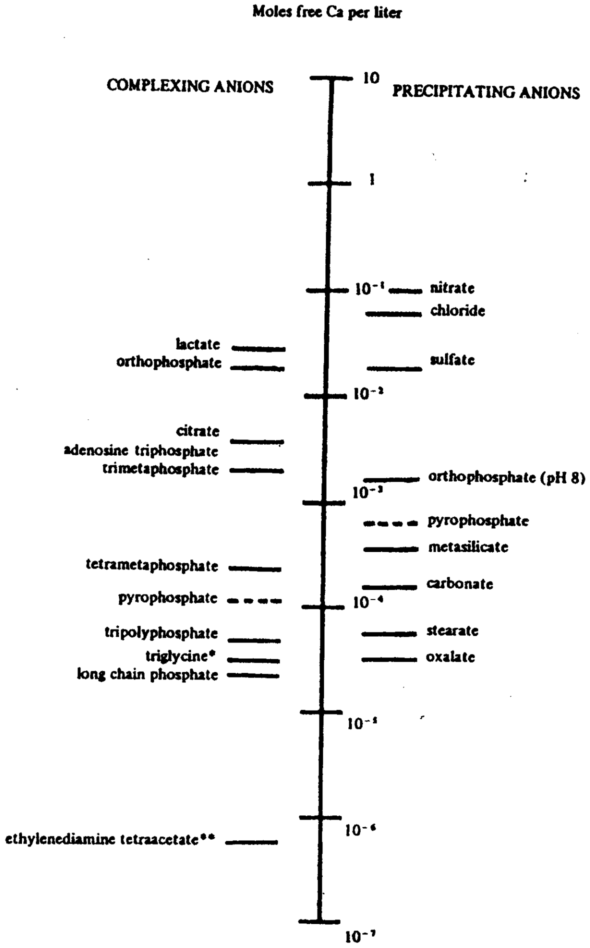


Fig. 1. Comparison of complexing agents with precipitating agents for calcium. The free calcium for the complexing agent is computed for the dissociation of a 0.01 mol solution of the 1:1 calcium complex. (Source: Van Wazer, J. R., and Callis, C. F., 1958, *Chem. Rev.* *58*:1011; with permission.)

*Triglycine is also called ammonia triacetate or Trilon A.
** A well known trade name for ethylenediamine tetraacetate (EDTA) is Versene®.

The stability of the phosphate anion in any food application is an important consideration. A number of studies of phosphate stability have been reported in the literature.[48,51-53] The pH and temperature of the system, the presence of phosphatase enzymes, colloidal gels, and complexing cations, and the chain lengths of the phosphates all affect their rate of hydrolysis. It is desirable to have hydrolysis of polyphosphates in certain applications, and it is undesirable in others. Therefore, conditions often must be adjusted to obtain the optimum effect.

The by-products of hydrolysis may also be important. Bell[53] reported that STP hydrolyzes to 1 mol each of ortho- and pyrophosphate. SHMP, however, hydrolyzes in such a way that one portion of the molecule forms the cyclic trimetaphosphate, and the other portion hydrolyzes directly to orthophosphate. Cyclic trimetaphosphate first hydrolyzes to tripolyphosphate, the

MATERIAL SAFETY DATA SHEET

Sodium Hexametaphosphate

Received by OMRI
APR 27 2001

ASTARIS

Page: 1 of 7
MSDS Ref. No: AST10053
Date Approved: 07/11/2000
Version: US/Canada
Revision No: New MSDS

---

1. CHEMICAL PRODUCT AND COMPANY IDENTIFICATION

PRODUCT NAME: Sodium Hexametaphosphate
MOLECULAR FORMULA: $Na_2OP_2O_5$
SYNONYM(s): SHMP; glassy Sodium Phosphate; Sodium Polyphosphates, glassy; Metaphosphoric Acid, Sodium Salt; Sodium Acid Metaphosphate; Graham's Salt
GENERAL USE: Food ingredient, cleaning compound.

MANUFACTURER
ASTARIS LLC
622 Emerson Road - Suite 500
St. Louis, MO 63141
General Information: (800) 244-6169

Emergency Telephone Numbers:
CHEMTREC (800) 424-9300

Emergency Phone (613) 996-6666
In Canada, call CANUTEC

---

2. COMPOSITION / INFORMATION ON INGREDIENTS

Chemical Name	CAS #	Wt.%
Sodium Polyphosphate, Glassy	68915-31-1	100

---

3. HAZARDS IDENTIFICATION

EMERGENCY OVERVIEW
IMMEDIATE CONCERNS:
Appearance and Odor: White powder, granules, or glass plates with no odor

WARNING STATEMENTS:

NO SIGNIFICANT HAZARDS ASSOCIATED WITH THIS MATERIAL.

POTENTIAL HEALTH EFFECTS:
Likely Routes of Exposure: Skin contact and inhalation

EYE CONTACT: No more than slightly irritating based on toxicity studies. The dry material may cause foreign body irritation in some individuals.

SKIN CONTACT: No more than slightly toxic or slightly irritating based on toxicity studies. Prolonged contact with the dry material may cause drying or chapping of the skin.

INHALATION: Inhalation of dust may cause coughing and sneezing.

length increased. Batra also found a direct relationship between the ionization properties of the various phosphates and their ability to form soluble complexes with alkali and alkaline-earth metal ions. The ability to form soluble complexes increased as the degree of dissociation of the phosphate compound decreased; thus, it was directly proportional to increasing chain length.

The ability of the phosphates to complex metal ions has been studied by Van Wazer and Campanella[46] and Van Wazer and Callis.[47] These authors have found that long-chain polyphosphates are strong complexing agents for the alkaline-earth and heavy-metal ions, while the ring phosphates form weaker complexes; orthophosphates form complexes only at very low concentrations, and they form precipitates at higher concentrations. Van Wazer and Callis[47] reported that the phosphate tetrahedra are geometrically arranged in such a way that oxygen atoms from each of three neighboring phosphate groups can be in close proximity with the metal ion being complexed by a polyphosphate molecule. The complexes are thought to involve both ionic and covalent bonds between the sequestrant anion and the complexed cation.[30]

The formation of a soluble complex is believed to be the result of the competition for the metal ion between a sequestrant anion and a precipitating anion in the same solution. As a result the formation of a soluble cation–anion complex prevents precipitation of a metal cation. For example, SHMP will solubilize precipitated calcium oxalate. Very small quantities of SHMP will also remove the calcium essential to the opacity, stability, and structure of the casein–calcium–phosphate complex in milk that results in a light-yellow, transparent serum. These characteristics have led Thilo[48] to describe the calcium-complexing ability of polyphosphates as ion-exchange reactions. The polyphosphate anion can bind calcium more firmly than sodium; therefore, sodium polyphosphates exchange their sodium ions for calcium ions when they are present. Figure 1 compares the ability of various types of anions to complex or precipitate calcium. Any complexing agent that appears below a precipitating agent on the scale will completely dissolve the calcium precipitate. The chart also allows one to appreciate the relative complexing ability of the various chain lengths of the polyphosphates. Irani *et al.*[49,50] studied the influence of temperature and pH on the ability of the polyphosphates to sequester calcium, magnesium, and iron; they also studied the influence of the chain length of the polyphosphates on their sequestering ability under any of these conditions. Both of these are valuable studies for anyone with further interest in the subject.

The ability of the polyphosphates to influence water binding was studied by Kutscher,[51] who believed it was caused by the phosphate reactions as highly charged anions. This leads to very strong hydration and will be found to be important in the later discussion of the interactions between polyphosphates and proteins, such as milk and meat proteins.

The highly charged anionic nature of the polyphosphates and their ability to interact as polyelectrolytes are also important in explaining their interactions with long-chain polyelectrolytes normally found in foods such as gums, pectins, and protein. These characteristics cause the polyelectrolytes to be attracted to and to orient themselves along the charged sites of the food polyelectrolytes; thus, they form stabilizing complexes with these organic molecules, which are useful in food processing.

6

IMDG Code: See US DOT

IATA/ICAO: See US DOT

* Applies only to packages containing an RQ quantity, and for shipments by water within the US Coastal Waterway.

15. REGULATORY INFORMATION

TSCA Inventory:
Listed as phosphoric acid, disodium salt

SARA Hazard Notification:
Hazard Categories Under Title III Rules (40 CFR 370): not applicable
Section 302 Extremely Hazardous Substances: not applicable
Section 313 Toxic Chemical(s): not applicable

CERCLA Reportable Quantity: 5,000 lb. RQ of sodium phosphate, dibasic

Release of more than 5,000 lbs. of this product into the environment, must be reported to the National Response Center (800-424-8802 or 202-426-2675).

Refer to Section 11 for OSHA Hazardous Chemical(s) and Section 13 for RCRA classification.

16. OTHER INFORMATION

Reason for revision: Routine review and conversion to the 16 section format. Also added new name and logo. Supersedes MSDS dated 2/03/92.

This material is certified to ANSI/NSF Standard 60 by NSF® International for use in potable water systems.

Solutia™ is a trademark of Solutia Inc.
Responsible Care® is a registered trademark of the Chemical Manufacturers Association

Dspa.997

The Cyclic Metaphosphates

There are two cyclic sodium polyphosphates, correctly termed metaphosphates. They are pure, crystalline compounds (not mixtures) that are prepared under very specific conditions for the thermal dehydration of orthophosphates. The cyclic metaphosphoric acid is known, but it is not commercially available.

Sodium Trimetaphosphate Sodium trimetaphosphate is a soluble, crystalline, cyclic polyphosphate. It is available as an anhydrous salt and as the hexahydrate. Its major food use is in preparation of cross-linked starch phosphates, described later in this chapter.

Sodium Tetrametaphosphate Sodium tetrametaphosphate is also a soluble, crystalline, cyclic polyphosphate. There are a number of proposed food applications for the compound, but no application has thus far been thought important enough to be approved for use in foods by the U.S. Food and Drug Administration.

Some General Chemical Characteristics of Phosphates

The phosphates discussed in the previous section have many common chemical characteristics. These chemical characteristics are directly related to phosphate structures. In excellent reviews of the structure of phosphates, Corbridge[44] and Van Wazer[29] described the phosphate anion as a tetrahedron in which the phosphorus atom is surrounded by 4 oxygen atoms. This tetrahedral structure allows the polymerization and formation of substances quite similar to those of polymerized carbon compounds. Many of the reactions of the phosphates with components of food systems are explained by the tetrahedral structure of the phosphate anions. For example, this structure allows the long-chain polyphosphates to coil in the shape of a helix and thus to undergo polyelectrolyte interactions with proteins and gums in food systems. This structure also explains the ability of longer-chain polyphosphates to complex or sequester the metallic ions in food systems.

All of the phosphates exhibit the properties of highly charged anions,[30] which is readily demonstrated by the titration curves of their acids. Tri- and tetrametaphosphoric acids, which have titration curves similar to those of hydrochloric acid, are very strong acids. The titration curve for H_3PO_4 has 3 inflection points, a strongly acidic point near pH 4.5, a weaker inflection point near pH 7, and a very weak inflection point near pH 10. Similar inflection points are found when pyro- and tripolyphosphoric acids are titrated. However, longer-chain polyphosphoric acids show only two inflection points, one near pH 4.5 and one near pH 10. The first inflection point demonstrates much stronger acid properties than the second one, and the second inflection point becomes weaker as the chain length increases. As a result of these properties, the polyphosphates react as typical polyelectrolytes, and the polyelectrolyte properties increase as the chain length increases.

Batra[45] found that the ionization properties of the various phosphates also explain some of their useful food applications. He found that sodium orthophosphates ionized completely, even at high concentrations, but that the condensed polyphosphates decreased in ionization properties as their chain

The following data have been classified using the criteria adopted by the European Economic Community (EEC) for aquatic organism toxicity. A legend summarizing the classification scheme appears below.

This product (in anhydrous and hydrated forms) has produced no genetic changes in standard tests using bacterial cells.

No algal toxicity data was available for this material.

Legend for Aquatic Organism Toxicity (Journal of the European Communities, Annex VII A, Section 5.2.1)

Values	Classifications
LC50 or EC50 < or = 1.0 mg/L	Very Toxic
LC50 or EC50 > 1.0 mg/L and < or = 10 mg/L	Toxic
LC50 or EC50 > 10 mg/L and < or = 100 mg/L	Harmful
LC50 or EC50 > 100 mg/L	Practically Nontoxic

No biodegradation data was available for this material.

13. DISPOSAL CONSIDERATIONS

This material when discarded is not a hazardous waste as that term is defined by the Resource, Conservation and Recovery Act (RCRA), 40 CFR 261. Dry material may be landfilled or recycled in accordance with local, state and federal regulations. Consult your attorney or appropriate regulatory officials for information on such disposal.

14. TRANSPORT INFORMATION

The data provided in this section is for information only. Please apply the appropriate regulations to properly classify your shipment for transportation.

US DOT Classification: (contains	Environmentally hazardous substance, solid, n.o.s. sodium phosphate, dibasic), 9, UN3077, III *
US DOT Label:	Class 9 *
US DOT Reportable Quantity: of sodium	Packages of 5,000 lbs or more contain a 5,000 lb. RQ phosphate, dibasic

TABLE 5
Molecular Composition of the Sodium Polyphosphates as Determined by Paper Chromatography[a]

	Analysis	*Percentage of Total P_2O_5 as*										
Weight per cent P_2O_5	Na_2O/P_2O_5 *R*	$\bar{n}$	*Ortho-*	*Pyro-*	*Tri-*	*Tetra-*	*Penta-*	*Hexa-*	*Hepta-*	*Octa-*	*Nona-*	*Higher*
53.383	2.000 00	2.0	0.00	100.0								
54.803	1.888 88	2.25	0.00	91.81	8.19							
55.994	1.800 00	2.5	0.00	72.24	27.76							
57.007	1.727 27	2.75	0.00	47.03	52.13	0.84						
57.881	1.666 67	3.0	0.00	24.32	48.55	20.41	5.11	1.61				
59.308	1.571 43	3.5	0.00	11.13	38.27	28.11	13.12	5.52	2.33	1.02	0.48	
60.426	1.500 00	4.0	0.00	6.65	28.25	27.43	16.87	9.41	5.70	2.74	1.77	1.16
61.324	1.444 44	4.5	0.00	4.74	22.17	23.99	17.30	11.52	8.24	4.60	3.15	4.29
62.063	1.400 00	5.0	0.00	3.24	16.24	20.16	16.45	12.68	9.43	6.71	4.39	10.69
62.681	1.363 64	5.5	0.00	2.65	13.94	19.14	17.92	14.12	8.92	6.40	4.76	12.15
63.205	1.333 33	6.0	0.00	1.88	10.09	14.89	13.46	11.28	9.61	9.26	6.94	22.58
63.655	1.307 69	6.5	0.00	1.81	8.71	13.07	12.32	11.70	11.12	9.11	6.32	25.84
64.389	1.266 67	7.5	0.00	1.24	6.38	9.44	9.09	10.74	9.91	8.53	7.74	36.92
65.204	1.222 22	9.0	0.00	0.95	4.35	7.63	6.52	9.74	8.00	7.49	6.13	49.19

[a] Potassium and other alkali metal polyphosphates have very similar molecular compositions.

Sources: Data from Westman, A. E. R., and Gartaganis, P. A., 1957, *J. Amer. Ceram. Soc. 40*:293; and Van Wazer, J. P., *Phosphorus and Its Compounds*, Copyright © 1958, Interscience Publishers, a division of John Wiley & Sons, Inc. Reprinted by permission.

Odor:	none	
pH:	9.0 (as a 1% solution)	
Solubility in Water:	(g./100 g. H2O):	1.7 @ 0 degrees C 11.5 @ 25 degrees C 51.7 @ 40 degrees C 78.8 @ 60 degrees C 102.4 @ 100 degrees C

NOTE: These physical data are typical values based on material tested but may vary from sample to sample. Typical values should not be construed as a guaranteed analysis of any specific lot or as specifications for the product.

10. STABILITY AND REACTIVITY

STABILITY: Product is stable under normal conditions of storage and handling. Store in a cool, dry place to maintain product performance.

MATERIALS TO AVOID: none known

HAZARDOUS DECOMPOSITION PRODUCTS: none

HAZARDOUS POLYMERIZATION: will not occur

11. TOXICOLOGICAL INFORMATION

The dry powder or granules may cause foreign body irritation in some individuals. Prolonged contact with the dry powder may cause drying or chapping of the skin. Due to the high alkalinity of this product, prolonged contact with the eyes or skin may cause slight irritation. Inhalation of dust has been reported to produce a mild drying effect on the respiratory tract membranes of exposed workers. Excessive inhalation of dust may be annoying and can mechanically impede respiration.

Sodium phosphates have been used as therapeutic agents in medicinal preparations for their laxative effects. These phosphate salts are incompletely absorbed from the intestinal tract. Due to their osmotic activity, they draw water into the intestine and produce purging.

Data from Solutia single-dose (acute) animal studies with this material are given below:

Oral - rat LD50: 5,950 mg/kg; practically nontoxic
Dermal - rabbit LD50: >7,940 mg/kg; practically nontoxic
Eye Irritation - rabbit: 4.2/110.0; slightly irritating
Skin Irritation - rabbit: 0.0/8.0 (24-hr. exp.); nonirritating
DOT skin corrosion - rabbit (4-hr. exp.): not corrosive

This product (in anhydrous and hydrated forms) has produced no genetic changes in standard tests using bacterial cells.

12. ECOLOGICAL INFORMATION

sodium polyphosphates. Literature references, often concerning the same compound, use several names interchangeably for these soluble, amorphous, or glassy sodium polyphosphates, as follows:

Graham's salt
glassy sodium phosphate
sodium hexametaphosphate
sodium metaphosphate
sodium polyphosphate

Two commercial names also are used frequently in the food-science literature for these compounds: Calgon® (those having $\bar{n}$ = 10-20) and Quadrafos® (usually refers to those with $\bar{n}$ = 4-8). As shown in Table 5, the chain-length distribution of sodium polyphosphates with $\bar{n}$ of 2.0-9.0 indicates that all are composed of mixtures of polyphosphates.[41, 42]

The food-science literature frequently refers to "reagent-grade polyphosphates," such as sodium hexametaphosphate sold by some of the chemical-supply houses. The analysis by paper chromatography[43] of several sodium hexametaphosphate preparations labeled "reagent grade" has demonstrated that these are typical commercial mixtures of varying chain lengths having the equilibrium composition shown in Table 5 for the P_2O_5 content. It is, therefore, incorrect to designate them as chemically pure or reagent-grade chemicals, nor is it correct to assign specific molecular weights to them. Any investigator wishing to use these compounds and wishing to know their specific compositions should obtain such from one of the manufacturers; he also should request a complete analysis of the specific preparation sent to him.

The food-science literature frequently mentions sodium tetrapolyphosphate, $Na_6P_4O_{13}$, also known as Quadrafos®. The preparation described usually contains relatively short-chain sodium polyphosphates having a $\bar{n}$ within the range of 4-8; it would be expected to have a P_2O_5 content of 57-60%, as shown in Table 5.

Sodium hexametaphosphate (SHMP), whose formula is often shown as $(NaPO_4)_6$ is frequently mentioned as a food ingredient in the food-science literature. This name is also applied to any soluble, glassy sodium polyphosphate. The common commercial sodium polyphosphate available today, designated as sodium hexametaphosphate, has an average chain length ranging between 10-15 phosphate units. Careful control of manufacturing processes can consistently produce a product with $\bar{n}$ of 11-13. Freshly prepared SHMP compounds can be shown by paper chromatography to contain few if any polyphosphates with chain lengths below 4 phosphate units. However, like all polyphosphate glasses, they gradually "vitrify," or hydrolyze, with time.[28-30] Increasing quantities of ortho-, pyro-, and tripolyphosphates appear as the product vitrifies.[38]

There are also some food applications for another type of sodium polyphosphate usually known as insoluble metaphosphate (IMP), or Maddrell's salt. This salt is so insoluble in water that it is often used as a dental polishing agent, but it can be dissolved with difficulty in solutions of ammonium and alkali-metal salts other than the sodium ion.

There also is a sodium Kurrol's salt, which is equivalent to its amorphous, fibrous potassium counterpart. It dissolves in solutions of ammonium or alkali-metal salts other than sodium and is infrequently mentioned in food applications.

quantity information.

7. HANDLING AND STORAGE

Handling:

HANDLE IN ACCORDANCE WITH GOOD INDUSTRIAL HYGIENE AND SAFETY PRACTICES. THESE PRACTICES INCLUDE AVOIDING UNNECESSARY EXPOSURE AND REMOVAL OF MATERIAL FROM EYES, SKIN, AND CLOTHING.

STORAGE: Product is slightly hygroscopic and should be stored in a dry area to prevent moisture pickup and caking.

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

EYE PROTECTION: This product does not cause significant eye irritation or eye toxicity requiring special protection. Use good industrial practice to avoid eye contact.

SKIN PROTECTION: Although this product does not present a significant skin concern, minimize skin contamination by following good industrial practice. Wearing protective gloves is recommended. Wash hands and contaminated skin thoroughly after handling.

RESPIRATORY PROTECTION: Avoid breathing dust. Use NIOSH/MSHA approved respiratory protection equipment when airborne exposure is excessive. Consult the respirator manufacturer to determine appropriate type equipment for a given application. Observe respirator use limitations specified by NIOSH/MSHA or the manufacturer. Respiratory protection programs must comply with 29 C.F.R. 1910.134.

VENTILATION: Provide natural or mechanical ventilation to control exposure levels below airborne exposure limits (see below). The use of local mechanical exhaust ventilation is preferred at sources of air contamination such as open process equipment.

AIRBORNE EXPOSURE LIMITS:

OSHA and ACGIH have not established specific exposure limits for this material. However, OSHA and ACGIH have established limits for particulates not otherwise regulated (PNOR) and particulates not otherwise classified (PNOC) which are the least stringent exposure limits applicable to dusts.

OSHA PEL	ACGIH TLV
15 mg/m3 (total dust) 8-hr. TWA	10 mg/m3 (inhalable) 8-hr. TWA
5 mg/m3 (respirable) 8-hr. TWA	3 mg/m3 (respirable) 8-hr. TWA

9. PHYSICAL AND CHEMICAL PROPERTIES

Chemical Formula:	Na_2HPO_4
Appearance:	white granules or powder

These compounds exist as glassy, amorphous, or fibrous materials. Because they are mixtures of a number of polyphosphates of varying chain lengths, they can never be crystallized and, therefore, are frequently called glassy or amorphous phosphates.

Polyphosphoric Acids Table 3 shows that the concentration of polyphosphoric acids with four or more phosphate units increases as the P_2O_5 content rises above 75.5%. Commercial preparations containing 82-85% P_2O_5 are available and are usually designated as polyphosphoric acids. All are equilibrium concentrations equivalent to those shown for the P_2O_5 content in Table 3. Preparations of relatively pure polyphosphoric acids having between four and nine phosphate units have been made by highly involved methods, but these are only made in sufficient quantities for laboratory studies.[30,32-34]

Although the equilibrium distribution of polyphosphoric acids in any commercial preparation can be determined by analyzing its P_2O_5 content and by referring to a table similar to Table 3, it is also common to refer to the average chain length of the preparation designated by the symbol $\bar{n}$. The average chain length is obtained by a titration procedure developed by Van Wazer[40] according to the following equation:

$$\bar{n} = \frac{2\text{ (ml of base to titrate to end point near pH 4.2)}}{\text{ml of base to titrate from pH 4.2 to end point near pH 9}}$$

The polyphosphoric acids will form rigid glasses but will never crystallize when they are prepared under laboratory conditions in moisture-free, sealed tubes. The commercial polyphosphoric acids are clear, colorless, viscous, hygroscopic liquids. Although they are highly soluble in water, they quickly hydrolyze upon dilution to lower-molecular-weight, shorter-chain-length phosphoric acids according to the equilibrium mixtures shown in Table 3. If diluted with the necessary amount of water, only orthophosphoric acid will remain.

Potassium Polyphosphates The heating of MKP above 150°C causes the MKP to lose water and polymerize to form potassium polyphosphate compositions of varying average chain lengths. The $\bar{n}$ of any particular preparation depends on the heat treatment and the degree of dehydration.[41,42] Since these compounds were first prepared by Kurrol just before the turn of the century, they are commonly referred to as Kurrol's salts.[30,32]

Potassium polyphosphate forms slender, needle-like crystals that overlap each other to form a fibrous structure much like asbestos. The literature often refers to them as potassium metaphosphates or potassium polymetaphosphates. They are nearly insoluble in water by themselves but readily dissolve to form viscous solutions in the presence of a soluble ammonium or alkali metal salt other than one having the potassium cation. As average chain lengths for these salts cannot be determined by the same method used for polyphosphoric acids,[40] they, therefore, are distinguished from each other by average molecular weights. Average molecular weights have been shown to range between 50 000 and 3 million, indicating that the chain lengths range from 400 to 20 000 phosphorus atoms per chain.[32]

Sodium Polyphosphates The sodium polyphosphates were discovered by Graham in the early 1800's; he named them metaphosphates because he thought they were cyclic polyphosphates. It has been impossible since then to obtain complete agreement to change this term to the more preferable designation of

POTENTIAL HEALTH EFFECTS

Likely Routes of Exposure: skin contact and inhalation

EYE CONTACT: No more than slightly irritating based on toxicity studies. The dry powder may cause foreign body irritation in some individuals.

SKIN CONTACT: No more than slightly toxic or slightly irritating based on toxicity studies. Prolonged contact with the dry powder may cause drying or chapping of the skin.

INHALATION: Inhalation of the dust may cause coughing and sneezing.

INGESTION: Is not toxic if swallowed based on toxicity studies. No significant adverse health effects are expected to develop if only small amounts (less than a mouthful) are swallowed. Swallowing large amounts may cause abdominal discomfort and diarrhea.

Refer to Section 11 for toxicological information.

4. FIRST AID MEASURES

IF IN EYES OR ON SKIN, immediate first aid is not likely to be required. However, this material can be removed with water. Wash heavily contaminated clothing before reuse.

IF INHALED, immediate first aid is not likely to be required. However, if symptoms occur, remove to fresh air. Remove material from eyes, skin and clothing.

IF SWALLOWED, immediate first aid is not likely to be required. A physician or Poison Control Center can be contacted for advice. Wash heavily contaminated clothing before reuse.

5. FIRE FIGHTING MEASURES

FLASH POINT: not combustible

HAZARDOUS PRODUCTS OF COMBUSTION: not applicable

EXTINGUISHING MEDIA: not applicable

UNUSUAL FIRE AND EXPLOSION HAZARDS: none

6. ACCIDENTAL RELEASE MEASURES

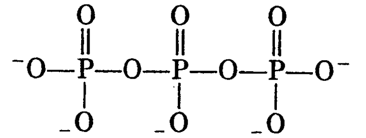
In case of spill, sweep, scoop or vacuum all material, contaminated soil and other contaminated material and place in clean, dry containers for removal. If possible, complete cleanup on a dry basis. After all practical dry cleanup has been done, residual contamination can be flushed with plenty of water.

Refer to Section 13 for disposal information and Sections 14 and 15 for reportable

A complex sodium iron (or ferric) pyrophosphate (SIP), $Na_8Fe_4(P_2O_7)_5 \cdot xH_2O$ (formula derived from the molecular ratios obtained by chemical analysis), also is used to some extent as an iron-enrichment compound in food formulations. Although it is insoluble in water, it is soluble in dilute hydrochloric-acid solutions of concentrations equivalent to those in the stomach.

The Tripolyphosphates

The addition of another orthophosphate unit to the pyrophosphate anion forms the next higher straight-chain polymer known as *tripolyphosphate*, often called triphosphate in European literature. The structure is as follows:



$$^{-}O-\underset{\underset{_{-}O}{|}}{\overset{\overset{O}{\|}}{P}}-O-\underset{\underset{_{-}O}{|}}{\overset{\overset{O}{\|}}{P}}-O-\underset{\underset{_{-}O}{|}}{\overset{\overset{O}{\|}}{P}}-O^{-}$$

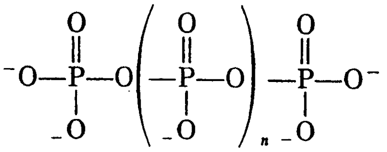
Tripolyphosphoric Acid Strong polyphosphoric acids containing 74% or more P_2O_5, as shown in Table 3, contain varying amounts of *tripolyphosphoric acid.* Although this acid cannot be crystallized, it can be prepared from its salts if special ion-exchange techniques are used. It has a very short life, as it quickly begins to revert to the equilibrium mixture of ortho- and polyphosphoric acids to be expected from the P_2O_5 concentration of the solution involved.[30,32] If the P_2O_5 content falls below 74%, any tripolyphosphoric acid in the solution hydrolyzes to a mixture of ortho- and pyrophosphoric acids.

Potassium Tripolyphosphate Only one of the theoretically possible potassium salts of tripolyphosphoric acid is utilized in food applications in which its cost can be justified. This salt is pentapotassium pyrophosphate (KTP), $K_5P_3O_{10}$. It is completely interchangeable with its sodium equivalent and is only used in products where less astringent flavor is desirable.

Sodium Tripolyphosphate As with potassium tripolyphosphate, only the fully neutralized salt sodium tripolyphosphate (STP), $Na_5P_3O_{10}$, is used in foods. It is less soluble and produces more astringent flavors than its potassium counterpart. However, since it is usually necessary to use low quantities of the salt, these characteristics are seldom a problem in food applications. Variations in the method of manufacture can result in either of two crystalline forms, known as Form I and Form II.[30,32] Form II is preferred in food applications, as it is much easier to dissolve than Form I, which has a great tendency to cake or to form lumps if the water to which it is added is not properly agitated.

The Longer, Straight-chain Polyphosphates

It is possible to produce a great variety of condensed phosphates having more than three phosphorus atoms linked to each other by shared oxygens, as shown in the following general formula for the polyphosphate anion:



$$^{-}O-\underset{\underset{_{-}O}{|}}{\overset{\overset{O}{\|}}{P}}-O\left(-\underset{\underset{_{-}O}{|}}{\overset{\overset{O}{\|}}{P}}-O\right)_{n}-\underset{\underset{_{-}O}{|}}{\overset{\overset{O}{\|}}{P}}-O^{-}$$

15. REGULATORY INFORMATION

A1 - SUSPECTED HUMAN...:	NOT LISTED
IARC GROUP 1 OR 2........:	NOT LISTED
LABEL LANGUAGE (US/CANADA)	
HEALTH................:	NOT HAZARDOUS BY OSHA NOR CANADIAN WHMIS DEFINITION.
PHYSICAL..............:	NOT APPLICABLE
HANDLING AND STORAGE...:	STORE CLEAN DRY AREA. FOR FOOD APPLICATIONS STORE AWAY FROM POSSIBLE CONTAMINATION.
FIRST AID.............:	IN CASE OF EYE OR SKIN CONTACT , FLUSH WITH PLENTY OF WATER. IF IRRITATION PERSISTS, OBTAIN MEDICAL ASSISTANCE.
STATE REGULATIONS........:	CONTAINS CHEMICALS FROM CALIFORNIA "PROP 65" LISTS OF CARCINOGENS AND REPRODUCTIVE TOXINS: PPM MAXIMUM ARSENIC 3, CADMIUM 2 AND LEAD 0.7.

16. OTHER INFORMATION

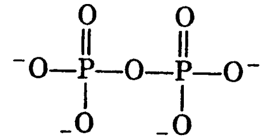
PRODUCT USES.............:	BOILER WATER CONDITIONER, CATTLE FEED SUPPLEMENT PIGMENTS, DETERGENTS, TEXTILE WEIGHTING AND DYEING, BUFFER, EMULSIFIER, PRECIPITANT FOR CALCIUM. ALSO IN EVAPORATED MILK, PROCESS CHEESE, PRECOOKED MEATS, PHARMACEUTICALS, AND LAXATIVES. MAY BE USED TO TREAT DRINKING WATER UP TO 14.3 MG/L.
NFPA 704	
HEALTH..............:	0
FLAMMABILITY........:	0
REACTIVITY..........:	0
SPECIAL HAZARD......:	NONE

(DEGREE OF HAZARD
0 = NO HAZARD
4 = SEVERE HAZARD)

THE CONTENTS AND FORMAT OF THIS MSDS ARE IN ACCORDANCE WITH OSHA HAZARD COMMUNICATION AND CANADA"S WORKPLACE HAZARDOUS MATERIAL INFORMATION SYSTEM (WHMIS)

The Pyrophosphates

The simplest of the condensed or polymeric phosphate anions is that of pyrophosphate, also called diphosphate in European literature. Its anion contains two phosphorus atoms linked through a shared oxygen, as follows:



$$^{-}O-\overset{\overset{O}{\|}}{\underset{\underset{-O}{|}}{P}}-O-\overset{\overset{O}{\|}}{\underset{\underset{-O}{|}}{P}}-O^{-}$$

Pyrophosphoric Acid Pyrophosphoric acid is the simplest of the polymeric phosphoric acids, and it is the only one that can be crystallized. As shown in Table 3, it begins to appear in phosphoric-acid compositions containing $>68.8\%$ P_2O_5. Either of two very pure forms of crystalline pyrophosphoric acid can be prepared by seeding a concentrated solution of phosphoric acid, cooled to about 10°C below its melting point, with crystals of the desired form. Both crystalline forms are extremely hygroscopic. If melted or dissolved in water, the pyrophosphoric acid immediately reverts to an equilibrium mixture of ortho- and polymeric phosphoric acids represented by the P_2O_5 content of the solution, as shown in Table 3.[30,32] The difficulty of maintaining pyrophosphoric acid in its pure crystalline form has prevented any significant application of the acid in foods.

Calcium Pyrophosphates A few references in the food-science literature and several patents have proposed calcium acid pyrophosphate, $CaH_2P_2O_7$, as a leavening acid. However, no commercial food applications for this salt are known. The dibasic calcium pyrophosphate, $Ca_2P_2O_7$, is not applicable in food, although it is used as an insoluble crystalline polishing agent in some toothpastes.

Ferric Pyrophosphate Another compound sometimes used as an iron-enrichment supplement is ferric pyrophosphate, $Fe_4(P_2O_7)_3$. Because it is highly insoluble in water, it is often used in foods containing fat, which might become rancid if it comes into contact with more soluble iron-enrichment compounds. Ferric pyrophosphate is soluble in dilute hydrochloric acid, such as exists in the stomach.

Potassium Pyrophosphate Only limited quantities of the anhydrous tetrapotassium pyrophosphate (TKPP) are used in foods as this salt is completely interchangeable with the less costly sodium salt.

Sodium Pyrophosphates Although there are four theoretically possible sodium salts of pyrophosphoric acid, only two are commonly available and used in foods. One is the acidic sodium acid pyrophosphate (SAPP), $Na_2H_2P_2O_7$, a common food acidulant. Variations in manufacturing processes and in the use of certain additives allow the formation of SAPP crystals, which have varying rates of solubility. These compounds, which are most useful in leavening reactions, will be discussed fully in the section on such applications. The second salt used in food processing is the so-called "neutral" salt, in which all of the hydrogens of pyrophosphoric acid have been replaced with sodium to form tetrasodium pyrophosphate (TSPP), $Na_4P_2O_7$. Two major characteristics of this salt are useful in food processing—its high alkalinity and its ability to complex or precipitate alkaline-earth, and heavy metal ions.

========================= 15. REGULATORY INFORMATION ====================

SKIN DESIGNATION.:	NOT APPLICABLE
ACGIH TLV-TWA..........:	NOT APPLICABLE
STEL.............:	NOT APPLICABLE
CEILING..........:	NOT APPLICABLE
SKIN DESIGNATION.:	NOT APPLICABLE
TARGET ORGAN EFFECTS.....:	NOT APPLICABLE
CARCINOGENIC POTENTIAL...:	DISODIUM PHOSPHATE
REGULATED BY OSHA......:	NO
LISTED ON NTP REPORT...:	NO
IARC GROUP 1, 2A, 2B...:	NO
U.S. EPA REQUIREMENTS	
RELEASE REPORTING	
CERCLA (40 CFR 302)	
LISTED SUBSTANCE(S)....:	NOT LISTED
RQ...............:	NOT APPLICABLE
CATEGORY.........:	NOT APPLICABLE
RCRA WASTE NO....:	NOT APPLICABLE
UNLISTED SUBSTANCE(S)..:	NOT APPLICABLE
RQ...............:	NOT APPLICABLE
CHARACTERISTIC...:	NOT APPLICABLE
RCRA WASTE NO....:	NOT APPLICABLE
SARA TITLE III SEC 313	
(40 CFR 372)...........:	NOT LISTED
LISTED TOXIC CHEMICAL..:	NOT LISTED
INVENTORY REPORTING	
SARA TITLE III SEC 311/312	
(40 CFR 370)	
SUBSTANCE(S)...........:	NOT LISTED
HAZARD CATEGORY........:	NOT APPLICABLE
PLANNING THRESHOLD.....:	NOT APPLICABLE
EMERGENCY PLANNING	
SARA TITLE III SEC 302-303	
(40 CFR 355)	
LISTED SUBSTANCE(S)....:	NOT APPLICABLE
RQ.....................:	NOT APPLICABLE
PLANNING THRESHOLD.....:	NOT APPLICABLE
U.S. TSCA STATUS.........:	LISTED IN INVENTORY
CANADA	
INGREDIENT DISCLOSURE LIST	
SUBSTANCE(S)...........:	NOT LISTED
CONTROLLED PRODUCT.......:	NO
HAZARD SYMBOLS...........:	NOT APPLICABLE
CLASS & DIVISION.......:	NOT APPLICABLE
PRODUCT IDENTIFICATION NO:	NOT APPLICABLE
DOMESTIC SUBSTANCE LIST..:	LISTED
CEPA PRIORITY LIST.......:	NOT LISTED
CARCINOGENICITY	
ACGIH APPENDIX A.......:	NO
A1 - CONFIRMED HUMAN...:	NOT LISTED

TABLE 4
Sodium Ortho- and Polyphosphates Used in Foods[a] (Continued)

Class	*Compound*	*Names*
Pyrophosphate	$Na_2H_2P_2O_7$	Disodium dihydrogen diphosphate[c] Disodium dihydrogen pyrophosphate Disodium diphosphate Disodium pyrophosphate Sodium acid pyrophosphate[d]
	[g]$Na_4P_2O_7$	Sodium pyrophosphate Tetrasodium diphosphate[c] Tetrasodium pyrophosphate[d]
Tripolyphosphate	$Na_5P_3C_{10}$	Pentasodium triphosphate[c] Sodium tripolyphosphate[d] Tripolyphosphate
Straight-chain polyphosphate	$(NaPO_3)_n$	Glassy sodium phosphate Insoluble sodium metaphosphate[h] Graham's salt Sodium hexametaphosphate[i] Sodium Kurrol's salt[h] Sodium metaphosphate[j] Sodium polyphosphate[k] Sodium tetraphosphate[l]
Cyclic polyphosphate	$(NaPO_3)_3$ [m]$(NaPO_3)_4$	Sodium trimetaphosphate Sodium tetrametaphosphate

[a] Information accumulated from references 28–30, 32, and 35–38.

[b] NaH_2PO_4 also occurs as a monohydrate, $NaH_2PO_4 \cdot H_2O$, and a dihydrate, $NaH_2PO_4 \cdot 2H_2O$.

[c] The name considered most correct.

[d] Common name for commercial product in the United States.

[e] Na_2HPO_4 also occurs as a dihydrate, $Na_2HPO_4 \cdot 2H_2O$, a heptahydrate, $Na_2HPO_4 \cdot 7H_2O$, and a dodecahydrate, $Na_2HPO_4 \cdot 12H_2O$.

[f] Na_3PO_4 also occurs as a monohydrate, $Na_3PO_4 \cdot H_2O$, and a dodecahydrate, $Na_3PO_4 \cdot 12H_2O$.

[g] $Na_4P_2O_7$ also occurs as a decahydrate, $Na_4P_2O_7 \cdot 10H_2O$.

[h] Common name for insoluble, long-chain sodium polyphosphates.

[i] Common name for soluble sodium polyphosphates with $n = 10$–15.

[j] Common name for soluble sodium polyphosphates with $n = 20$–100.

[k] Straight-chain sodium polyphosphates would most accurately be named with the average chain length or the Na_2O/P_2O_5 ratio added; e.g., sodium polyphosphate, $n = 10$–15, or sodium polyphosphate, $Na_2O/P_2O_5 = 1.1$.

[l] Common name for soluble sodium polyphosphates with $n = 4$–10.

[m] $(NaPO_3)_4$ also occurs as a quadrahydrate, $(NaPO_3)_4 \cdot 4H_2O$.

Some food applications have been reported for a double sodium phosphate salt known as *hemisodium orthophosphate.* Its formula is commonly shown as a complex of MSP and H_3PO_4, as shown in Table 2. It has, however, also been reported to be a double salt of MSP monohydrate and polyphosphoric acid, $(HPO_3)_n \cdot NaH_2PO_4 \cdot H_2O$.[39]

Three *sodium aluminum orthophosphates* (SALP's) have recently been approved as food ingredients. Two are acidic salts commonly used as leavening acids; their formulas are shown in Table 2. The third is an alkaline salt mostly used in cheese processing; its formula also is shown in Table 2. All three have the advantage of delayed release of acidity or alkalinity.

12. ECOLOGICAL INFORMATION

ENVIRONMENTAL FATE.......: INORGANIC PHOSPHATES IN CONTACT WITH THE SOIL, SUB-SURFACE OR SURFACE WATERS MAY BE TAKEN UP BY PLANTS AND UTILIZED AS ESSENTIAL NUTRIENTS. PHOSPHATES MAY ALSO FORM PRECIPITATES, USUALLY WITH CALCIUM OR MAGNESIUM. THE RESULTANT COMPOUNDS ARE INSOLUBLE IN WATER AND BECOME A PART OF THE SOIL OR SEDIMENT. THE TERM BIODEGRADABILITY, AS SUCH, IS NOT APPLICABLE TO INORGANIC COMPOUNDS.

ENVIRONMENTAL EFFECTS....: AQUATIC TOXICITY DATA
96 HR LC50 > 100 MG/L, NON-TOXIC (RAINBOW TROUT, INLAND SILVERSIDES AND MYSID SHRIMP) FMC STUDIES I89-1085, -1086 & -1087
48 HR EC50 > 100 MG/L, NON-TOXIC (DAPHNIA MAGNA) FMC STUDY I89-1088

13. DISPOSAL CONSIDERATIONS

WASTE DISPOSAL METHOD....: THIS PRODUCT DOES NOT PRESENT A DANGER OR HAZARD FOR DISPOSAL. EXCEPT FOR FOOD APPLICATIONS, SALVAGE AND RETURN TO CONTAINER; PROCESS OR RECYCLE FOR OTHER USES. MAY BE DISPOSED OF IN LANDFILLS ACCORDING TO APPLICABLE REGULATIONS.

14. TRANSPORT INFORMATION

DOT PROPER SHIPPING NAME.: NONE; NOT REGULATED
IATA.....................: NONE; NOT REGULATED
IMDG.....................: NONE; NOT REGULATED
DOT CLASSIFICATION.......: NOT REGULATED
DOT LABELS...............: NOT REQUIRED
DOT MARKING..............: NOT REQUIRED
DOT PLACARD..............: NOT REQUIRED
UN NUMBER................: NONE
HAZARDOUS SUBSTANCE/RQ...: NOT LISTED
49 STCC NUMBER...........: NONE
PRECAUTIONS TO BE TAKEN IN TRANSPORTATION..: NONE
OTHER SHIPPING INFORMATION..........: NONE

15. REGULATORY INFORMATION

OSHA
EXPOSURE LIMITS
SUBSTANCE(S)...........: DISODIUM PHOSPHATE
OSHA PEL-TWA..........: NOT APPLICABLE
STEL...........: NOT APPLICABLE
CEILING..........: NOT APPLICABLE

extent in foods, but only in applications where a characteristic of the less expensive sodium salts precludes their use. A characteristic of the sodium salts most often requiring replacement is their highly astringent flavor. The potassium phosphates are usually less astringent than their sodium counterparts. Chemical characteristics of the potassium phosphates are identical to those of the sodium phosphates, making them interchangeable wherever their cost is worthwhile. Three potassium phosphates are listed in Table 2; these are usually used as their anhydrous salts.

Sodium Orthophosphates Mono-, di-, and trisodium salts of H_3PO_4 are commonly used in food applications. They can exist as anhydrous as well as hydrated salts. There are ten different crystalline sodium orthophosphate salts commercially available for uses in food processing, as shown in Table 4. Any of them can be used, as long as one makes adjustments in formulation to account for the amount of water of hydration in the phosphate.

Monosodium orthophosphate (MSP) is mildly acidic, as shown in Table 2, and is most frequently used as a mild acidulant. *Disodium orthophosphate* (DSP) is mildly alkaline, while *trisodium phosphate* (TSP) is a rather strong alkaline compound. Both are used to increase the pH of a food product. In addition to being able to adjust pH, sodium orthophosphates are also commonly used to stabilize the optimum pH in a food system. Combinations of MSP and DSP usually are used in buffering systems.

TABLE 4
Sodium Ortho- and Polyphosphates Used in Foods[a]

Class	*Compound*	*Names*
Orthophosphate	[b]NaH_2PO_4	Acid sodium phosphate Monosodium dihydrogen monophosphate[c] Monosodium monophosphate Monosodium orthophosphate Monosodium phosphate[d] Primary sodium phosphate Sodium biphosphate Sodium dihydrogen phosphate Sodium phosphate monobasic
	[e]Na_2HPO_4	Disodium hydrogen phosphate Disodium monohydrogen monophosphate[c] Disodium monophosphate Disodium orthophosphate Disodium phosphate[d] Secondary sodium phosphate Sodium phosphate dibasic
	[f]Na_3PO_4	Sodium phosphate tribasic Trisodium monophosphate[c] Trisodium orthophosphate Trisodium phosphate[d]

10. STABILITY AND REACTIVITY

CONDITIONS TO AVOID......:	NOT APPLICABLE
MATERIALS TO AVOID.......:	NOT APPLICABLE
MAJOR CONTAMINANTS THAT..: CONTRIBUTE TO INSTABILITY	NONE
INCOMPATIBILITY..........:	NONE
HAZARDOUS DECOMPOSITION..: PRODUCTS	NONE
SENSITIVITY TO MECH......: IMPACT	NONE
SENSITIVITY TO STATIC....: DISCHARGE	NONE

11. TOXICOLOGICAL INFORMATION

EYE CONTACT..............:	MINIMALLY IRRITATING TO UNWASHED EYES; PRACTICALLY NONIRRITATING TO WASHED EYES (RABBIT). SOURCE: FMC REPORT I86-0931 DATE: 1986
SKIN CONTACT.............:	MILD IRRITANT SOURCE: RTECS DATE: 1981-82
SKIN ABSORPTION..........:	NO PUBLISHED DATA
INHALATION...............:	NO PUBLISHED DATA
INGESTION................:	NO SIGNIFICANT HAZARD EXPECTED SOURCE: FED. REG. 44 (244): 74845 DATE: 1979
ACUTE EFFECTS FROM.......: OVEREXPOSURE	NO HUMAN DATA AVAILABLE. ANIMAL EYE IRRITATION STUDIES NOTE THIS MATEIAL IS A MINIMAL IRRITANT TO UNWASHED EYES AND NON-IRRITATANT TO WASHED EYES; IT IS A MILD SKIN IRRITANT.
CHRONIC EFFECTS FROM.....: OVEREXPOSURE (EFFECTS CONSIDERED INCLUDE: SENSITIVITIES, CARCINOGENICITY, TERATOGENICITY, MUTAGENICITY, SYNERGISTIC PRODUCTS, AND ANY MEDICAL CONDITIONS GENERALLY RECOGNIZED AS BEING AGGRAVATED BY EXPOSURE.)	HUMAN INDUSTRIAL EXPERIENCE HAS SHOWN NO SIGNIFICANT INHALATION HAZARD OR SKIN IRRITATION WHEN GOOD PERSONAL HYGIENE PRACTICES ARE FOLLOWED.

Calcium Orthophosphates Several calcium salts of H_3PO_4 are commercially available, four of which are commonly used in food applications.

Anhydrous Monocalcium Phosphate Monobasic calcium orthophosphate exists as the anhydrous and monohydrate salts. Anhydrous monocalcium phosphate (AMCP)[a] is used in large quantities as a leavening acid; it is generally given the formula $Ca(H_2PO_4)_2$. It is highly soluble and very hygroscopic in its normal crystalline form, and it can be manufactured in this form. However, it would be useless in leavening applications because of its hygroscopicity. The crystals of AMCP, therefore, are coated with a mixture of potassium, aluminum, calcium, and magnesium metaphosphate during the manufacturing process. Upon contact with water, the coated AMCP does not immediately begin to dissolve as would its uncoated form. Coated AMCP, therefore, becomes a delayed-reaction leavening acid. More of the characteristics of this compound will be described in the section on leavening acids.

Monocalcium Phosphate Monohydrate The second form of the monobasic calcium salt of H_3PO_4 is monocalcium phosphate monohydrate ($MCP \cdot H_2O$); its chemical formula is usually shown as $Ca(H_2PO_4)_2 \cdot H_2O$. This compound is also a very soluble calcium salt of H_3PO_4. It is a common acidifying agent in many food applications, as will be discussed in subsequent sections.

Although AMCP and $MCP \cdot H_2O$ are soluble, neither completely dissolves in water. When $MCP \cdot H_2O$ is added to water, the following reaction is believed to occur:

$$Ca(H_2PO_4)_2 \cdot H_2O + xH_2O = CaHPO_4 + H_3PO_4 + (x + 1)H_2O$$

This is an example of a compound that disproportionates or is incongruently soluble, as the $MCP \cdot H_2O$ forms DCP and H_3PO_4. The DCP reacts in the same manner as a leavening acid, as described in the following paragraph.

Dicalcium Phosphate Dihydrate Dicalcium phosphate (DCP), $CaHPO_4$, also can be prepared in an anhydrous and a hydrated form. Only the dihydrate, $CaHPO_4 \cdot 2H_2O$, is used in food applications. As it is quite insoluble in water at temperatures below 140°F (60°C), it is commonly used when it is desirable to have acidic characteristics released only at temperatures of 140°F or above, as in a delayed leavening reaction until the dough or batter is baking in the oven. This, too, will be further discussed in a subsequent section under leavening reactions.

Tricalcium Phosphate The fully neutralized calcium salt of H_3PO_4, commonly called tricalcium phosphate (TCP), is very insoluble and has a variable composition. Its formula, based on x-ray patterns, is usually written as $Ca_5(OH)(PO_4)_3$, a hydroxyl apatite. It can be produced in a very fine powdered form, and it is often used as an adsorbent for liquids, as a drying agent, and as a flow agent for powdered foods.

Ferric Orthophosphate Small quantities of ferric orthophosphate are used as iron-enrichment compounds in food applications. This is a highly complex salt whose formula is usually written as $FePO_4 \cdot xH_2O$, derived from the molecular ratios determined by chemical analysis. Although it is insoluble in water, it is soluble to varying degrees in dilute hydrochloric-acid solutions, such as those in the stomach. The degree of solubility can be controlled by the method of manufacture.

Potassium Orthophosphates Potassium salts of H_3PO_4 are used to some

---

[a] The abbreviations in parenthesis following the name of a food phosphate will be used to designate that phosphate in most subsequent references to it in this chapter.

8. EXPOSURE CONTROLS/PERSONAL PROTECTION ******

PROTECTION FOR INHALATION, SKIN AND EYE MAY BE REQUIRED.

RECOMMENDED PERSONAL PROTECTIVE EQUIPMENT	
RESPIRATORY........:	USE APPROVED DUST RESPIRATORY PROTECTION IF RELEASE OF THE PRODUCT INTO THE WORK AREA IS EXPECTED.
EYES...............:	WEAR CHEMICAL GOGGLES, WHEN AIRBORNE DUST IS EXPECTED.
GLOVES.............:	USE IMPERVIOUS GLOVES WHEN CONTINUOUS CONTACT IS EXPECTED.
SPECIAL CLOTHING...: AND EQUIPMENT	USE LONG SLEEVE WORK SHIRT TO REDUCE EXPOSED SKIN AREA.
FOOTWEAR...........:	NO SPECIAL REQUIREMENT

9. PHYSICAL AND CHEMICAL PROPERTIES ==========

MELTING/FREEZING POINT...:	-H20,180*C
BOILING POINT............:	NOT APPLICABLE
VAPOR PRESSURE...........:	NON-VOLATILE
VAPOR DENSITY (AIR=1)....:	NON-VOLATILE
ROOM TEMPERATURE.........: APPEARANCE AND STATE	WHITE GRANULES OR POWDER
ODOR.....................:	NONE
SPECIFIC GRAVITY (H20=1).:	BULK DENSITY 0.8 G/ML
SOLUBILITY IN H20 % BY WT:	12 @ 25*C
% VOLATILES..............:	NON-VOLATILE
EVAPORATION RATE.........: (BUTYL ACETATE=1)	NON-VOLATILE
PH (AS IS)...............:	NOT APPLICABLE
PH (1% SOLUTION).........:	9
ODOR THRESHOLD...........:	NOT APPLICABLE
DENSITY (G/ML)...........:	CA 0.8
PARTITION COEFFICIENT....: N-OCTANOL/WATER	NOT AVAILABLE
FLASH POINT..............:	NON COMBUSTIBLE
AUTOIGNITION TEMPERATURE.:	NON COMBUSTIBLE
FLAMMABLE LIMITS UPPER..:	NOT APPLICABLE
(AIR) LOWER..:	NOT APPLICABLE
EXPLOSIVE PROPERTIES.....:	NONE
OXIDIZING PROPERTIES.....:	NONE
SOLUBILITY...............: - FAT SOLUBILITY (SOLVENT - OIL)	NOT AVAILABLE

10. STABILITY AND REACTIVITY ===============

STABILITY................:	PRODUCT IS STABLE.
HAZARDOUS POLYMERIZATION.:	WILL NOT OCCUR

(CONTINUED) PAGE 03

as the concentration of P_2O_5 continues to increase. This is shown in Table 3. It is important to remember that these polymers begin to appear at the higher concentrations of the anhydride. By diluting any of the higher concentrations to a lower concentration, the amount of polymers is decreased until one polymer finally has only the monomer present at approximately 66.8% P_2O_5. It is, therefore, the ratio of $H_2O:P_2O_5$ that determines the distribution of different lengths of polymers in the phosphoric acid; this composition will be constant, regardless of how the acid has been prepared or of its previous history.[30] Table 3 has been developed by Huhti and Gartaganis[34] through the analysis of various phosphoric acid compositions by a paper-chromatographic method developed in 1956. Similar tables, which are available from any supplier of phosphoric acid, are based on this work. Several salts of H_3PO_4 are useful in food applications. These uses are shown in the orthophosphate section of Table 2 and are reviewed by Ellinger,[28] Van Wazer,[29,30] and Bell.[29]

Ammonium Orthophosphates Two ammonium-orthophosphate salts are used in a few foods. These are monoammonium phosphate, $NH_4H_2PO_4$, and diammonium phosphate, $(NH_4)_2HPO_4$; both are commercially available as their anhydrous salts. Their most common food applications are as sources of nitrogen and phosphorus in yeast foods, although they may often replace the alkali metal phosphate salts in many of their applications.

TABLE 3
Composition of Polyphosphoric Acids

Composition, wt % P_2O_5	*Per cent of Total Phosphorus as*									
	Ortho-	*Pyro-*	*Tri-*	*Tetra-*	*Penta-*	*Hexa-*	*Hepta-*	*Octa-*	*Nona-*	*"Hypoly-"*
68.80	100.00	Trace								
69.81	97.85	2.15								
70.62	95.22	4.78								
72.04	89.91	10.09								
72.44	87.28	12.72								
73.43	76.69	23.31								
74.26	67.78	29.54	2.67							
75.14	55.81	38.88	5.31							
75.97	48.93	41.76	8.23	1.08						
77.12	39.86	46.70	11.16	2.28						
78.02	26.91	49.30	16.85	5.33	1.60					
78.52	24.43	48.29	18.27	6.75	2.26					
79.45	16.73	43.29	22.09	10.69	4.48	1.92	0.80			
80.51	13.46	35.00	24.98	13.99	6.58	3.14	2.84			
81.60	8.06	27.01	22.28	16.99	11.00	5.78	3.72	2.31	1.55	1.28
82.57	5.10	19.91	16.43	16.01	12.64	8.89	6.41	4.11	3.51	6.99
83.48	4.95	16.94	15.82	15.91	12.46	9.71	6.77	5.04	2.99	9.42
84.20	3.63	10.60	11.63	13.05	12.17	9.75	8.19	5.92	4.91	20.16
84.95	2.32	6.97	7.74	11.00	10.45	9.62	8.62	7.85	6.03	29.41
86.26	1.54	2.97	3.31	5.16	5.32	5.54	3.51	3.30	3.30	66.03

Note: These figures are given to two decimal places for further computation purposes, but the precision may not be better than 1% total phosphorus in some cases.

Sources: Bell, R. N., 1948, *Ind. Eng. Chem.* *40*:1464; and Huhti, A. L., and Gartaganis, P. A., 1956, *Can. J. Chem.* *34*:785.

4. FIRST AID MEASURES

	OR DISCOMFORT OCCURS AND PERSISTS, OBTAIN MEDICAL ATTENTION.
INGESTION................:	DRINK PLENTY OF WATER. NEVER GIVE ANYTHING BY MOUTH TO AN UNCONSCIOUS PERSON. IF ANY DISCOMFORT PERSISTS, OBTAIN MEDICAL ATTENTION.
NOTES TO PHYSICIAN.......:	LARGE DOSES MAY CAUSE NAUSEA, VOMITING AND DIARRHEA. SYSTEMIC ORAL TOXICITY IS EXTREMELY RARE AND HAS CONSISTED OF ACIDOSIS AND HYPOCALCEMIC TETANY.

5. FIRE FIGHTING MEASURES

EXTINGUISHING MEDIA......:	PRODUCT IS NONCOMBUSTIBLE
SPECIAL FIREFIGHTING.....: PROCEDURES	NOT APPLICABLE
DEGREE OF FIRE AND.......: EXPLOSION HAZARD	NONE
HAZARDOUS DECOMPOSITION..: PRODUCTS	NONE

6. ACCIDENTAL RELEASE MEASURES

PROCEDURE FOR RELEASE....: OR SPILL	MATERIAL SHOULD BE SWEPT UP FOR SALVAGE OR DISPOSAL.

7. HANDLING AND STORAGE

HANDLING.................:	ANIMAL STUDIES AND MANUFACTURING EXPERIENCE INDICATE THAT EXPOSURE TO THE PRODUCT MAY RESULT IN EYE AND SKIN IRRITATION UNDER NORMAL CONDITIONS OF USE. IN THE EVENT OF CONTACT, IMMEDIATELY FLUSH EYES WITH WATER; WASH OFF SKIN.
VENTILATION..............:	CONTROL MEASURES SUCH AS LOCAL EXHAUST VENTILATION MAY BE REQUIRED WHERE EXCESSIVE AIR-BORNE DUST LOADING MAY BE PRESENT.
STORAGE..................:	THE PRODUCT SHOULD BE STORED IN A CLEAN DRY AREA TO MAINTAIN PRODUCT QUALITY AND TO PREVENT POSSIBLE CONTAMINATION BY OTHER CHEMICALS.

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

CONTROL MEASURES.........:	PREVENTION OF EYE AND SKIN CONTACT MAY BE REQUIRED UNDER NORMAL USE CONDITIONS. HOWEVER, SEVERE AGITATION OR DISPERSION INTO THE WORK ENVIRONMENT MAY REQUIRE ENCLOSURE OF THE PROCESS AND LOCAL EXHAUST VENTILATION AT THE SOURCE TO PREVENT RELEASE INTO AIR. IF WORK ENVIRONMENT CONTROLS ARE NOT IMPLEMENTED, THEN PERSONAL

supplied in the diet.[1,75] The higher animals have a mechanism, the parathyroid gland, that controls the levels of inorganic phosphate. Hormones from this gland can cause release or deposition of phosphate to and from the skeleton, depending on the level of blood calcium. When the blood level of phosphate is too low, hormones cause its absorption from the intestinal walls. When excess phosphate is present, the hormones again cause it to be eliminated through the kidneys.[37,75] In addition, phosphatase enzymes are also present in the blood and tissues for further regulation of the phosphate-anion levels in the blood. These enzymes require magnesium and calcium for activation. The blood serum of human adults normally carries 2.5–4.5 mg of phosphorus/100 ml, while that of children carries a higher level. It is also estimated that adult humans require a minimum of 0.88 g of phosphorus in their daily diets.[75]

Several critics of the use of phosphate in food processing have speculated that phosphates prevent the utilization, and possibly absorption, of calcium, iron, magnesium, copper, and similar essential ions through their ability to precipitate or sequester these metals. Numerous studies have demonstrated that the absorption and metabolism of these ions is inhibited in no way, even when the diet contains excessive levels of the various phosphates, including those of very long chain length.[37,62,64,65,76,77] Several investigators have established that polyphosphates actually increase the absorption and retention of essential mineral ions.[37,65,77] For example, STP and SHMP have been shown to increase absorption and retention of calcium in the bodies of rats, with SHMP being more effective than STP. The same investigators demonstrated that the SHMP-calcium complex is absorbed intact through intestinal walls, while STP and calcium are absorbed independently of each other. Both STP and SHMP then are hydrolyzed to orthophosphate after absorption into the body.

The orthophosphates are known to be readily absorbed through the intestinal wall. The shorter-chain, condensed phosphates, such as pyrophosphate and tripolyphosphate, also are probably capable of passing intact through the intestinal walls, but they are quickly hydrolyzed to orthophosphate.[78] Mitchell[79] demonstrated that synthetic digestive fluids were capable of hydrolyzing polyphosphates in a step-like fashion to orthophosphate. Feeding studies by other investigators have confirmed that the longer-chain polyphosphates are absorbed through the intestinal walls only after hydrolysis to shorter-chain polyphosphates or orthophosphate.[21,75,79–84] Furthermore, only 10–40% of the phosphorus in SHMP and longer-chain polyphosphates is absorbed from the intestinal tract. The balance of the phosphorus is eliminated in the feces.[61,76,80–82] This has been confirmed by studies with diets containing radioactive polyphosphate.

Acceptable Daily Intakes for Humans

The FAO/WHO Expert Committee on Food Additives studied the various factors affecting toxic reactions to phosphates in the diet. These factors include the total level of phosphorus in the diet, the presence of calcium and other minerals, the degree of hydrolysis of polyphosphates to shorter-chain polyphosphates or orthophosphates, and others. Since it is impossible to predict the presence or absence of any of the factors that would determine whether any particular level of phosphate would be toxic or not, the Committee has recommended an unconditional acceptance level for total dietary phosphorus

1078 **FMC**

ATERIAL SAFETY DATA — DISODIUM PHOSPHATE

7558 -79 -4

U.S./CANADA VERSION — EFFECTIVE: 07/20/93 — PRINTED: 06/14/96

PRINTED FOR...............: INDEPENDENT CHEMICAL CORP
79-51 COOPER AVE
GLENDALE NY 11385

1. CHEMICAL PRODUCT/COMPANY IDENTIFICATION

PRODUCT NAME..............: DISODIUM PHOSPHATE

SYNONYMS..................: DISODIUM ORTHOPHOSPHATE; DISODIUM HYDROGEN PHOSPHATE; SODIUM PHOSPHATE, DIBASIC; DSP; DISODIUM MONOPHOSPHATE

INFORMATION PROVIDED BY..: FMC CORPORATION
1735 MARKET STREET
PHILADELPHIA PA 19103

EMERGENCY PHONE NUMBERS
- CHEMTREC...............: (800) 424-9300
- MEDICAL................: (303) 595-9048 CALL COLLECT
- PLANT/OTHER............: CHEMTREC: (800) 424-9300 TRANSPORTATION

2. COMPOSITION/INFORMATION ON INGREDIENTS

CAS # AND COMPONENTS.....: 7558-79-4
DISODIUM PHOSPHATE

3. HAZARD IDENTIFICATION

EMERGENCY OVERVIEW.......: PRODUCT IS NOT CONSIDERED HAZARDOUS BY KNOWN GOVERNMENTAL DEFINITIONS. HOWEVER, CONTINUOUS CONTACT MAY CAUSE SKIN IRRITATION.

HEALTH EFFECTS...........: MINIMALLY TO MODERATELY IRRITATING TO UNWASHED EYES AND MINIMALLY TO MILDLY IRRITATING TO WASHED EYES IN RABBITS. SKIN IRRITATION FROM CONTINUOUS CONTACT HAS BEEN REPORTED DURING MANUFACTURING WHEN PROTECTIVE MEASURES FOR CONTACT OR PERSONAL HYGIENE PROCEDURES ARE NOT FOLLOWED.
HUMAN INDUSTRIAL EXPERIENCE HAS SHOWN NO SIGNIFICANT INHALATION HAZARD OR SKIN IRRITATION WHEN EXPOSURES ARE PROPERLY CONTROLLED. EXPOSURE MONITORING INDICATES THAT THE AMOUNT OF RESPIRABLE DUST IN THE PRODUCT IS LOW.
THERE HAVE BEEN NO MEDICAL CONDITIONS REPORTED AS BEING AGGRAVATED BY EXPOSURE.

4. FIRST AID MEASURES

EYES.....................: FLUSH EYES WITH LARGE AMOUNTS OF WATER. IF IRRITATION OCCURS AND PERSISTS, OBTAIN MEDICAL ATTENTION.

SKIN.....................: WASH WITH PLENTY OF SOAP AND WATER. GET MEDICAL ATTENTION IS IRRITATION OCCURS AND PERSISTS.

INHALATION...............: REMOVE TO FRESH AIR. IF BREATHING DIFFICULTY and a conditional acceptance level. The unconditional acceptance level is considered safe in any type of diet known in the world; the conditional level is acceptable only when the dietary calcium level is high. These levels are as follows:[37]

1. unconditional acceptance level: <30 mg/kg body wt
2. conditional acceptance level: 30–70 mg/kg body wt.

Summary

The results of animal-feeding studies reported in the scientific literature indicate that levels of 0.5% of the phosphates could be tolerated in the diet without adverse physiological effects. Higher levels could possibly be tolerated if a proper dietary balance of other ions, particularly calcium, magnesium, and potassium, is maintained.

Few, if any, applications for the phosphates require over 0.5% in order to obtain the desired effect, and higher levels often produce adverse physical and chemical effects and off-flavors. Because the phosphates produce adverse effects in numerous food systems, it is not feasible to add them to all foods. As a result, the level of phosphates likely to be found in the diet, even though fully utilized in all of the potential applications, is self-limiting. It is highly unlikely that a level of 0.5% phosphate could ever appear in the total human diet.

Attitudes of Regulatory Agencies

The U.S. Food and Drug Administration

The U.S. Food and Drug Administration (FDA) considers the orthophosphoric and polyphosphoric acids and their calcium, potassium, sodium, and ammonium salts as GRAS *(generally recognized as safe)*. Lehman[83] referred to the work of Gosselin[80,84] and Mitchell[79] as evidence that the straight-chain polymeric phosphates are hydrolyzed to monophosphate. This work is used as the basis for the GRAS status of these food additives.

Based on the same references, Lehman[83] states that the cyclic metaphosphates may not be safe food additives. Gosselin *et al.*[80,84] found that the injection of cyclic phosphates resulted in recovery of most of the intact cyclic phosphate in the urine. Lehman failed to note that Gosselin *et al.*[84] and Hodge[70,73] have shown that little, if any, cyclic metaphosphate is absorbed through the intestinal wall when administered orally. The metaphosphates must first be hydrolyzed to tripolyphosphate and next to orthophosphate, which then can be absorbed. It would appear that the use of the cyclic phosphates in foods would be no more, or even less, toxic than any other condensed phosphate.

A list of the phosphate food additives listed as GRAS by FDA is shown in Table 8. Each phosphate is listed under functional categories for its applications.[85] No tolerance levels or limitations are given; however, the quantity of the substance added to the food must not exceed the amount required to accomplish its intended purpose.

There has been some confusion in the past regarding the sodium metaphosphate listed under the category of sequestrants. Recently, this seems to

Material Safety Data Sheet

A. FMC and Astaris – Disodium Phosphate, Disodium Phosphate Anhydrous, Dihydrate
B. Astaris – Sodium Hexametaphosphate
C. Astaris – Trisodium Phosphate Anhydrous

have been clarified to mean that any compound that meets the specifications for sodium metaphosphate in the *Food Chemicals Codex* is GRAS.[38] It is also understood that the ammonium, calcium, potassium, and sodium salts are equally acceptable.

TABLE 8
Phosphate Food Additives Listed as GRAS by FDA

Emulsifying agents

Monosodium phosphate derivatives of mono- and diglycerides

Nutrients and/or dietary supplements

- Calcium glycerophosphate
- Calcium phosphate (mono-, di-, tribasic)
- Calcium pyrophosphate
- Ferric phosphate
- Ferric pyrophosphate
- Ferric sodium pyrophosphate
- Magnesium phosphate (di-, tribasic)
- Manganese glycerophosphate
- Manganese hypophosphite
- Potassium glycerophosphate
- Sodium phosphate (mono-, di-, tribasic)

Sequestrants

- Calcium hexametaphosphate
- Calcium phosphate (monobasic)
- Dipotassium phosphate
- Disodium phosphate
- Sodium acid phosphate
- Sodium hexametaphosphate
- Sodium metaphosphate
- Sodium phosphate (mono-, di-, tribasic)
- Sodium pyrophosphate
- Sodium pyrophosphate (tetra)
- Sodium tripolyphosphate

Miscellaneous and/or general-purpose food additives

- Ammonium phosphate (mono- and dibasic)
- Calcium phosphate (mono-, di-, tribasic)
- Phosphoric acid
- Sodium acid pyrophosphate
- Sodium aluminum phosphate
- Sodium phosphate (mono-, di-, tribasic)
- Sodium tripolyphosphate

Source: §121.101(D), Part 121, *Code of Federal Regulations, Title 21* (revised as of January 1, 1971), U.S. Government Printing Office, 1971.

The Meat Inspection Division, USDA

The Meat Inspection Division (MID), Consumer and Marketing Service, U.S. Department of Agriculture, also provides regulations for the use of phosphates as additives to meat products. All of the substances acceptable for addition to meat are listed in the *Code of Federal Regulations*;[86] the phosphate additives are summarized in Table 9. As shown in this table, there are certain applications for the phosphates in meat products that have limitations for the quantity that can be used. These are clearly listed. The longest-chain polyphosphate allowed by MID is SHMP; therefore, none of the longer-chain sodium metaphosphates or the highly polymerized potassium polymetaphosphates are allowed in meats under federal inspection. Many state regulations do not prevent the use of the longer-chain polyphosphates, and some of the intra-state meat packers have been using potassium polymetaphosphate (Kurrol's salt).

Further information on each of the phosphate food additives will be found in Part II, "Regulatory Status of Direct Food Additives," of this handbook.

Technical/Customer Services

Solutia employs a staff of food scientists who have worked with the food industry for many years. Through cooperative studies and application research, we have developed new products to meet industry needs. A computer software program has been developed for Solutia customers to assist them with calculations and application development. This program provides interactive and accessible technical information in computer software format to increase efficiency. Please contact us today for assistance at 1-800-244-6169 (Food Phosphates Group) or by FAX at 314-674-7005.

Sales Offices

United States

Atlanta
Suite 500
320 Interstate North Parkway
Atlanta, Georgia 30339
Tel: (770) 951-7600
Fax: (770) 951-7680

Chicago
Suite 595
500 Park Blvd.
Itasca, Illinois 60143
Tel: (630) 250-4400
Fax: (630) 250-4432

Los Angeles
Suite 400
24012 Calle de la Plata
Laguna Hills, California 92653
Tel: (949) 461-5963
Fax: (949) 461-5966

St. Louis
P.O. Box 66760
St. Louis, Missouri 63166-6760
Tel: (314) 674-1000
Fax: (314) 674-7005

Latin America

Argentina
Solutia Argentina S.R.L.
Maipu 1210
6° Floor, Capital Federal
1006 Buenos Aires, Argentina
Tel: 54-1-313-2429
Fax: 54-1-313-2447

Brazil
Solutia Brazil Ltda.
Rua Paes Leme 524
Edificio Passarelli
05424-904 Pinheiros
Sao Paulo, SP, Brazil
Tel: 55-11-817-6233
Fax: 55-11-211-9922

Colombia
Solutia Colombia Ltda.
Carrera 7 #72-51, Piso 12
Torre Banco Union Colombiano
Santafe de Bogota, Colombia
Tel: 57-1-312-2455
Fax: 57-1-312-0750

Mexico
Solutia Mexico, S. de R.L de C.V.
Bosque de Duraznos 61-Piso 3
Bosques de las Lomas
11700 Mexico, D.F
Mexico
Tel: 011-525-246-2600
Fax: 011-525-246-2687

Puerto Rico
Solutia Inter-America, Inc.
P.O. Box 70168
San Juan, Puerto Rico 00936-8168
Tel: 787-258-9600
Fax: 787-286-4289

Venezuela
Solutia Venezuela S.R.L.
Avenida Francisco de Miranda
Edificio Parque Cristal
Torre Este, Piso 8 Ofc 8-12
Los Palos Grandes
Caracas 1062, Venezuela
Tel: 58-2-285-0944
Fax: 58-2-285-9125

Europe

Belgium
Solutia Europe N.V./S.A.
Rue Laid Burniat, 3
Parc Scientifique-Fleming
B-1348 Louvain-la-Neuve (Sud)
Belgium
Tel: 32.10.48.12.11
Fax: 32.10.48.12.12

Asia Pacific

Singapore
Solutia Singapore Pte. Ltd.
101 Thomson Road, #19-00
United Square, Singapore 307591
Tel: 65-250-2000
Fax: 65-253-5039

For customer assistance, please call our Customer Service Dept.
Toll Free (800) 244-6169.

H.T. MCP, Py-Ran, Levn-Lite, Stabil-9, Pan-O-Lite, Emulsi-Phos, Nutrifos, KATCH Lustre-Phos, Leverage, Mag-nificent and SnowFresh are registered trademarks of Solutia Inc.

SOLUTIA™
Applied Chemistry, Creative Solutions™

P.O. Box 66760
St. Louis, Missouri 63166-6760
(314) 674-1000
www.solutia.com

NOTICE: Although the information and recommendations set forth herein (hereinafter "Information") are presented in good faith and believed to be correct as of the date hereof, Solutia Inc. makes no representations or warranties as to the completeness or accuracy thereof. Information is supplied upon the condition that the persons receiving same will make their own determination as to its suitability for their purposes prior to use. In no event will Solutia Inc. be responsible for damages of any nature whatsoever resulting from the use of or reliance upon Information or the product to which Information refers. Nothing contained herein is to be construed as a recommendation to use any product, process, equipment or formulation in conflict with any patent, and Solutia Inc. makes no representation or warranty, expressed or implied, that the use thereof will not infringe any patent. NO REPRESENTATIONS OR WARRANTIES, EITHER EXPRESSED OR IMPLIED, OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR OF ANY OTHER NATURE ARE MADE HEREUNDER WITH RESPECT TO INFORMATION OR THE PRODUCT TO WHICH INFORMATION REFERS.

TABLE 9
Phosphate Food Additives Acceptable for Use in Meat Processing

Class of Substance	*Phosphate*	*Purpose*	*Products*	*Amount*
Cooling and retort water treatment agents	TKPP SHMP TSPP STP	To prevent staining on exterior of canned goods	Various	Sufficient for purpose
Hog scald agents	SHMP STP TSP	To remove hair	Hog carcasses	Sufficient for purpose
Phosphates	DSP MSP SHMP STP TSPP SAPP	To decrease amount of cooked-out juices	Cured hams, pork shoulder picnics, loins; canned hams and pork shoulder picnics; chopped ham; bacon	5.0% of phosphate in pickle at 10% pump level; 0.5% of phosphate in product (only clear solution may be injected into product)
Rendering agents	TCP TSP	To aid rendering	Animal fats	Sufficient for purpose
Synergists (used in combination with antioxidants)	H_3PO_4	To increase effectiveness of antioxidants	Lard and shortening	0.01%

Source: §318.7(4), *Code of Federal Regulations, Title 9* (revised as of January 1, 1971), U.S. Government Printing Office, 1971.

Some General Functions of Phosphates in Foods

As the phosphates are capable of interacting with many of the constituents of food systems, they have very useful and important functions in food processing. Some of these general functions will be discussed briefly in this section, and specific functions will be discussed under each of the food categories in later sections of this chapter.

Inactivation of Metal Ions and Processing Water Treatment

The phosphates can inactivate metallic ions, which are capable of interfering with necessary food-processing reactions. They inactivate the metallic ions either by precipitating and removing them from interference with the desired food-processing reactions or by complexing and maintaining them in a soluble, bound state.

The orthophosphates precipitate calcium, magnesium, iron, and similar alkaline-earth and transition-metal ions. They reportedly form complexes with calcium when the phosphates are present in low concentration, but they begin to form precipitates as the concentration of phosphate increases.[47]

The polyphosphates, including those ranging from two to many phosphate units per molecule, form soluble complexes with nearly all of the metallic ions.

Product Index

Phosphate Ingredient	Application Information is found on pages:
Sodium Phosphates	
Monosodium Phosphate Anhydrous (MSP)	20, 23, 25, 26, 27, 35, 36
Disodium Phosphate Anhydrous (DSPA)	11, 20, 21, 23, 27, 35, 36
Disodium Phosphate Dihydrate (DSPD)	11, 20, 21, 23, 27, 35, 36
Trisodium Phosphate Anhydrous (TSPA)	20, 23, 27, 35, 36
Trisodium Phosphate Crystalline (TSPC)	20, 23, 35, 36
Emulsi-Phos® 440	19, 20, 23, 35, 36
Emulsi-Phos® 660	19, 20, 23, 35, 36
Emulsi-Phos® 990	19, 20, 23, 35, 36
Sodium Acid Pyrophosphates (SAPP)	8, 14, 20, 21, 23, 36
Leavening Grades	7, 8, 35
SAPP RD-1	
SAPP 26	
SAPP 28	
SAPP 37	
SAPP 40	
SAPP 43	
Non-Leavening Grade NL	13, 14, 17, 25, 33, 34, 35
Tetrasodium Pyrophosphate (TSPP)	15, 17, 20, 21, 23, 25, 26, 27, 35, 36
Sodium Tripolyphosphate (STP)	13, 14, 15, 17, 21, 23, 27, 35, 36
Nutrifos® Polyphosphates	
Nutrifos® 088	15, 17, 25, 26, 35, 36
Nutrifos® STP Powder	17, 35, 36
Nutrifos® B-90	15, 17, 26, 35, 36
Nutrifos® B-75	15, 17, 35, 36
Nutrifos® H-30	14, 15, 17, 35, 36
Nutrifos® L-50	15, 17, 35, 36
Nutrifos® SK	15, 17, 35, 36
Katch® Fish Phosphate	15, 17, 35, 36, 40
Sodium Potassium Tripolyphosphate (SKTP)	15, 27, 35, 36

Phosphate Ingredient	Application Information is found on pages:
Sodium Phosphates (continued)	
Sodium Hexametaphosphate (SHMP)	13, 14, 15, 20, 21, 23, 25, 26, 27, 35, 36
Sodium Aluminum Phosphates (SALP)	
Levn-Lite®	7, 8, 35, 36
Stabil-9®	7, 8, 9, 35, 36
Pan-O-Lite®	7, 8, 9, 35, 36
Calcium Phosphates	
H.T.® Monocalcium Phosphate Monohydrate (MCP)	7, 8, 9, 11, 21, 23, 25, 35, 36
Py-Ran® Anhydrous Monocalcium Phosphate (AMCP)	7, 9, 35, 36
Dicalcium Phosphate, Anhydrous (DCPA)	11, 25, 27, 35, 36
Dicalcium Phosphate, Dihydrate (DCPD)	7, 9, 25, 27, 35, 36, 40
Tricalcium Phosphate (TCP)	25, 26, 27, 35, 36
Calcium Pyrophosphate, (CPP)	27, 35, 36
Potassium Phosphates	
Monopotassium Phosphate (MKP)	11, 20, 23, 25, 26, 27, 35, 36
Tetrapotassium Pyrophosphate (TKPP)	15, 17, 20, 23, 26, 27, 35, 36
Ammonium Phosphates	
Monoammonium Phosphate (MAP)	11, 23, 35, 36
Diammonium Phosphate (DAP)	11, 23, 35, 36
Phosphoric Acid – 75%, 80% or 85%	1, 2, 11, 23, 33, 35, 40
Adipic Acid	7, 9, 28, 35, 40
Magnesium Phosphates	
Leverage	4, 5, 7, 9, 36
Mag-nificent	5, 25, 36

"Functions of Solutia Food Phosphates" are summarized in Table A on pages 4-5.

"Properties of Solutia Food Phosphates" are summarized in Table G on pages 30-31.

Thus, they are considered to undergo ion-exchange reactions, in which a hydrogen, sodium, or potassium ion is exchanged for one of the alkaline-earth or transition-metal ions.[23,48,51] Very weak, soluble complexes are formed with alkali-metal and ammonium ions. More stable but somewhat dissociated complexes are formed with the alkaline-earth metals, such as calcium and magnesium. Very stable, soluble complexes are formed with the transition-metal ions, such as copper, nickel, and iron. A significant advantage in the use of phosphates to complex nutritionally important ions, such as calcium, magnesium, and iron, is that the ions can still be absorbed through the intestinal walls and utilized by the body, and their absorption and retention may actually be increased in the form of their complexes.[23,37,62,64,65,76]

Since pyrophosphates, as well as the long-chain polyphosphates, form soluble complexes of metal ions, the complexing ability of the phosphates apparently does not necessarily depend on chain length. A precipitate forms initially upon addition of a polyphosphate to a system that contains a metal ion. However, the precipitate rapidly dissolves upon the addition of more of the polyphosphate. This formation of soluble complexes, which prevent formation of precipitates between the metal ions and other constituents of the system, is often called "sequestration."[32] As very weak, if any, complexes are formed between metal ions and the cyclic, condensed phosphates sodium trimetaphosphate and sodium tetrametaphosphate, they are, therefore, not used for this purpose.

The water used in food processing often contains sufficient quantities of alkaline-earth and transition-metal ions to cause undesirable reactions in food processing. It is, therefore, common practice to treat the water with a phosphate, such as SHMP, SHMP plus an alkali, a shorter-chain polyphosphate, or, in some cases, orthophosphate, or mixtures of all of these to precipitate and/or complex the interfering ions. This is often necessary in the canning of fruits and vegetables, in which the alkaline-earth and transition-metal ions tend to toughen the skins and tissues or to precipitate and form gels with the pectins in the fruit or vegetable tissues. The treatment of waters used in food processing for drinking has been thoroughly reviewed in many publications and will not be further discussed here.[28,87–91]

Complexing Organic Polyelectrolyte Food Constituents

Some functions of phosphates in food processing depend on their ability to form complexes and reaction products with constituents of foods other than mineral elements. This is demonstrated by the ability of phosphates to interact with many organic polyelectrolytes, such as protein, pectin, starch, etc. Numerous complicated protein-phosphate or protein-phosphate-salt complexes are known and have been studied and reported.[92–94] The most frequently studied of these complexes is probably that of the casein-calcium-phosphate complex in milk. One has only to review the numerous publications of Leviton, Morr, Rose, Waugh, Zittle, and their co-workers, and numerous others to appreciate the enormous effort that has been expended in research on this complex. Even so, the exact structure, its chemistry, and how it can be modified to obtain desired effects are still unknown. Further discussions of these important complexes will appear under specific sections of this chapter.

Available Literature

Included with all the products from Solutia comes our commitment to serve your information needs. For the products described in this brochure, the following information can be requested:

- Material Safety Data Sheets
- Specification Sheets
- Kosher Certification
- Nutritional Data Sheets

In addition, here's a sampling of the literature you can obtain regarding Solutia Food Phosphates:

- Leavening Phosphates by Solutia
- Leavening Agent Calculator
- Solutia Phosphoric Acid: A Guide to Applications, Handling and Storage
- Katch® Fish Phosphates by Solutia
- Nutrifos® Polyphosphates for Meat, Poultry and Seafood Applications
- Adipic Acid
- Dicalcium Phosphate Dihydrate - Dentifrice Code 260

For copies of available literature, contact your Solutia sales representative or technical specialist. Some literature is also available in other languages. Please refer to the listing of sales offices on the back cover.

Applications Index

Applications are summarized in Table F on pages 28-29.

Direct Chemical Reactions with Food Constituents

In addition to the formation of complexes between organic polyelectrolytes and phosphates, phosphate may undergo esterification reactions and cross-linking between molecules of proteins and starches. These reactions will be discussed further in subsequent sections.

Buffering or pH Stabilization

Another important function of phosphates is their buffering ability, which can be used to stabilize the optimum pH required for processing or stabilizing a food.

Dispersion of Food Constituents

Phosphates have the ability to promote dispersion and peptization of relatively insoluble food constituents, such as proteins, in concentrated milk and pasteurized, processed cheese. Entire food particles are dispersed in some cases, much as phosphates act as dispersants for clay particles.[30]

Emulsion Stabilization

Phosphates can stabilize emulsions; their ability to stabilize sausage emulsions, for example, will be discussed in the section on meat applications.

Increasing Hydration and Water Binding

The phosphates also can interact with animal and vegetable proteins in such a way that hydration is promoted. This important function is utilized in preventing freeze-thaw drip in meats, poultry, and fish.

Mineral Supplementation

Calcium, iron, sodium, and potassium phosphates are also used to improve the nutritional properties of numerous cereal products, such as flour, prepared mixes, baked goods, and breakfast cereals.

Acidification or Lowering pH

Phosphoric acid and its acidic salts are used in food acidification. The acidic phosphate salts are used as acidifying agents to react with baking soda in baking powders, prepared mixes, self-rising flour, and corn meal and to produce acidic pH values in many other foods. Orthophosphoric acid is the most common acidic constituent used in soft drinks to produce a natural, fruity tartness, just as it is frequently the acidic factor in natural fruit juices.

Alkalization or Raising pH

The alkaline phosphate salts function to produce alkaline pH values where these are necessary. As an example, DSP and TSP are used in the preparation of pasteurized, processed cheese to produce the slightly alkaline pH values necessary for optimum protein dispersion, as well as to interact with the proteins themselves to improve their emulsification and water-binding abilities.

Glossary of Terms

Emulsifier
Substances which modify the surface tension of components in a dispersion and enable the formation of a uniform single phase dispersion or emulsion.

Emulsion
A homogeneous, uniform system formed by initially incompatible liquid phases (e.g., oil and water, air and batter).

Esterification
The process of forming an ester by the reaction of an acid and an alcohol.

FCC
The Food Chemicals Codex: A publication listing properties and tests for food additives. Although it is published in the U.S., many other countries also use it as a standard.

FDA
The U.S. Food and Drug Administration which is responsible for implementing federal legislation for regulating the food and drug industries in the U.S.

Flow Conditioner
Substances added to finely divided powdered or crystalline products to minimize caking, lumping or agglomeration.

Gelation
The process of converting a liquid to a non-flowing phase. Starches in cereal products absorb water from the batter to undergo gelatinization.

GRAS
The abbreviation used to refer to Generally Recognized As Safe – listing in the CFR of approved food additives. There are two lists – the second listing is identified as Reaffirmed As Generally Recognized As Safe. This refers to materials which have been re-evaluated as safe. These listing are found in Title 21, Parts 182 and 184, respectively.

Hydrophilic
Water-loving. A descriptive term applied to materials which are preferentially wet by water rather than non-aqueous materials.

Hydrophobic
Water-hating. The opposite of hydrophilic and applied to materials which are preferentially wet by non-aqueous materials.

Inorganic
Substances which are generally comprised of elements other than carbon (e.g., salts, minerals).

Isoelectric
A property at which proteins exhibit no electrical charge and will generally precipitate.

Isotonic
Compositions in which the electrolytes are present at the same concentrations as in body fluids.

Leavening
The process of expanding dough or batter by generating a gas (e.g., carbon dioxide by the fermentation of carbohydrate with yeast, or chemically by the neutralization of bicarbonates by acids).

Leavening Acid
A dry powder which provides acid when dissolved or solubilized in water and then reacts with sodium bicarbonate to generate carbon dioxide.

Meat Binding
The process of adhering meat pieces together into a cohesive whole.

Meltability
The melting characteristics of process cheese under various cooking conditions.

Mineral Supplementation
The addition of substances (e.g., calcium phosphates) to foods to increase their nutritional characteristics.

NF
National Formulary, a compendium listing materials approved for use in over-the-counter drugs and which includes required specifications and test methods.

Neutralize
A process in which acidic or alkaline material react. If equal molar quantities are used, the composition will contain no free acid or base and will have a neutral pH of 7.

Neutralizing Value
The parts of soda neutralized by 100 parts of leavening acid.

Nucleation
Formation of many small bubbles in the batter when mixing. The bubbles expand in size during baking producing a fine cell structure.

Nutrient
A substance metabolized by microorganisms as part of their growth cycle.

Prevention of Caking

Several applications for insoluble phosphates as anticaking agents will be discussed in subsequent sections. This is a very common use for these highly insoluble salts, as they can be prepared in a very fine powdered form, which can be used to separate crystals of substances that normally adhere to each other. They are often used also as water-absorbent anticaking agents. Warning and Schille[95] used a mixture of aluminum phosphate and TCP as an anticaking agent for salt. Lubeck[96] proposed the use of DCP and dimagnesium phosphate to produce a free-flowing table salt. TCP also has been proposed as an anticaking agent for dietary seasoning compositions.[97] A somewhat unrelated example of the ability of TCP to maintain free flow of particles is that patented by Sorgenti, Nack, and Sachsel,[98] who advocated the use of TCP as the solid particles in a fluidized-bed cooking process for food products.

Food Preservation

The phosphates, and especially the polyphosphates, have been found to prevent or retard the oxidation of unsaturated fats in aqueous food systems and to inhibit the growth of some of the microorganisms involved in the spoilage of foods. Although some investigators relate these functions to the ability of the phosphates to complex metal ions or organic polyelectrolytes essential to the fat oxidation or spoilage organisms, others report evidence of additional factors involved in this important application. The antioxidant and microbiological preservation applications of the phosphates will, therefore, be treated separately in subsequent sections.

The following sections consist of further discussions of the various functions of phosphates and their applications in the processing of foods and food ingredients. The sections are arranged according to general food categories with a discussion of the functions of the phosphates in the processing of specific foods and their reactions with food ingredients under each category.

Phosphate Applications in Beverages

The food-science literature reports that phosphates have been applied as buffers, metal-complexing agents, microbiological inhibitors, acidifiers, mineral supplements, and flow agents in alcoholic, carbonated, powdered, and nutritional beverages.[28] Some examples of each application follow.

Applications in Alcoholic Beverages

Buffering The buffering action of mixtures of the acidic and basic orthophosphates has been used to obtain optimum pH values in the preparation of alcoholic beverages. Heyer,[99] for example, demonstrated that buffering a boiling suspension of hops to pH 8.0–8.3 gave maximum conversion of humulon to isohumulon in the preparation of the dried hops extract.

Microbiological Control The treatment of yeast used in brewing beer and ale with a solution of H_3PO_4 and sodium persulfate at 5°C was reported to control the bacteria that often contaminate such brewing yeasts.[100] The viability of yeast used in brewing beer and its resistance toward contaminating

Glossary of Terms

ch physically removes
ersed substances (e.g.,
om a solution or disper-
s them at its surface.

bstance (e.g., phosphoric
roperties include the abil-
th bases or alkalis in water
rm salts.

r gas to bakery products;
emulsifiers increase the
pped air and create a
product.

hage
le of replicating in a bacter-
estroy bacterial cultures
se fermentation.

ted solution of sodium chlo-
er ingredients used for
t or poultry. Polyphosphates
rtant component.

that stabilizes pH; used in
harmaceuticals.

f Federal Regulation which
ons published by Federal
gencies; FDA is listed in Title
A in Title 9.

Dioxide
duced by the action of acid
, soda; also by yeast during
tation of carbohydrates.

protein present in milk
6).

Chelating Agent
A special type of sequestering agent that reacts with metallic ions in water and with other substances. Many are organic compounds, but polyphosphates and other materials are also very effective. (See Sequestering Agent.)

Chelation
Holding or trapping a metal ion between two atoms of a single molecule; often used as a synonym for sequester.

Clarification
A process for clearing a turbid solution by removing dispersed insoluble particles or color bodies.

Coagulant
A material which has the ability to cause small particles in a dispersion to agglomerate, which can then be removed.

Color Development
(Red meat color) Forms from the reaction of nitrite with myoglobin, an iron-containing protein. Processing conditions often do not allow sufficient time for full color to develop. The addition of pyrophosphate lowers the pH and thus accelerates the color development while maintaining suitable emulsion conditions in such products as frankfurters, sausages, etc.

Comminuted
Material which has been chopped or ground to small particle sizes (e.g., hamburger, sausages).

Cryoprotection
Protecting various properties during freezing (e.g., meat texture, water retention).

Cure
Imparting a unique flavor and/or color to a food, especially as applied to meats, and which generally also results in increased shelf life.

Denaturation
A process in which a protein structure is changed by treatment with a chemical, heat, radiation, shear, etc.

Dispersing Agent
A material that increases the stability of particles in a liquid (e.g., minimizes settling or agglomeration).

Double Acting
A leavening system that provides leavening action during mixing, is dormant during bench holding, and is reactivated and generates carbon dioxide during baking.

Dough Rate of Reaction (DRR)
The rate of carbon dioxide released during mixing and in the holding period of the bakery product. The rate number is the percentage of CO_2 released at a given time compared with the total available CO_2 from the bicarbonate.

Emulsification
The process of dispersing one liquid into another liquid with which it is immiscible or insoluble. In process cheese and meats, phosphates will cause solubilization of proteins which then form a coating around fat particles, making the modified fats disperse or become miscible with the water.

bacteria were increased by treating the yeast with TKP prior to its addition to the beer wort.[101] Kohl and Ellinger[102,103] reported that bacteria, fungi, and yeasts could be inhibited in alcoholic beverages, among many other food systems, by treating them with polyphosphates. The polyphosphates could be added to draft beers, for example, to inhibit the last traces of organisms.

Complexing Metal Ions The ability of the phosphates, and especially the polyphosphates, to complex alkaline-earth and heavy metal ions that are troublesome in the preparation of alcoholic beverages has long been recognized. The polyphosphates also are frequently used to soften the water used in preparations of these beverages.

Iron, copper, and calcium ions are especially troublesome, since they can introduce off-flavors and contribute to haze formation in the beverages. Libby[104] prevented cloud or haze formation by the addition of 0.1–1.0 g of SHMP/gal of beer or wine. Peynaud[105] significantly reduced the iron content in wines by the addition of 100–450 mg of STP or SHMP/l. Copper and iron were reported to be removed by filtering the beverage through insoluble calcium phosphates.[106] The direct formation of a precipitate of DCP in the beverage was reported by Shrivanek[107] to co-precipitate and remove undesirable impurities from the beverage. Opportunities for the formation of cloud or haze in wines were reduced by Ohara and co-workers[108] by the addition of ammonium phosphate to reduce the tannin and acid contents of the wines.

Applications in Carbonated Beverages

Complexing Metal Ions The presence of heavy-metal ions in the water used in carbonated beverages can result in more rapid dissipation of carbonation, as the ions serve as nuclei for the formation of carbon dioxide bubbles. Karlson[109] used soluble sodium polyphosphate glasses having a $Na_2O:P_2O_5$ ratio of 1.2:1 to sequester these ions and prevent the loss of carbonation. It was discovered that such treatment of the beverage would reduce the necessary carbonation by 25–90% of that required by use of untreated water. As the water used in the preparation of carbonated beverages is always deionized, the phosphates, particularly the polyphosphates, are frequently implemented in this deionization.

Acidification Many soft-drink beverages, particularly those flavored with leaf, root, or nut extracts, such as cola beverages, are acidified with H_3PO_4.[27,110,111] This acid gives a natural tartness to the beverage, possibly because it is a normal constituent of many fruits and their juices. The acidic, crystalline phosphate salts are also utilized in preparation of beverage powders,[27,39] and can be used in preparation of effervescent, carbonated drink powders.[28,39,112,113]

Improving Flow of Powders The insoluble phosphates, particularly TCP, can be used to improve flow properties of powdered beverage mixes. For example, Common[114] found that the addition of TCP to a powdered beverage mix beneficially influenced not only the flow properties but also the particle-size distribution of the dry mix.

Applications in Other Beverages

Acidification Increased yields of coffee extract were obtained when DiNardo[115] used H_3PO_4 or sulfuric acid to hydrolyze a portion of the extracted

Glossary of Abbreviations

AMCP	Monocalcium Phosphate Anhydrous
DAP	Diammonium Phosphate
DCPA	Dicalcium Phosphate Anhydrous
DCPD	Dicalcium Phosphate Dihydrate
DMP	Leverage
DMPT	Mag-nificent
DSPA	Disodium Phosphate Anhydrous
DSPD	Disodium Phosphate Dihydrate
Emulsi-Phos 440	DSP & IMP
Emulsi-Phos 660	TSP & IMP
Emulsi-Phos 990	TSP & IMP
H.T. MCP	Monocalcium Phosphate Monohydrate
IMP	Insoluble Metaphosphate
Katch Fish Phosphate	Polyphosphate Blend
Leverage	DMP
Levn-Lite	SALP
Mag-nificent	DMPT
MAP	Monoammonium Phosphate
MCP	Monocalcium Phosphate
MKP	Monopotassium Phosphate
MSP	Monosodium Phosphate
Nutrifos STP Powder	STP
Nutrifos 088	STP
Nutrifos BC	STP
Nutrifos STP Powder	STP
Nutrifos B-90	STP & SHMP
Nutrifos B-75	STP & SHMP
Nutrifos H-30	Polyphosphate Blend
Nutrifos L-50	STP & TSPP
Nutrifos SK	SKTP
Pan-O-Lite	SALP & MCP
Py-Ran	AMCP
SALP	Sodium Aluminum Phosphate
SAPP	Sodium Acid Pyrophosphate
SHMP	Sodium Hexametaphosphate
SKTP	Sodium Potassium Tripolyphosphate
Stabil-9	SALP & AMCP
STP	Sodium Tripolyphosphate
STMP	Sodium Trimetaphosphate
TCP	Tricalcium Phosphate
TCPP	Tetracalcium Pyrophosphate
TKPP	Tetrapotassium Pyrophosphate
TSPA	Trisodium Phosphate Anhydrous
TSPC	Trisodium Phosphate Crystalline (Decahydrate)
TSPP	Tetrasodium Pyrophosphate

coffee grounds in the preparation of instant coffee and imitation coffee products. Stayton[116] prepared improved coffee-chickory blends by neutralizing histidine compounds, which contribute the characteristic undesirable aromas and flavors of the chickory, by acidifying the chickory with acidic phosphates and pyrophosphates.

Mineral Supplementation A number of nutritional beverages for various purposes, including complete meals, have appeared on the grocery store shelves in recent years. Sodium iron pyrophosphate, ferric pyrophosphate, and ferric orthophosphate have been used as sources of iron in some of these beverages.[27] Calcium and phosphorus have also been provided through the addition of calcium phosphate.

Complexing Metal Ions Natural or added ascorbic acid can be inactivated through oxidation if heavy metal ions are present in a beverage. The ascorbic acid and the color of vitamin-C-fortified beverages have been found to be stabilized by the addition of polyphosphoric acids to complex metal ions.[28,29,117-119]

Phosphate Applications in Cereal Products

The first applications of phosphates in foods probably were as leavening acids in baking. Applications in cereal products include pH adjustment, buffering, dough conditioning, and mineral enrichment. Reviews of phosphate applications in cereal products have been numerous,[26-30,120] and examples are discussed in the following paragraphs.

Applications as Leavening Acids

The prepared-mix and baking industries probably are the largest consumers of phosphates in the food industry because of the many phosphate applications in chemical leavening systems. The salts of H_3PO_4 and its polymers are particularly useful as leavening acids, as the acids can be partially neutralized to form acidic salts. The acidic phosphate salts are capable of neutralizing sodium bicarbonate, common baking soda, during which carbon dioxide (CO_2) is released to become a portion of the leavening gases.

Characteristics of Leavening Systems The term *leavening* refers to the introduction and expansion of a gas in a batter or dough system. The gas may be incorporated through the mixing action during preparation of the dough or batter, through the formation of steam from the water in the dough or batter during baking, or through the formation of gas from a biological or chemical leavening system. The contributions of these various leavening systems have been thoroughly reviewed in the literature.[28,120-138]

.The chemical leavening system to be discussed in this section is that provided by the reaction between sodium bicarbonate and an acidic phosphate salt. The acidic phosphate salt, which will have at least two replaceable hydrogen atoms in its molecule, will react with soda, as represented by the following general formula:

$$MH_2PO_4 + 2NaHCO_3 = M(Na)_2PO_4 + 2H_2O + 2CO_2$$

where M can be a hydrogen, an alkali metal, or an alkaline-earth metal ion.

Packaging Guide

Table J – Food Phosphates

Chemical Description	Solutia Product	Solutia Package Size*
1. Calcium Phosphates		
Anhydrous Monocalcium Phosphate	Py-Ran	50 Lb. Bag
Dicalcium Phosphate Anhydrous	DCPA	50 Lb. Bag/350 Lb. Drum
Dicalcium Phosphate Dihydrate	DCPD	50 Lb. Bag/225 Lb. Drum
Monocalcium Phosphate Monohydrate	H.T. MCP	50 Lb. Bag
Spray-Dried Grade 200	MCP Fines	50 Lb. Bag
Spray Dried Grade 110	MCP Regular	50 Lb. Bag
Spray-Dried Grade 130	MCP Granular	50 Lb. Bag
Tricalcium Phosphate	TCP	50 Lb. Bag
Tetracalcium Pyrophosphate Normal	TCPP	50 Lb. Bag
2. Sodium Phosphates		
Disodium Phosphate Anhydrous	DSPA	50 Lb. Bag
Disodium Phosphate Dihydrate	DSPD	50 Lb. Bag
Monosodium Phosphate Anhydrous	MSP	50 Lb. Bag
Sodium Acid Pyrophosphates		
Slowest Reacting Grade	SAPP RD-1	50 Lb. Bag
Second Slowest Grade	SAPP 26	50 Lb. Bag
Baking Powder Grade	SAPP 28	50 Lb. Bag
Fast Reacting Grade	SAPP 37	50 Lb. Bag
Doughnut Grade	SAPP 40	50 Lb. Bag
Fastest Reacting Grade	SAPP 43	50 Lb. Bag
Food Grade (Non-Leavening)	SAPP NL	50 Lb. Bag
Sodium Hexametaphosphate	SHMP	50 Lb. Bag
Sodium Tripolyphosphate	Nutrifos 088, Nutrifos BC	50 Lb. Bag
Sodium Tripolyphosphate Powder	Nutrifos STP Powder	50 Lb. Bag
STP/SHMP Blend	Nutrifos B-90	50 Lb. Bag
STP/SHMP Blend	Nutrifos B-75	50 Lb. Bag
Polyphosphate Blend	Nutrifos H-30	50 Lb. Bag
Sodium Potassium Tripolyphosphate	Nutrifos SK	50 Lb. Bag
STP/TSPP Blend	Nutrifos L-50	50 Lb. Bag
Sodium Polyphosphate Blend	Katch Fish Phosphate	50 Lb. Bag
Tetrasodium Pyrophosphate	TSPP	50 Lb. Bag
Trisodium Phosphate Anhydrous	TSPA	50 Lb. Bag
Trisodium Phosphate Decahydrate	TSP Crystalline	50 Lb. Bag
DSPA/IMP Blend	Emulsi-Phos 440	50 Lb. Bag
TSPA/IMP Blend	Emulsi-Phos 660	50 Lb. Bag
TSPA/IMP Blend	Emulsi-Phos 990	50 Lb. Bag
3. Sodium Aluminum Phosphates		
Sodium Aluminum Phosphate (SALP)	Levn-Lite	50 Lb. Bag
SALP + MCP Blend	Pan-O-Lite	50 Lb. Bag
SALP + AMCP Blend	Stabil-9	50 Lb. Bag
4. Ammonium Phosphates		
Monoammonium Phosphate	MAP Granular	50 Lb. Bag
	MAP Powder	50 Lb. Bag
Diammonium Phosphate	DAP Regular	50 Lb. Bag
	DAP Powder 2% TCP	50 Lb. Bag
5. Potassium Phosphates		
Monopotassium Phosphate	MKP	50 Lb. Bag
Tetrapotassium Pyrophosphate	TKPP (60% solution)	Bulk T.T.
6. Acidulants		
Phosphoric Acid	75%, 80%, 85%	Bulk
Adipic Acid	Adipic Acid	50 Lb. Bag

---

* Solutia can provide some products in bulk hopper trucks and semi-bulk supersacks.

The acidic phosphate salts provide three major characteristics in a leavening system: (1) acidification for the formation of carbon dioxide, (2) buffering to provide the optimum pH for the baked product, and (3) interaction with the protein constituents of flour to produce optimum elastic and viscosity properties in the dough or batter.[28-30,120,121]

Numerous factors influence the characteristics contributed by any leavening system to a batter or dough. Among these are the proper selection of the acidic phosphate salts, the size and distribution of the bubbles incorporated during mixing action, the quality of the gluten in the flour, the viscosity of the system, and the type of emulsification in the system. Excellent reviews have discussed these in further detail.[28-30,120-131] Since sodium bicarbonate is highly soluble, it dissolves as soon as it is immersed in water; therefore, the rate at which CO_2 is released in a chemically leavened system depends on the rate of dissolution of the leavening acid used.[121] The *dough rate of reaction*, or *DRR*, is a value that reflects the rate of reaction of a leavening acid with soda during the mixing stage and during *bench action* (the holding period after mixing is completed). The DRR is obtained by mixing a standard, dry biscuit mix containing the proper amount of leavening acid and soda with water under standardized conditions in a gas-tight apparatus. The apparatus automatically measures the amount of gas released at 27°C. The DRR is then calculated as the per cent of the theoretical amount of gas expected from the amount of soda present in the mix. This per cent of the theoretical volume of gas is plotted against time.[28,30,121,133-136] The DRR's for typical commercial leavening acids are shown in Figure 2. The amounts of gas evolved after 2 minutes, which represents the mixing stage, and after 10 minutes, which represents 8 minutes of bench action, are usually considered as important DRR values for each leavening acid.[28,121,133-138]

The *neutralizing value*, sometimes called neutralizing strength, of a leavening acid represents the number of grams of sodium bicarbonate that will be neutralized by 100 grams of the leavening acid. It is determined by titration of the acid and can be expressed as the following equation:

$$NV = \frac{a}{b} \times 100,$$

where a = pounds of sodium bicarbonate neutralized and b = pounds of leavening agent required.[28,121,134,137] The neutralizing value is used to calculate the amount of leavening acid necessary to provide the desired amount of leavening gas and the optimum pH for the baked product.

Characteristics of Commercial Leavening Acids The important leavening properties of some of the common commercially available phosphate leavening acids are shown in Table 10; other chemical characteristics of these acids are shown in Table 2. Additional acidic phosphates have been proposed and patented, but those listed in Table 10 are commonly in use at the present time.

Monocalcium phosphate monohydrate, $MCP \cdot H_2O$, has been used as a leavening acid since the middle of the nineteenth century.[28] As shown in Figure 2 and Table 10, it is one of the fastest reacting leavening acids in common use. It seldom is used by itself and usually is combined with slower-reacting leavening acids to preserve leavening action for the baking stage. *Anhydrous monocalcium phosphate*, AMCP, is also very rapid reacting and is extremely

Regulatory Information

Solutia food phosphates and phosphoric acid, including the components of blends, meet the specifications of the Food Chemicals Codex (FCC), as well as other codex compendia used by other countries. Solutia food phosphates and phosphoric acid are approved as Kosher (U), and confirmatory letters are available upon request. Many of the phosphates and some grades of phosphoric acid also meet specifications defined by the U.S. Pharmacopeia and the National Formulary.

Solutia food grade phosphates and phosphoric acid are approved for use by the Food and Drug Administration (FDA) in Title 21 in the Code of Federal Regulations (CFR). In Parts 182 and 184, they are identified as substances Generally Recognized As Safe (GRAS). Under Part 182, they are listed with functional groupings as follows:

- Subpart B: Multiple Purpose GRAS Food Substances
- Subpart F: Dietary Supplements
- Subpart G: Sequestrants
- Subpart I: Nutrients

(Note – Not all phosphates are identified under every classification.)

Applications in the Meat and Poultry industry are regulated by the U.S. Department of Agriculture (USDA) and are listed in Title 9 of the CFR. Specific approvals are as follows:

- Part 318.7: Use in Meat Products
- Part 381.147: Use in Poultry Products

The USDA limits the use of phosphates in these products to 0.5% by weight of the final product. The USDA specifically prohibits the use of phosphates in fresh meat and poultry products. Meat and poultry products processed with phosphates should be labeled appropriately, and the label must be approved by the USDA. Only clear solutions may be injected into meat and poultry. Letters issued by the Proprietary Mix Committee of the USDA regarding the use of Solutia food phosphates and blends are available upon request. These provide information on use and proper labeling.

Current regulations by the FDA in the U.S. limit the level of phosphates in seafoods to Good Manufacturing Practice (GMP) and must be labeled accordingly. Solutia recommends phosphate levels should not exceed 0.5% by weight of the final product. Lower levels, however, are generally sufficient for functionality. Current Compliance Guides issued by the FDA limit the amount of water that can be added to seafood products.

Non-food uses of various phosphates in USDA-inspected plants are listed in Miscellaneous Publication Number 1419, "List of Proprietary Substances and Nonfood Compounds." These include such applications as cleaners and egg washing.

Many food phosphates are also approved for use as indirect ingredients and other applications. Specific references follow:

- 21 CFR 172.892: Use of various phosphates in preparation of modified food starches
- 21 CFR 173.310: Use of phosphates and polyphosphates in boiler water
- 21 CFR 173.315: Use of phosphates in washing or to assist in lye peeling of fruits and vegetables
- 21 CFR 175: Subpart B – Substances for use only as components of adhesives; Subpart C – Substances for use as components of coatings
- 21 CFR 176: Indirect Food Additives – Paper and Paperboard Components.

Since regulation of alcoholic beverages is the responsibility of the Bureau of Alcohol, Tobacco and Firearms, the approval of ammonium phosphates for treatment of wine and alcoholic juices is listed in 27 CFR 24.246

Many phosphates are included in the Standards of Identity of many standardized foods, including processed cheese, processed cheese food, processed cheese spread, evaporated milk, baking powder, phosphated flour, self-rising flour, enriched self-rising flour, self-rising white corn meal, self-rising yellow corn meal, and bread, rolls and buns. Certain seafood products are described by a Standard of Identity as well. Limitations are set for some products. Details are listed in 21 CFR Parts 130-169.

In addition, approvals for use in pet foods and animal feeds are listed in 21 CFR Part 582.

Food products containing food phosphates must be appropriately labeled, and attention is directed to Nutrition Labeling and Education Act (NLEA) of 1990. To assist with nutritional labeling requirements, "Nutrient Data" is listed in Table G on page 32.

Iron Iron is also an essential mineral, as it is found in a number of iron-containing enzymes. Approximately 80% of the iron supply in the body is found in the hemoglobin of red blood cells.[181] The human body maintains a sophisticated system for regulating the level of iron and its absorption and utilization.[182]

The presence of relatively soluble iron salts in cereals and other fat-containing products often increases the rate of rancidity development in fat. It has been found that the iron phosphate salts, such as ferric orthophosphate, ferric pyrophosphate, and sodium iron pyrophosphate, have little, if any, effect on increasing fat oxidation.[27,28,30,110,111] However, a great controversy has arisen in scientific circles regarding the availability of the iron from these compounds when they are used to supplement cereal products or other food systems in the diet.[28,183-198] Partly as a result of this controversy, the FDA has recently published a proposal in the *Federal Register* for a significant increase in the levels of iron supplementation in flour and cereal products.

A recent development in iron supplementation has been reported by Jones of the U.S. Department of Agriculture.[199] It involves the treatment of whey protein with a "ferri-polyphosphate" to form a whey-protein-iron complex. No studies have been reported of the oxidative stability of foods supplemented with this material; as far as can be determined, there also have been no studies of the ability of the human body to utilize iron from this complex. Such studies should be made before the complex becomes a useful material for iron supplementation.

Decreasing Cereal Cooking Times The addition of orthophosphates to various cereal grains during processing has been reported to significantly reduce the cooking times required to prepare cereal products.[28,30,200-202] Levels of 0.2-2.0% phosphate were used to buffer the pH of the system at an optimum range for the most rapid cooking of the cereal. The cooking times of macaroni and related pasta products also have been decreased by the addition of 0.5-1.0% phosphate salts; FDA regulations now permit the addition of DSP to these products.[30]

Miscellaneous Applications Phosphates have been reported to improve color, reduce the rate of respiration, and decrease rootlet development during germination of barley malt.[203,204] The color of precooked "cocoa noodles" was improved by treating them with SAPP prior to drying.[205] The color of processed soybeans was improved by treating them with calcium phosphates during processing.[206] The addition of a soda-phosphate leavening acid system to a gravy mix was reported to prevent lumping during its preparation.[207] Steeping corn in a solution containing MSP, DSP or TSP was advantageous in the preparation of the corn for making tortillas and similar products.[208]

Phosphate Applications in Dairy Products

As so many investigations of phosphate functions and their applications in milk products have appeared in the literature, only a portion of them will be reviewed here. The phosphates have been shown to be useful in processing nearly every type of dairy product.[28,29] The greatest amount of work reported in the literature involves the interaction of phosphates and inorganic cations,

Table H • Phosphoric Acid Typical Analysis and Physical Properties

Characteristics	**75%**	**80%**	**85%**
Appearance	a clear colorless liquid	a clear colorless liquid	a clear colorless liquid
Odor	no foreign odor	no foreign odor	no foreign odor
Specific Gravity @ 25°C	1.575	1.633	1.692
P_2O_5, %	54.39	58.20	61.92
% Equivalent H_3PO_4	75.1	80.35	85.5
Lbs/gallon	13.17	13.66	14.15
Lbs P_2O_5/gallon	7.16	7.95	8.76
Melting Point, °C	-17.5	+4.6	+21.1

Additional Typical Properties and Nutritional Data for Solutia Food Grade Phosphoric Acid:

Color, APHA	10	10	20
Turbidity, APHA	1	1	1
Arsenic as As, ppm	<3	<3	<3
Fluoride as Fl, ppm	<10	<10	<10
Heavy Metal as Pb, ppm	<10	<10	<10
Calories per Gram	0	0	0
Fat (g)	0	0	0
Carbohydrates (g)	0	0	0
Protein (g)	0	0	0
Iron, ppm	<5	<5	<5
Phosphorus, %	23.7	25.4	27.0

Table I • Relative Sourness of Phosphoric Acid and Other Food Acids

Acid Used	**R**	**P**	**pK**
Tartaric acid crystals (99.5%)	100	0.722	3.02
Citric acid crystals (91%)	100	0.773	3.06
Citric acid solution (50%)	100	0.425	3.06
Acetic acid (56%)	70	0.356	4.76
Lactic acid (44%)	100	0.266	3.86
Phosphoric acid (75%)	100	1.000	2.12

R = relative sourness of 0.01 Normal solution of the acid.
P = pounds of 75% phosphoric acid required to give same sourness as one pound of acid used.

especially calcium, and of phosphates and the milk proteins. There are numerous other functions of the phosphates of extreme importance in the processing of milk.

Interactions of Phosphates with Milk Constituents

A number of investigators have studied the chemistry of the casein-calcium-phosphate complex. A review of the current knowledge and four proposed structures for the casein micelles of milk have been published by Rose.[94] Calcium orthophosphate is intimately involved in the formation and stability of the casein micelles, which provide the white, opaque appearance of milk. Many of the applications of phosphates in the processing of dairy products involve the interactions between the phosphates and the casein or the calcium in these micelles. Further discussion of these interactions follows:

Interaction with Milk Calcium Sommer and Hart[209] first proposed that the addition of phosphate or citrates changes the salt balance of the milk through the formation of complexes with the calcium and magnesium ions. However, recent work has shown that other effects of equal or greater importance also occur.[209–216] The ion-exchange reactions of casein[210,214] result in a reduction in levels of free-calcium ions and an increase in bound or colloidal calcium as phosphates are added.[211,213,215,216] The addition of orthophosphates to milk is believed to precipitate calcium,[211,213] while the addition of polyphosphates is believed to cause the formation of casein-calcium-phosphate complexes from which it is difficult to remove the calcium.[210,211,215,217,218]

The addition of polyphosphates, such as SHMP, to milk appears to do more than just complex calcium ions. SHMP reduces the turbidity of milk at much lower levels than other calcium-complexing agents.[28,219,220] As little as 1 part SHMP to 20 parts of the protein in fluid skim milk causes almost complete loss of opacity, and the milk becomes a yellow-green, translucent serum;[220] the addition of EDTA did not result in a similar loss of opacity. Odagiri and Nickerson[219] reported that casein appears to combine with a portion of SHMP to form a large, stable complex. If, however, an excess of SHMP is added above that required for the formation of the casein-SHMP complex, the casein micelles are completely dispersed, with the resultant loss in the normal opacity of the milk.

Effect of Phosphates on Heat Stability of Milk The addition of orthophosphates increases the heat, rennet, and alcohol coagulation times of milk.[212,221–229] This effect is very useful in the manufacture of cheese and the stabilization of evaporated milk; it also could be useful in stabilizing the effects of seasonal variations in calcium levels in milk.[229,230] Studies by Zittle and Pepper[222] showed that the aggregation of calcium caseinate was reduced within any given time and that the effect of heat also was lowered by the addition of phosphate. Rose[223,224] found that the amount of calcium and phosphate ions absorbed on the surface of casein micelles had a direct bearing on the heat stability of milk. Other studies confirmed that the degree of heat stability of milk was inversely proportional to the ratio of soluble calcium:soluble orthophosphate.[225–229]

Interactions with Milk Proteins The reactions of the various phosphates with milk proteins differ in direct relation to their chain lengths. The addition of under 15 mmol of orthophosphates to milk causes little change in the

Typical Nutrient Data for Solutia Food Phosphates

Calories/Gram	Fat (g)	Sodium (%)	Carbohydrates (g)	Protein (g)	Calcium (%)	Iron (ppm)	Phosphorus (%)	Potassium (%)
0	0	19.1	0	0	–	–	25.8	0.2
0	0	32.3	0	0	–	5	21.8	–
0	0	25.8	0	0	–	< 5	17.3	–
0	0	42	0	0	–	3	18.8	–
0	0	19	0	0	–	1.4	7.9	–
0	0	29.4	0	0	–	–	24.2	–
0	0	30.4	0	0	–	–	25.6	–
0	0	23.4	0	0	–	10	29.6	0.01
0	0	20.7	0	0	–	12	27.9	0.1
0	0	34.5	0	0	–	10	23.2	–
0	0	31.1	0	0	–	15	25.3	–
0	0	31	0	0	–	16	25.7	–
0	0	30	0	0	–	16	26.2	–
0	0	27.1	0	0	–	14	26.3	0.04
0	0	32.8	0	0	–	12	24.3	–
0	0	17.2	0	0	–	5	23.2	19.5
0	0	31	0	0	–	16	25.7	–
0	0	23.4	0	0	–	21	29.4	–
0	0	22.5	0	0	–	50	30.4	–
0	0	7.4	0	0	1.3	50	26.9	0.01
0	0	4.6	0	0	reg. 9.8/hical >10.8	200	reg. 24.5/hical 26.1	–
0	0	5.9	0	0	4.3	100	26.4	–
0	0	0.05	0	0	17.6	400	24.4	–
0	0	0.05	0	0	17.5	400	25.8	–
0	0	0.04	0	0	28.7	350	22.3	–
0	0	0.11	0	0	23.2	300	18.1	–
0	0	0.03	0	0	37.9	400	17.6	–
0	0	0.2	0	0	31	260	24.4	–
0	0	–	0	0	–	20	22.7	28.7
0	0	0.04	0	0	–	–	17.8	44.8
0	0	–	0	0	–	–	18.8	47.3
0	0	–	0	0	–	4	26.9	–
0	0	–	0	0	–	< 5	23.4	–
0	0	–	0	0	–	< 5	23.7 (75%), 25.4 (80%), 27.0 (85%)	–

viscosity of the milk, but the addition of greater quantities causes the milk to gel at a rate in direct proportion to the amount of phosphate added. The degree of gelation also increases in proportion to the calcium-ion concentration and the level of milk-solids-not-fat.[231] Vujicic and deMan[232] reported that orthophosphates were not bound when they were added to a 1% solution of casein. However, all of the polyphosphates, from pyrophosphate through long-chain polyphosphates, were bound when added to a similar solution of casein.

Casein is precipitated by pyrophosphates to form thick gels.[217,218,233] Zittle[217] believed that the negatively charged pyrophosphate anions were bound to the positively charged casein at the normal pH values of milk. This resulted in a reduction of the net charge of the casein so that it was precipitated the same as at its isoelectric point. The heating of pyrophosphate-treated milk eliminated the gels.[218] Pyrophosphate, however, did not precipitate the soluble proteins in milk.

The longer-chain polyphosphates precipitate both casein and the soluble proteins, such as β-lactoglobulin. Of course, polyphosphates are well known, general protein-precipitating agents.[217,234-240] The acidic polyphosphate anion is believed to form cross-links between protein molecules by reacting with basic amino groups on different protein molecules. Thus, large, compact particles, or micelles, are formed.[241,242] Leviton[240] studied the stabilizing effect of polyphosphates, such as SHMP, on milk proteins. Although the polyphosphate was rapidly hydrolyzed to pyrophosphate in the milk, no gels were formed from the presence of pyrophosphate anions. Leviton believed that the polyphosphates stabilized the milk proteins against gelling by the formation of cross-linkages, most likely involving the pyrophosphate formed upon hydrolysis of the longer-chain polyphosphate. It has also been reported that the digestibility of milk and milk foods for babies and convalescents could be improved by treating the milk product with STP or SHMP.[243] This may result from the unfolding of protein molecules during the dispersion of the casein molecule.

Further study of the reactions of the polyphosphates with the natural protein systems in milk and other foods should lead to many new practical applications of the above phenomena. Similar studies of the reactions of polyphosphates on meat proteins are now in process, and preliminary reports show the similarity between their reactions with meat and those with milk protein. A recent excellent review of phosphate interactions with the milk proteins was published by Melnychyn.[29]

Applications in Milk-based Beverages

The phosphates have several functions in the processing of milk-based beverages. For example, Kawanishi[244] stabilized the color of a strawberry-juice-containing milk drink by chelating traces of iron in the drink with $<0.3\%$ polyphosphate. Wouters[245] adjusted and buffered the pH of pasteurized milk to 6.3 with a mixture of DSP and trisodium citrate for preparation of solid-milk-drink products. Jackson[246] sensitized spoilage bacteria in cocoa and in cocoa and malt mixtures intended for use in chocolate-flavored-drink products. First, he acidified a syrup of these ingredients with H_3PO_4 prior to heating them to sterilization temperatures, and then he restored the initial pH by addition of DSP. Roland[247] prepared thickened aqueous dispersions of

pH(1)	Solubility(2)	DRR(4)		*f*(5)	Grade(6)
4.6	48	70		120.0	G, P
9.0	11			142.0	G, P
9.0	13			178.0	G
12.0	13			164.0	G
12.0	18			354.2	G, P
					P
					P
					P
4.2 - 4.8	13	72		221.9	
			21 - 25		P
			22 - 26		P
			24 - 30		P
			34 - 38		P
			37 - 41		P
			41 - 45		P
					P
10.2	6			265.9	G, P
9.8	13			369.9	G, P
9.6	15				G
9.0	>15				G
7.1 - 7.3	13				P
10.0	> 6				P
10.0	37			400.1	G, P
9.6	15				G
6.9	> 60				P, Plate, Crush
6.7	23			305.9	P
3.4	(Slight)			897.8	
		100	24		P
		92			P-Reg., P-HiCal
		100			P
4.6	(Slight)	80	70	252.1	Fine Medium Coarse
4.6	(Slight)	80	62	234.1	FG
7.5	(Insoluble)			136.1	P-FCC, P-USP
7.5	(Insoluble)	33	18	172.1	P-FCC, P-USP
7.3	(Insoluble)			1004.7	Conditioner, NF, Polymer
6.0	(Insoluble)			254.1	P
4.6	21	65		136.1	G
10.5	> 60			330.3	60% Solution
4.6	28	62		115.0	G, P
8.0	41			132.1	G, P
1.6		172		98.0	Liquid

milk products, such as chocolate milk, by the addition of long-chain, insoluble potassium and sodium salts of polyphosphates; these then could be added to untreated, flavored, aqueous milk dispersions to maintain proper viscosities in the final product. Van Wazer[30] reported that the addition of small quantities of powdered TSPP to malted-milk powders improved the wetting of the particles, the color, and the flavor; it also stabilized the drink made from the powders through production of a thin gel.

Applications in High Butterfat Dairy Products

Butter Phosphates were used by Malkov and his co-workers[248] to remove iron and copper ions from solution and thus to stabilize butter against oxidative spoilage during storage. North[249] reported that phosphoric and other acids aided the clarification of butter oil by coagulating suspended materials that cause cloudiness. Meyer and Weck[250] reported that buffering milk with alkali salts, such as DSP, TSPP, sodium polyphosphates, etc., allowed sour whole milk to be used to prepare stable, sweet-tasting butter from its cream and to produce cheese from the milk. A 1:1 mixture of DSP and basic sodium citrates was especially effective.

Buttermilk Corbin and Long[251] reported a direct acidification, two-stage process for the production of buttermilk that had four times greater refrigerated shelf-life than cultured buttermilk. The process involved the treatment of the milk with ammonium or alkali-metal salts of orthophosphates and pyrophosphates prior to acidification; H_3PO_4 was used for acidification. The process required only 1–5 hours for preparation, compared to 15–48 hours for the cultured process. Van Wazer[30] reported that the addition of TSPP to buttermilk acted as a dispersing or deflocculating agent for the curd, which normally formed from casein in the acidic buttermilk; in contrast, TSPP acted as a gelling agent for milk at its normal pH.[217,218,233]

Cream The phosphates can improve the whipping properties, flavor, and stability of cream. Rothwell[252] obtained improved overrun and stability against leakage when whipping cream was treated with sodium alginate or TSPP, although the sodium alginate was more effective than the TSPP. Wilson and Herreid[253] reported that the flavor of sterilized cream was stabilized by the addition of a sodium polyphosphate with an average chain length of 5 to 7, plus ascorbic acid and/or α-tocopherol. Coffee cream that was served to the author in individual containers listed disodium and sodium tetraphosphates or DSP among its ingredients;[28] the label on the container reported the product to be half-and-half with stabilizers added.

Applications in Condensed and Evaporated Milks

Because they are canned and sterilized by retorting to approximately 240°F, condensed and evaporated milks must be stabilized against heat coagulation by the addition of either DSP or sodium citrate. Failure to do so results in gelling of the milk during storage.[27,30,110,111] The federal standard of identity for evaporated milk allows the processor to add $<0.1\%$ of anhydrous DSP.[254]

Condensed and evaporated milks can also be prepared by the aseptic canning techniques that have recently reached commercial development. Edmondson[255] found that it was necessary to control the initial viscosity of the

Product Name	Abbreviation	Synonyms	Formula
Monosodium Phosphate, Anhydrous	MSP	Monosodium dihydrogen phosphate Sodium phosphate, monobasic Sodium biphosphate Acid sodium phosphate Sodium phosphate, primary	NaH_2PO_4
Disodium Phosphate, Anhydrous	DSPA	Disodium monohydrogen phosphate Sodium phosphate, dibasic Neutral sodium phosphate	Na_2HPO_4
Disodium Phosphate, Dihydrate	DSPD	Disodium phosphate duohydrate	$Na_2HPO_4 \cdot 2\ H_2O$
Trisodium Phosphate, Anhydrous	TSPA	Trisodium orthophosphate Sodium phosphate, tribasic Basic sodium phosphate Sodium phosphate, tertiary	Na_3PO_4
Trisodium Phosphate, Crystalline Decahydrate	TSPC	Trisodium phosphate decahydrate	$Na_3PO_4 \cdot 10\ H_2O \cdot \frac{1}{4}\ NaO$
Emulsi-Phos® Phosphate Blends Emulsi-Phos 440 (Blend of DSPA & IMP) Emulsi-Phos 660 (Blend of TSPA & IMP) Emulsi-Phos 990 (Blend of TSPA & IMP)			
Sodium Acid Pyrophosphates Leavening Grades SAPP RD-1 SAPP 26 SAPP 28 SAPP 37 SAPP 40 SAPP 43 Nonleavening SAPP NL	SAPP	Acid sodium pyrophosphate Disodium dihydrogen diphosphate Dibasic sodium pyrophosphate Disodium pyrophosphate	$Na_2H_2P_2O_7$
Tetrasodium Pyrophosphate	TSPP	Sodium pyrophosphate tetrabasic Tetrasodium diphosphate Sodium diphosphate	$Na_4P_2O_7$
Nutrifos® Polyphosphates Nutrifos 088 Sodium Tripolyphosphate	STP	Pentasodium triphosphate Sodium triphosphate Triphosphoric acid, pentasodium salt	$Na_5P_3O_{10}$
Nutrifos B-90 (Blend of STP & SHMP) Nutrifos B-75 (Blend of STP & SHMP) Nutrifos H-30 (Blend of STP, SHMP & SAPP) Nutrifos L-50 (Blend of STP & TSPP)			
Nutrifos SK Sodium Potassium Tripolyphosphate	SKTP	Trisodium dipotassium triphosphate	$Na_3K_2P_3O_{10}$
Katch® Fish Phosphate (Polyphosphate Blend)			
Sodium Hexametaphosphate	SHMP	Graham's salt Sodium phosphate glass	$Na_{n+1}P_nO_{(3n+1)}$ n=13 - 18
Sodium Trimetaphosphate	STMP	Trisodium metaphosphate	$(NaPO_3)_3$
Sodium Aluminum Phosphates Levn-Lite® SALP Stabil-9® (Blend of SALP & AMCP) Pan-O-Lite® (Blend of SALP & MCP)	SALP		$Na_3A_{12}H_{15}(PO_4)_8$
H.T.® Monocalcium Phosphate Monohydrate	MCP	Calcium phosphate, monobasic Calcium phosphate, primary Calcium acid phosphate Calcium biphosphate	$Ca(H_2PO_4)_2 \cdot H_2O$
Py-Ran® Anhydrous Monocalcium Phosphate	AMCP		$Ca(H_2PO_4)_2$
Dicalcium Phosphate, Anhydrous	DCPA	Calcium phosphate, dibasic Calcium phosphate, secondary	$CaHPO_4$
Dicalcium Phosphate, Dihydrate	DCPD		$CaHPO_4 \cdot 2\ H_2O$
Tricalcium Phosphate	TCP	Calcium phosphate, tribasic Calcium hydroxyapatite	$Ca_{10}(OH)_2(PO_4)_6$
Calcium Pyrophosphate	CPP	Cal pyro Tetracalcium pyrophosphate (soft calcium pyrophosphate)	$Ca_2P_2O_7$
Monopotassium Phosphate	MKP	Acid potassium phosphate Potassium phosphate, monobasic	KH_2PO_4
Tetrapotassium Pyrophosphate	TKPP	Potassium pyrophosphate, tetrabasic Tetrapotassium diphosphate Potassium diphosphate	$K_4P_2O_7$
Monoammonium Phosphate	MAP	Ammonium biphosphate Ammonium phosphate, monobasic	$NH_4H_2PO_4$
Diammonium Phosphate	DAP	Ammonium phosphate, dibasic	$(NH_4)_2HPO_4$
Phosphoric Acid — 75%, 80%, or 85%		Acid orthophosphoric Acid monophosphoric	H_3PO_4

---

(1)pH = of 1% solution or 10% slurry (2)Solubility = g/100g saturated solution at 25°C (3)NV = Neutralizing Value (4)DRR = Dough Rate of Reaction (5)MW = Molecular Weight (6)G = Granular, FG = Fine Granular, P = F sterilized milk through the addition of calcium chloride and DSP to a level just below that which would cause immediate coagulation of the milk. Martynova[256] reported that the addition of DSP or sodium citrate to the milk prior to pasteurization increased the shelf-life and stabilized evaporated milk against thickening for at least 6 months of storage at room temperature. Ascorbic acid, vitamin A, glucose oxidase, and SHMP were effective inhibitors of Maillard-type discoloration compounds during an 8-month shelf-life test of sweetened condensed milk, which is especially susceptible to such discoloration; DSP and vitamin E were found to be ineffective.[257] Muller[258] found that DSP prevented the coagulation of evaporated milk prepared from skim-milk powder recombined with butter oil.

Applications in Sterile, Concentrated Milk

An aseptically canned, sterile, whole-milk concentrate recently was developed by dairy scientists. The milk, after concentrating, is given a high-temperature, short-time sterilization treatment; it then is canned under aseptic conditions in separately sterilized cans.[259-274] Some investigators have reported that the milk is stable at room-temperature storage for as long as 2 years, as either a 2:1 or a 3:1 concentrate, with the 3:1 concentrate being the most practical.

There are three major problems in the production of the sterile-milk concentrate, as defined in an excellent review by Seehafer.[259] First, the milk proteins tend to coagulate or gel during heat processing. Second, the concentrated milk is unstable during storage, since it has a tendency either to form gels or to separate into a solid and a serum phase during storage. The third major problem is that of flavor stability. Polyphosphates have been reported by numerous investigators to improve the heat and storage stabilities of the sterile-milk concentrates.[259-267] The addition of polyphosphates, ranging from sodium tetrapolyphosphate through the very-long-chain sodium polyphosphates, has been reported to increase the storage life from 3-fold to as much as 10-fold over the sterile, concentrated milk given no phosphate treatment. The level of phosphates used has been reported to range from 0.01–1.0%.[262,263] According to Herreid and Wilson[264] the polyphosphate molecule penetrated the casein micelle to combine with the proteins and calcium, to bind the calcium, and to form covalent linkages to the stable calcium–caseinate, calcium–orthophosphate complex, thus retarding gelation. Leviton[240] reported that the polyphosphates were almost instantly hydrolyzed to pyrophosphate during the sterilization process (15 seconds, heating at 137.8°C). He further speculated that the pyrophosphate resulting from this hydrolysis formed cross-linkages within the casein micelle that stabilized the micelle. When pyrophosphate was added directly to the milk, Leviton believed it interacted with the magnesium and calcium ions to form insoluble colloidal complexes; it was, therefore, unavailable to stabilize the casein micelles in the same manner as the pyrophosphate derived during the hydrolysis of polyphosphates.

Milks produced at different seasons of the year have different heat stabilities during the sterilization step, according to Swanson and Calbert.[265] A computer program has been developed by Magnino[266] and by Bixby and Swanson[267] for use in correlating the characteristics of milk at various seasons with the necessary processing conditions to produce stable, sterile-milk

Table F - Applications by Product

Solutia Product	Applications		
Pyrophosphates			
Sodium Acid Pyrophosphate	Bakery Mixes Baking Powder Canned Seafood Cured Meats	Icing & Frostings Imitation Cheese Potatoes Poultry	Processed Cheese Processed Meat Seafood Vegetables
Tetrasodium Pyrophosphate	Cured Meat Flavored Milk Powders Instant Cheesecake Instant Pudding	Pet Food Poultry Processed Meat Seafood	Starch Vegetables Whipped Topping
Tetrapotassium Pyrophosphate	Cured Meat Flavored Milk Powders Instant Cheesecake Instant Pudding	Pet Food Poultry Processed Meat Seafood	Starch Vegetables Whipped Topping
Polyphosphates			
Sodium Tripolyphosphate	Dips Eggs Meat Pet Food Poultry	Processed Cheese Seafood Sour Cream Table Syrup Vegetable Protein	Vegetables Whey Whipped Toppings Yogurt
Sodium Trimetaphosphate	Starch	Vitamins	
Sodium Hexametaphosphate	Cream Eggs Half & Half Ice Cream	Meat Poultry Processed Cheese Seafood	Table Syrup Vegetables Whey Whipped Toppings
Sodium Potassium Tripolyphosphate	Dips Eggs Meat Pet Food Poultry	Processed Cheese Seafood Sour Cream Table Syrup Vegetable Protein	Vegetables Whey Whipped Toppings Yogurt

concentrates. The nutritional properties of the sterile, concentrated milks were found to be equivalent to those of spray-dried whole milk by Bolt and Kastelic.[270]

The reactions of consumers to the sterile, concentrated milks were reported to be highly favorable in a number of investigations.[265,271,273] Their favorable reactions probably were influenced by the fact that these milks could be sold at a lower price than milk delivered to the home and that they require no refrigeration.

The polyphosphates also have been reported to be useful in the stabilization of frozen and irradiated, concentrated milks against gelling and other instabilities during storage.[275-279] In spite of the reports indicating successful processes for production of concentrated, sterile milks and their acceptance by the public, a demand does not yet seem to exist. However, if increases in labor costs and the costs of delivery continue, this situation may very well change.

Applications in Milk Gels and Puddings

Instant, milk-gel puddings have largely replaced the former cooked, starch puddings as desserts in the U.S. household. The milk-gel puddings are purchased as dry mixes. Cold milk is added to the mix; the mixture is blended thoroughly and allowed to set for a short time at refrigerator temperatures. In one type of mix, the milk is gelled by the action of TSPP on the milk proteins in the presence of calcium acetate;[30,280] the calcium ion acts as a coagulation or gelation accelerator, causing the mixture to set up to pudding consistency after about 10 minutes. Another type of mix utilizes MCP $\cdot$ H_2O as the gelation accelerator and also includes acetylated monoglycerides.[281] A third type utilizes orthophosphates, such as MSP and DSP, as gelation accelerators in place of the calcium salts.[282] Typical formulations from these three types of pudding mixes are summarized in Table 15.

The optimum pH for acceptable puddings ranges between 7.5–8.0. Although some of the necessary alkalinity is contributed by the TSPP, it is often necessary to add alkalizing agents. Not all lots of TSPP will produce firm, nonlumping puddings in reasonable setting times of 10–15 minutes after the addition of the milk.[283] Thus, it is necessary for manufacturers to test all batches of TSPP in order to select those that will provide acceptable puddings. At least one manufacturer now labels his acceptable batches as "Pudding Grade."

Other recent developments have demonstrated that pudding-like milk gels can be prepared from combinations of carrageenan and milk in the presence of phosphates, such as SHMP, STP, TSPP, and TSP.[284] Another report utilizes combinations of TSPP and sodium hydroxide with an additional calcium phosphate for milk puddings.[285] Partridge[286] prepared milk gels by using water-insoluble, crystalline potassium metaphosphates, solubilized by the addition of a compatible, edible sodium salt. The resulting milk gels could be used to stabilize chocolate-milk preparations, improve the viscosity of cream, and improve ice cream and sherbet mixes, custards, puddings, and milk-containing confectionery products.

A recent development has been the marketing of refrigerated or frozen ready-to-eat puddings that, according to McGowan,[287] utilize TSPP and sometimes DSP to provide proper gelling of the milk proteins and the desired

Table F - Applications by Product

Solutia Product	Applications		
Acids			
Phosphoric Acid	Beef Jerky Beer Cola Beverages	Cottage Cheese Fats & Oils Fillings	Jams & Jellies Pet Food Sugar
Adipic Acid	Bakery Mixes Candy	Desserts Gelatin	Jams & Jellies Pudding
Orthophosphates			
Monoammonium Phosphate	Breads & Doughs	Cheese Starter Cultures	Yeast
Diammonium Phosphate	Breads & Doughs Cheese Starter Cultures	Cookies Crackers	Yeast
Monosodium Phosphate	Cola Beverages Dry Powder Beverages Egg Yolks	Gelatin Instant Cheesecake	Instant Pudding Isotonic Beverages
Disodium Phosphate	Breakfast Cereal Cheese Condensed Milk Cream Evaporated Milk Flavored Milk Powders Gelatin	Half & Half Ice Cream Imitation Cheese Infant Food Instant Cheesecake Instant Pudding Isotonic Drinks	Nonfat Dry Milk Pasta Pet Food Processed Cheese Starch Vitamin Capsules Whipped Topping
Trisodium Phosphate	Cereals Cheese	Imitation Cheese Isotonic Beverages	Processed Cheese
Monopotassium Phosphate	Breads & Doughs Dry Powder Beverages Eggs	Isotonic Beverages Mineral Supplement	Starter Cultures Yeast
Monocalcium Phosphate	Bakery Mixes Baking Powder Dough Conditioner Dry Powder Beverages	Flour Fruits Infant Food Milk-Based Beverages	Multivitamin Capsules Pet Food Pudding Yogurt
Dicalcium Phosphate	Bakery Mixes Cereals Dry Powder Beverages Flour	Food Bars Infant Food Milk-Based Beverages Mineral Supplementation	Multivitamin Tablets Pet Food Yogurt
Tricalcium Phosphate	Cereal Dry Powders Grated & Powdered Cheese Infant Food Lard	Milk-Based Beverage Mineral Supplementation Multivitamins Pet Food Polymers	Salt Spice Blends Sugar Yogurt
Sodium Aluminum Phosphate	Bakery Mixes	Baking Powder	
Dimagnesium Phosphate	Bakery Mixes Beverages	Cereals Infant Formula	

firmness of the gel. TSPP is also useful in the preparation of instant cheesecake fillings that require only the addition of milk; the mixture then is blended thoroughly and poured into a prepared, baked graham-cracker crust. After being refrigerated for 15 minutes, the instant cheesecake is ready to serve.

TABLE 15
Instant Pudding-mix Formulas for Addition to One Pint of Cold Milk

Ingredients	*Patent 2,607,692*[a]		*Patent 2,801,924*[b]		*Patent 3,231,391*[c]
	Vanilla, g	*Chocolate, g*	*Vanilla, g*	*Chocolate, g*	*Unflavored,*[d] *g*
Sucrose	82.4	81.2	66.5	65.5	78.3
Pregelatinized starch	20.0	22.0	20.0	26.0	16.7
Cocoa	—	16.0	—	16.0	—
Vanilla flavor	2.0	2.0	2.5	1.4	—
Salt	2.4	2.4	—	—	0.6
Color	2.6	—	0.3	0.4	—
TSPP	2.8	2.8	1.5	1.5	2.2
Calcium acetate	1.2	1.2	—	—	—
MCP·H_2O	—	—	—	—	1.6
DSP, anhydrous	—	—	1.5	3.0	—
Acetylated monoglyceride	—	—	—	—	0.6
Total mix weight	113.4	127.6	92.3	113.8	100.0[d]

[a] From Kennedy, M. H., and Castagna, M. P. (Standard Brands, Inc.), U.S. Patent 2,607,692, 1952; with permission.

[b] From Clausi, A. S. (General Foods Corporation), U.S. Patent 2,801,924, 1957; with permission.

[c] From Breivik, O. N., Slupatchuk, W., Carbonell, R. J., and Weiss, G. (Standard Brands, Inc.), U.S. Patent 3,231,391, 1966; with permission.

[d] The addition of flavors and colors to this mix is usually required.

Typical formulas for ready-to-eat puddings and cheesecake fillings are summarized in Table 16.

The phosphates, particularly polyphosphates, can be used to form very thin gels of milk protein in order to reach a sufficient viscosity to suspend chocolate particles throughout chocolate milk.[288] They also can form proteinaceous gels from casein or sodium caseinate by means of orthophosphate, pyrophosphate, and a soluble calcium salt for use in binding water and reducing the migration of fat in various types of food compositions.[289]

Several studies have been made of the gelling phenomena of phosphates in milk. Fox and his co-workers[231] reported that orthophosphates have little effect on milk viscosity at concentrations below 15 mmol. Higher concentrations of orthophosphate tend to form milk gels in direct relation to the concentration of the orthophosphate. In contrast, the polyphosphates retard milk gelation when they are present below certain critical concentrations, which differ for each polyphosphate, but they form protein gels above those critical concentrations. This work of Fox *et al.* appears to explain why polyphosphates can be used in low concentrations to prevent the gelation during storage of sterile concentrated milk, and yet they can be used at higher concentrations to form milk gels. Zittle[217] studied the interaction between the positively charged

Dental Applications of Solutia Phosphates

Phosphates are used in a variety of dental applications. More effective dentifrices have been developed over the last two decades, combining therapeutic (anticaries), cosmetic (whitening, tarter control), and cleaning benefits. Solutia produces a complete line of calcium phosphate products which span a wide range of abrasive levels for use as polishing agents, including dicalcium phosphate dihydrate, dicalcium phosphate anhydrous, calcium pyrophosphate and Lustre-Phos®. Other phosphates, including sodium and potassium pyrophosphates, sodium tripolyphosphate and tricalcium phosphate, are currently being used in dentifrices and mouth rinses for functions such as anti-calculus activity and sensitive teeth protection.

Pet Food Applications of Solutia Phosphates

Phosphates and phosphoric acid are used in pet foods for the same functionalities they exhibit in human food. For cats, it is important to provide the correct pH in order to meet the cat's palate requirements. Phosphoric acid is used to adjust the pH of both dry and moist food products. The polyphosphates (STP, SKTP, TKPP, TSPP, SHMP) can be used to solubilize protein in the production of canned pet food for both canines and felines. The solubilized protein provides binding and moisture retention, which aid in product release from the can.

The orthophosphates (MSP, DSP, TSP and MKP) are incorporated for pH and buffering. The calcium phosphates are used to provide nutrient supplementation in both pet food and animal feed. The potassium salts can be used to increase potassium levels in food for cats. This aids in the prevention of urinary tract disease. In animal feeds, phosphoric acid is used to adjust the pH for palatability for many different animals. Sodium and potassium phosphates can be used in salt blocks. Phosphates (STP and SAPP) are also Generally Recognized As Safe (GRAS) as general-purpose additives in Animal Feed and Pet Foods and are listed in Title 21 CFR 582. The use of phosphates in animal feed products is regulated by Association of American Feed Control Officials, Incorporated (AFCO).

Technology, New Applications and Formulations

Whether it's new technology for your company or for the industry, Solutia has a staff of technical specialists prepared to assist you in designing a product that meets your specifications. Solutia researchers are continually exploring new trends and are available to assist in optimization of products.

For most applications, a recommendation is available on which phosphate to use and what level to use it. For many applications, starting formulations can be provided.

Solutia stands ready as your partner to create the best food products possible!

casein and the negatively charged pyrophosphate ions, which results in the reduction of the casein net charge and its precipitation; this interaction is similar to the one that occurs at the isoelectric point of casein. The gelling effect of the pyrophosphate on milk proteins is completely reversed if the milk is heated.

TABLE 16
Formulas for Ready-to-eat Puddings and Cheesecake Filling

Ingredients	*Firm-bodied Pudding,*[a] %	*Creamy Pudding,*[a] %	*Cheesecake Filling,*[b] %
Cheese, dried			9.61
Sugar (sucrose)	6.44	10.00	7.69
Corn sugar (dextrose)	6.87	4.35	3.08
Cornstarch, modified	4.94	2.61	3.84
Tapioca starch, modified	1.07	2.61	
Nonfat dried milk	7.78		
Buttermilk, dried			7.69
Whole milk, liquid		66.95	61.51
Shortening, dry	2.68		5.77
Salt	0.11	0.22	0.38
TSPP, anhydrous	0.05	0.22	0.31
$MCP \cdot H_2O$			0.12
DSP, anhydrous	0.04		
Water	70.02	13.04	
Flavor	*q.s.*[c]	*q.s.*	*q.s.*
Color	*q.s.*	*q.s.*	*q.s.*
Total	100.00	100.00	100.00

[a] Adapted from McGowan, J., 1970. *Food Prod. Devel.* 4(5):16, 18.
[b] Courtesy of Stauffer Chemical Company.
[c] A sufficient quantity (*quantum sufficiat*).

TABLE 17
Effect of Various Ingredients on Starch-free, Cold-milk Gel

TSPP[a]	*MCP*[b]	*Alginate*	*Milk*	*Viscosity, cps*
X	X	X	X	33 700
X	X	X		19 200
X	X		X	6 400
X			X	3 200
		X	X	0
		X		0

Source: Lauck, R. M., and Tucker, J. W., 1962, *Cereal Sci. Today* 7(9):314, 322.

[a] TSPP—tetrasodium pyrophosphate.
[b] MCP—monocalcium phosphate monohydrate.

Lauck and Tucker[233] studied starch-free, cold-milk gels prepared with various combinations of TSPP, $MCP \cdot H_2O$, alginate, and milk. As shown in

Vegetables

Nutrifos 088, Sodium hexametaphosphate (SHMP) or **Tetrasodium pyrophosphate** (TSPP) are used in the canning or freezing of fresh peas or beans to improve tenderness. These phosphates, included in the wash or blanch water, can prevent toughening of skins due to absorption of calcium and magnesium from the water.

Egg Products

Phosphates serve a multitude of functions in processed eggs:

- Nutrifos 088 and SHMP inhibit development of rancidity in yolk lipids
- MSP and MKP preserve the color of egg yolk during refrigerated or frozen storage
- Nutrifos 088, Nutrifos B-90 or SHMP can prevent the coagulation of dried eggs during the heat-intensive drying period
- SHMP or Nutrifos 088 improve whipping efficiency and foam stability in dried-egg products. This improves functionality of the dried egg in cakes and meringues.

Fats and Oils

- Phosphoric acid acts synergistically with other additives to prevent oxidative rancidity in vegetable shortening
- TCP added to lard and then filtered out removes color and absorbs iron, which promotes rancidity
- Phosphoric acid can be used in the degumming processes for the purification of soy and other vegetable oils. It also provides pH control and ties up small amounts of transition metal ions, such as iron, nickel and copper, which catalyze the development of rancidity.

Miscellaneous Food Applications

Flow Conditioning

TCP is generally applicable as a flow conditioner for powdered and fine granular products due to its small particle size and inertness.

Gelatin Desserts

MSP and disodium phosphate (DSP) serve as buffers in gelatin desserts. They control the water-binding capacity, which is dependent on pH.

Peanuts

SHMP and Nutrifos 088 are used to economically salt peanuts in the shell by making it possible for brine to quickly penetrate into the shells.

Gels and Gums

Gel strength of alginate, agar, carrageenan and other gums is modified by the presence of phosphates, such as TSPP, TKPP, DSP, DCP, SHMP and Nutrifos 088. Polyphosphates also can retard syneresis in these gels.

Microbiological Operations

Phosphoric acid and phosphate salts are used as nutrients and buffering agents in microbiological operations, such as yeast and antibiotic production.

Sugar Processing

Phosphoric acid aids in the clarification step in sugar processing. Impurities are removed by treating heated sugar liquid with phosphoric acid and lime in a long, shallow tank in the presence of air introduced from the bottom of the tank. The precipate of calcium phosphate, together with occluded insolubles and non-sugars precipitated from the liquid, is carried to the top to form a scum, which is separated mechanically. The scum is filtered to recover contained sugar, but the liquor itself is not filtered. The process is superior to the older procedure (of only liming the liquid) with respect to removal of colored and other soluble impurities.

Salad Dressing

Phosphoric acid is employed in small amounts to impart an acidic flavor to salad dressings. It is also used to increase the biological activity of preservatives in the dressings.

Jams and Jellies

Phosphoric acid is used in the jam and jelly industry, especially for preparing firm, nonsoaking jellies, such as those used in doughnuts, jelly rolls and cake fillings. The acid is added during the final stages of cooking to minimize hydrolysis of the pectin. Phosphoric, together with citric and tartaric acid, is used as a buffering agent to control the acidity so as to give the firmest pectin gel and, at the same time, to complex heavy metal cations, such as iron, which give a dull color to the jelly.

Table 17, they produced the highest viscosities when all four ingredients were present; however, substantial viscosities were produced in gels formed without the presence of milk at all by using the calcium phosphate as a calcium source. The authors hypothesized that the gels formed by treating milk with TSPP were those formed between calcium and TSPP rather than between the milk protein and the pyrophosphate.

Applications in Nonfat Milk

The phosphates have been found to improve the properties of dried and liquid skim-milk products through their interactions with the milk proteins and through their ability to complex calcium.[290-298] The solubility of nonfat milk solids for food use could be increased by adding metaphosphates,[290] MSP, DSP, or citrates[291,298] to the milk either before drying or after reconstitution. The addition of the solubilizing compounds to the milk prior to drying was more effective than when it was added during reconstitution.

Curry[292] prepared a skim-milk colloid with excellent fat-emulsifying properties for use in table spreads, ice cream, and similar high-fat dairy foods. He treated the skim milk with TSPP to form a stiff gel and hydrolyzed the lactose to produce the emulsifying colloid.

Lindewald and Kimstad[293] increased the whipping properties of milk casein so that it could be used as a replacement for egg white. The casein was coagulated with rennet, and then the suspended protein was treated with orthophosphate or pyrophosphate at pH 6.3-6.7. Lewis and her co-workers[294] significantly improved the whipping qualities of nonfat-milk solids by the addition of 1% SHMP or STP, which formed very stable foams. Sodium citrate and EDTA also improved foaming properties, but the foams were very unstable. Table 18 illustrates the effects of various calcium sequestering agents on the whipping ability of nonfat-milk solids. Table 19 illustrates the effects of SHMP and STP on the whipping properties and stability of a high-quality preparation of nonfat-milk solids.

TABLE 18
Effect of Various Sequestering Agents on the Whipping Ability of Nonfat-milk Solids

Sequestering Agent Added (1% in Nonfat-milk Solids)	*Increase in Volume,* %	*Drainage in 20 Min,* %
Control	330	100
Sodium orthophosphate	370	100
Sodium tripolyphosphate	750	64
Sodium hexametaphosphate	750	56
Maddrell's salt	560	100
Sodium citrate	660	100
Versene	610	100

Source: Lewis, M. A., Marcelli, V., and Watts, B. M., 1953, *Food Technol.* 7:261-264, Table 1. Reprinted by permission.

Kempf and Blanchard[295] prepared a dried coffee whitener from either fluid or concentrated milk by treating the milk with 1.4-3.7% DSP prior to drying.

Other Applications of Solutia Phosphates

Pharmaceutical and Nutritional Products

The calcium phosphates are broadly utilized in nutritional supplementation and fortification, since they are a quality source of both calcium and phosphorus. For infant foods and formulas, the calcium phosphates provide both calcium and phosphorus, essential nutrients for proper growth and bone development. The fine particle size of both DCP and TCP make them particularly useful in infant formulas. Both DCP and TCP can be used as excipients for tableting applications in vitamins and drugs.

Mag-nificent is an ideal source of magnesium and phosphorus for a number of products, such as infant formula, geriatric beverages, nutritional supplements, vitamins and ready-to-eat cereals. It is compatible for use with calcium phosphates, so that all the essential minerals can be balanced.

Beverages

Phosphoric acid is used as an acidulant for cola and root beverages. The usual cola contains about 0.05% phosphoric acid and has a pH of about 2.3. Root beer has a higher pH of about 5.0 and contains 0.01% phosphoric acid. On a price performance basis, phosphoric acid is less expensive than organic acid alternatives. It provides many advantages in the formulating of these products:

- Sparkling bite and astringency counteract the heaviness of root and cola flavors
- Low pH improves flavor and storage stability
- Chelation of troublesome metal ions helps establish a stable carbonation

Monocalcium phosphate monohydrate (MCP) can be used in the formulation of beverage powders. MCP has many benefits:

- Economical pH buffer to control tartness
- Nonhygroscopic acidulant replaces up to 50% of citric acid
- Calcium and phosphorus are contributed to the products' nutrient profile.

Tricalcium phosphate (TCP) is also commonly used for dry powder formulations where it contributes several useful properties:

- Flow conditioner for dry base products
- Clouding agent in reconstituted beverages
- Calcium and phosphorus are contributed to the products' nutrient profile

Monosodium phosphate (MSP) and **Monopotassium phosphate** (MKP) are used in isotonic formulations. They are added to the formulation to replace sodium and/or potassium that are lost as a result of athletic or physical activity.

In nutritionally fortified beverages, the metal complexing properties of polyphosphates afford protection for Vitamin C, which is readily oxidized in the presence of some metal ions.

Monoammonium and Diammonium phosphates are used in the wine industry in production of sparkling wines.

Produce

Potatoes

Sodium acid pyrophosphate non-leavening (SAPP NL) and **Tetrasodium pyrophosphate** (TSPP) are used for several processed potato applications:

- Protection from after-cooking darkening in french fries and frozen potatoes. This iron-induced phenomenon is eliminated by the metal-complexing ability of SAPP NL and TSPP.
- Production of dehydrated mashed potatoes where SAPP NL or TSPP are added during mixing, just before drying
- Protection of color in sweet potatoes by SAPP NL, TSPP, or SAPP NL plus Nutrifos 088

Fruits

Calcium phosphates, such as MCP, are used to increase the firmness in canned fruit by increasing the calcium pectinate content. Other fruit applications include:

- Phosphoric acid to furnish acidity and optimal gel strength in jellies or bakery filling
- Polyphosphates to delay color changes in preserves made from red berries
- Sodium hexametaphosphate (SHMP) to extend shelf life of apple cider and other juices

A heat treatment also was involved; the authors reported a direct relationship between the DSP level and the heat and time necessary to prepare an acceptable product. Kumetat[296] prepared a replacement for whole eggs for use in sponge-cake and similar baked products by treating concentrated milk or suspensions of casein with calcium-sequestering polyphosphates or citrates and then heating them. Hayes and his co-workers[297] demonstrated that STP could be used to disperse suspensions of calcium caseinate; the level of STP had to be varied according to the amount of calcium in the caseinate.

TABLE 19
Effect of Polyphosphates on Whipping Ability of High-quality, Nonfat-milk Solids

Added Polyphosphate (4% of Milk Solids)	*Milk Solids in 50 ml Water, g*	*Volume Increase, %*	*Drainage in 2 hr, %*
Control	10	560	60
Hexametaphosphate	10	800	50
Tripolyphosphate	10	750	52
Control	31	390	10
Hexametaphosphate	31	420	0
Tripolyphosphate	31	420	0

Source: Lewis, M. A., Marcelli, V., and Watts, B. M., 1953, *Food Technol.* 7:261-264, Table 2. Reprinted by permission.

Applications in Frozen Dairy Desserts

The beneficial effects of phosphates on the properties of ice cream and similar dairy products have been frequently reported.[30,299-304] Until 1967 phosphates were allowed only in chocolate ice cream and similar frozen desserts as stabilizers for chocolate suspensions. Since then, however, the phosphates have been approved for use in other dairy desserts.

Phosphates are utilized in frozen desserts to stabilize fat particles against agglomerating and forming what is called "sandy" ice cream. This phenomenon is also known as *churning*. Churning has been prevented by the addition of DSP, TSPP, SHMP, and sodium citrate at levels too small to affect the pH or to allow the processor to neutralize acidic or spoiled cream for the manufacture of the frozen dessert.[300-302] As a result these compounds are now allowed in frozen desserts at levels up to 0.2%.[303] Wallander[304] reported that the treatment of milk with polyphosphates retarded lipase activity and, thus, improved flavor stability.

Applications in Whey, Lactose, and Lactalbumin

The phosphates have been shown by a number of investigators to improve the properties of cheese whey; thus, more whey can be used in food processing.[28] Whey is the liquid residue remaining after cheese curd has been removed from

Some of the major applications for phosphates in the dairy industry are described in Table E, along with recommended usage levels for each particular application.

Table E - Dairy Applications of Solutia Phosphates

Application	Phosphates	Usage Level
Evaporated, Condensed Milk, Cream	DSP	0.02-0.10% of final product
Flavored Milk Powders	TSPP, TKPP	0.1-0.3%
Non-Dairy Coffee Creamers	DSP	1.0-2.0% of dry product 0.1-1.0% of liquid product
Buttermilk	TSPP, TKPP, Phosphoric Acid	0.01-1.0%
UHT Concentrated Milk	SHMP	0.1-1.0%
Dried Milk-Drink Products	DSP	2.0% milk solids' weight
Sterile Concentrated Milk, Cream	SHMP	0.1-1.0%
Instant Pudding, No-Bake Cheesecake	TSPP, DSP, MCP, SAPP, STP, TKPP	2-7% total phosphate
Milk Foams	TSPP, TKPP, SHMP	1.5-2.0% milk solids' weight
Imitation Sour Cream, Chip Dips	STP	0.05-0.20% oil basis
Spray-Dried Cheese	DSP, SHMP	1-3%
Canned Cream and Cheese Soups	DSP	0.2%
Whipped Toppings	TSPP, TKPP, DSP	0.025-1.0% of complete liquid base
Process Cheese	Emulsi-Phos 440, 660, 990, MSP, DSP, TSP, MKP, SAPP, TSPP, SHMP, TKPP	0.5-3.0%
Cheese Sauce	DSP, TSP, SHMP	0.5-3.0%
Starter Cultures	DSP, MAP, DAP, MKP	2-3%
Frozen Desserts, Ice Cream	DSP, TSPP, SHMP, TKPP	0.1-0.2% of final product
Direct-Set Cottage Cheese	MCP, Phosphoric Acid	0.03%

milk in the processing of natural-cheese products. About 4.2 billion pounds of the 14 billion pounds of whey produced annually is processed for human and animal feed; the balance is often a serious pollutant in streams adjacent to cheese-processing plants.[305] Approximately 26% of the whey that is processed is used for the production of lactose; 11% is used for the manufacture of whey proteins, while the balance is dried for use in human or animal foods.

The polyphosphates have been implemented in the manufacture of lactose to maintain the whey proteins in a soluble state, while the liquid is concentrated to the point where lactose crystallizes from the solution.[306,307] Ward and his co-workers[308] produced a dried whey product that overcame many of the problems resulting from the replacement of dried milk with whey in baked products. They added a soluble calcium compound and a soluble phosphate compound, then neutralized the liquid whey prior to drying to pH 6.8–7.5. The treated dried whey tolerated the addition of amounts of moisture somewhat similar to dried milk, while it still maintained good structural properties in the dough.

The 14 billion pounds of liquid cheese whey represents a potential source of approximately 70 million pounds of whey protein. Arena[309] reported that undenatured whey protein, commonly called *lactalbumin*, is similar to the proteins of human milk; therefore, it is nutritionally more valuable than casein, the major protein of cow's milk. The lactalbumin commercially available usually is obtained during the processing of lactose from whey. As it is highly denatured by heat, it is probably nutritionally less valuable than undenatured lactalbumin.

The abilities of long-chain polyphosphates to react as polyanions and of large protein molecules to react as polycations have been utilized to isolate undenatured proteins.[28,30,234–239] Gordon[310] isolated undenatured whey proteins from liquid whey by the use of SHMP or longer-chain polyphosphates. McKee and Tucker,[311] Wingerd,[312] Hartman,[313] and Hartman and Swanson[314] have extended Gordon's work, reporting processes for the preparation of undenatured lactalbumin or the complex of lactalbumin-polyphosphate. The sodium and the calcium salts of lactalbumin-phosphate are now commercially available.[315] McKee and Tucker[311] have reported that lactalbumin-phosphate would replace part or all of the nonfat-milk solids used in the preparation of many baked products. Wingerd[316,317] used lactalbumin-phosphate in the preparation of instant, cold-water-soluble gelatin products and of liquid-type emulsifiers for use in preparing food emulsions.

Ellinger[318] used lactalbumin-phosphate to replace sodium caseinate both functionally and nutritionally in the preparation of imitation dairy products; Broadhead[319] used it to replace part or all of the egg white in layer cakes, angel food cake, doughnuts, pancakes, and similar baked products.

The ability of the polyphosphates to improve protein dispersion is utilized in processing foods, such as whey products. Endo[320] added sodium polyphosphate to whey and other milk products that were then used in the preparation of mayonnaise-like products. Ellinger and Schwartz[321] added polyphosphates to liquid and dried whey, demineralized whey, and similar modified whey products to improve the dispersion of the whey proteins; the phosphate-treated whey products could be used to form stable, imitation dairy products, while the untreated wheys would not function in such a manner.

Natural Cheese

Phosphates can be used during the production of natural cheese. Bacteriophages typically require free calcium to multiply in starter cultures. Through precipitation of calcium by DSP, these cultures can be protected from phages. Ammonium and potassium phosphates are used to supply valuable nutrients to the starter culture media.

During cheese manufacture, milk can be directly acidified by MCP or phosphoric acid to decrease processing time, increase yield, and increase calcium levels in cheese, especially cottage cheese. The use of TSPP will also shorten processing time. It is added with the culture, rennet and phosphoric acid to produce a curd that can be molded and allowed to start the aging process immediately.

Dried Milk Products

Incorporating DSP into skim milk before drying yields a nonfat dry milk that will dissolve more smoothly in water. The phosphate keeps milk proteins dispersed by protecting them from heat coagulation during spray drying.

Powdered TSPP helps disperse and suspend cocoa and malted milk powder in milk, thus minimizing sediment. In addition, incorporating TSPP at the appropriate level promotes formation of a thin gel layer around the milk proteins. The gel enriches both the flavor and the color and contributes to the smooth mouthfeel of the final beverage.

The use of instant pudding and "no-bake" cheesecake mixes depends on the reaction between TSPP and calcium in the milk protein, which induces gelation. The addition of DSPA will accelerate setting of the pudding but may not be necessary, depending on the calcium content of the milk protein. In some cases, calcium is added to the pudding system in the form of MCP to strengthen the gel.

DSP and SHMP are commonly used during the production of spray-dried cheese. These phosphates protect milk proteins from heat denaturation. In addition, they act to disperse milk proteins upon spray drying to assist in solubility of cheese powder upon reconstitution with water. They also stabilize the protein-water-fat emulsion to enhance flavor, body and appearance of the reconstituted product.

Fluid Milk Products

To prevent heat coagulation in condensed and evaporated milk or cream, DSP is used to stabilize casein in the milk.

Sterilized milk, cream and half-and-half products, including UHT concentrated products, gain added storage life when stabilized with DSP or SHMP to prevent age gelation during storage. Buttermilk produced by direct acidification via the addition of phosphoric acid has a reduced processing time and a longer refrigerated shelf life than cultured buttermilk. Addition of TSPP prior to acidification acts as a dispersing agent for the curd that would normally be formed in the acidic medium. Thus, TSPP enhances: flavor, viscosity, body, stability to whey-off, and appearance of buttermilk.

Cream Products

To maintain fat dispersion in ice cream mix, DSP, TSPP or SHMP may be added so "churning" will not form lumps of butter during the freezing operation. In chocolate ice cream, DSP, TSPP and SHMP also function to maintain a stable chocolate suspension. These phosphate ingredients can also serve the same purpose in other frozen desserts.

DSP is used in canned cream and cheese soups which are subjected to high sterilization temperatures. The DSP functions as a stabilizer to prevent proteins from flocculation and to maintain a smooth appearance and taste.

The addition of STP in imitation sour cream and chip dips controls syneresis. STP interacts with proteins to promote swelling of the molecules.

Whipped Toppings and Non-Dairy Coffee Whiteners

Whipped toppings of various composition obtain increased whipping efficiency and foam stability from addition of TSPP. By stabilizing the protein films, SHMP inhibits weeping in milk-based toppings, while DSP functions similarly in products based on other protein sources such as soybean.

In non-dairy coffee whiteners, a phosphate buffering system consisting of DSP, SAPP and/or STP contributes to stability of the protein layer around the fat droplets, thus preventing syneresis. This buffer system also prevents feathering and fat separation when the coffee whitener is added to the hot acidic coffee medium. TSPP has also been used as a stabilizing agent to help disperse soy proteins.

Applications in Imitation Dairy Products

The high cost of milk and the marketing success of margarine, the first imitation dairy product, have stimulated dairies, as well as other food manufacturers, to market other imitation dairy products. Two types of imitation dairy products are now being marketed in those areas where they are legally acceptable. One type is designated as a "filled" dairy product; it is prepared by replacing only the butterfat with vegetable fat, while utilizing all other constituents of the natural dairy product. The second type is labeled "imitation" dairy product; it contains no dairy constituents. Imitation dairy products are combinations of vegetable fat, sugars, proteins (such as soy and whey proteins or sodium caseinate), stabilizers, emulsifiers, and sufficient water to prepare a product that closely resembles the appearance and other characteristics of the real dairy product. Vitamins and minerals are added to some of these products in order to duplicate the nutritional properties of the natural dairy products.[322-324]

Although very few of the filled products contain phosphates, they would be most useful in them. The imitation dairy products utilize phosphates as buffers to maintain the optimum pH for protein dispersion; thus, they aid in stabilizing the fat particles in the product. The most common phosphates in use are DSP or DKP; DKP is usually preferred, because it does not contribute as much astringent flavor as DSP.

Imitation Milk Replacements for liquid milk have begun to appear in the larger markets on the east and west coasts of the United States. These completely synthetic products duplicate very closely the appearance, textural properties, and nutritional characteristics of cow's milk.[322-327] Some are bases that require the addition of water, and perhaps a vegetable fat; the mixture is then pasteurized, homogenized, and packaged for sale to the consumer.[323,327] Ingredient costs for imitation milks appear to be approximately one-half of the cost for similar unit volumes of cow's milk.[322-324]

Kozin and Rodionova[325] studied the effect of adding increasing quantities of DSP to an imitation-milk emulsion. The pH decreased from 6.95 to 6.2 as the level of DSP was increased from 0.1 to 0.25 g/g protein; the protein began to precipitate at this pH. As more phosphate was added, however, the pH rose and finally reached 7.3 at 0.5 g phosphate/g protein. The precipitated protein was redispersed as the phosphate increased, and the size of the fat globules decreased with increasing phosphate. Sabharwal and Vakaleris[326] reported that the addition of calcium ion, phosphate, and citrate salts at the proper levels in the proper sequence was necessary to prepare stable imitation-milk emulsions. They developed a heat- and storage-stable, synthetic milk system, containing all of the minerals of regular milk, by adding the salts in the following order: citrate, calcium, and phosphate.

Coffee Whiteners Replacements for liquid coffee cream have been marketed in the United States for approximately 20 years. One of the first to appear was a "dried cream," which was prepared from liquid cream that had been treated with DSP.[328] A similar product was prepared from dried milk by Brochner,[329] who added alkali-metal phosphates or citrates, or mixtures of the two, and additional lactose to produce a powdered coffee whitener.

Completely synthetic coffee whiteners are now marketed in nearly every part of the United States. These usually contain combinations of vegetable

Table D - Solutia Phosphates for Process Cheese Manufacture

Emulsifying Agent	Properties	Recommended Usage Level
Emulsi-Phos 440	A blend of DSPA and IMP. Produces soft, easily melted product. Gives greater flexibility than using either DSP or TSP.	3% Can be used singly or in combination
Emulsi-Phos 660	A blend of TSPA and IMP. Used exclusively when high processing fluidity and softer, more meltable cheese is desired. Gives greater flexibility than using either DSP or TSP.	3% Can be used singly or in combination
Emulsi-Phos 990	A blend of TSPA and IMP. Normally used in combination with another phosphate for process cheese production to maximize desired texture and melt characteristics. Gives greater flexibility than using either DSP or TSP.	3% Can be used singly or in combination
MSP	Used to decrease the pH and melt spread and to firm the cheese. Added late in mixing. Produces acidic cheese if used alone.	Very low Used in combination with DSP, TSP or TSPP
DSPA	Produces cheese that is soft and meltable. Sufficiently prevents oil-off during melting. Allows for optimum pH control.	1.8% in process cheese; higher in cheese foods and spreads
DSPD	Hydrated species of DSP. Same properties as DSPA.	2.3% in process cheese; higher in cheese foods and spreads
TSPA	An alkaline orthophosphate which, like DSPD, produces soft, easy-melting products. Recommended where maximum melt strength is desired.	1.2%
TSPC	Hydrated species of TSP. Same properties as TSPA.	2.8%
MKP	Low-sodium alternative to MSP. Used to decrease pH and melt spread and to firm the cheese.	Very low Used in combination with other emulsifying agents
SAPP	Produces hard, non-melting cheese for use in specialty products. Melts only at higher temperatures. Produces acidic cheese if used alone.	Very low Used in combination with TSPP, DSP and/or TSP
TSPP	Produces hard cheese, which will melt only at higher temperatures.	2% Used in combination with MSP, DSP and/or TSP
TKPP	Alkaline, sodium-free pyrophosphate with excellent solubility to produce hard cheese with sharp flavor.	2%
SHMP	Contributes texture to process cheese. Normally used in conjunction with other emulsifying agents to increase firmness of product. Produces brittle cheese if used alone.	0.5-1.5%

fats, sodium caseinate or soy protein, gums as viscosity stabilizers, phosphate or citrate salts as stabilizers for the proteins and as buffering agents, corn-syrup solids or sugar as bodying agents and sweeteners, lipid-type emulsifiers to enhance emulsification of the fats, and flavors and colors to duplicate the characteristics of cream. Typical levels of the various ingredients in formulas for liquid and dried coffee whiteners are shown in Table 20. The functions of the various ingredients have been discussed by a number of investigators.[28,330–338]

TABLE 20
Ingredient Levels in Typical Non-dairy Coffee Whitener Formulas[a]

Ingredients	*Liquid Whiteners, % (total wt)*	*Spray-dried Whiteners, % (Dry)*
Vegetable fat	3.0–18.0	35–45
Protein	0.5–3.0	4.5–10.0
Corn-syrup solids	1.5–10.0	40–60
Sucrose	0–3.0	—
Emulsifiers	0.1–1.0	0.2–3.0
Gum stabilizers	0–0.5	—
Phosphate stabilizing salts	0.1–1.0	1.0–2.0
Flavor	q.s.	q.s.
Color	q.s.	q.s.
Water	To 100%	—
Anticaking agent	—	q.s.

[a] Compiled from references 330–338

The proper type of phosphate to use in coffee whiteners is determined largely by the composition of the other ingredients in the system. Most coffee whiteners contain sodium orthophosphate salts, although potassium orthophosphate salts are used wherever flavor is a problem. Thus, DSP and DKP are most commonly used,[330,332,333,335,337] and polyphosphates[336] and SALP[338] have also been proposed. The phosphates are thought to maintain the optimum pH at which a continuous protein layer will be formed about the fat droplets in order to prevent syneresis, or "wheying off." The phosphates also prevent *feathering*, or curdling of the protein, and fat separation when the coffee whitener is added to an acidic coffee medium.

Whipped Toppings Whipped toppings represent replacements for high-fat cream products, just as coffee whiteners represent replacements for low-fat cream products.[339] Although whipped toppings usually are prepared from the same types of ingredients as coffee whiteners,[340] greater quantities of vegetable fat are used in whipped toppings. The phosphates again serve as buffers and stabilizing agents for the protein films necessary in the formation of stiff, stable foams and in the prevention of syneresis, or weeping. Powdered whipped-topping compositions also are available.[341]

When properly formulated and stabilized, whipped toppings have more improved functional properties than those of natural whipping cream; phosphates can significantly contribute to the stabilization of these improved

Dairy Applications of Solutia Phosphates

Received by OMRI
APR 27 2001

There is a great variety of phosphate applications in the dairy industry. Phosphate functionality in dairy products involves interactions between phosphates and milk proteins and between phosphates and calcium. Solutia phosphates perform the following functions in dairy products:

- Buffer products within the desired pH range
- Stabilize casein proteins in milk against heat coagulation
- Disperse flavors and proteins in reconstituted milk powders
- Coagulate proteins to enhance gelation
- Acidify products
- Interact with proteins to promote emulsification

Solutia has the appropriate phosphate for virtually any dairy application. We will work with you and supply any technical support you may need.

Process Cheese Products

Phosphates are used in process cheese products primarily to help maintain the emulsion of butterfat in its protein-water matrix. Consequently, the product is uniform in flavor, and fat does not separate from the cheese when melted. In addition to stabilizing the protein-water-fat emulsion, phosphates also buffer the product at an optimum pH and give the product appropriate firmness and melting characteristics.

Phosphates are used for the same functionality in "filled cheese" products, imitation cheese products, and pasteurized cream cheese products.

Federal regulations govern the use of emulsifying agents in the manufacture of pasteurized process cheese (CFR 133.169), cheese food (CFR 133.173), and cheese spread (CFR 133.179). Under these regulations, emulsifying agents may not exceed 3% of the weight of the finished product.

The most economical level of use for the cheese processor is the maximum limit of 3%. Few phosphates can be used at this maximum level without compromising the quality of the finished product. Solutia has developed three blends that can be used at the maximum 3% level: Emulsi-Phos® 440, Emulsi-Phos 660 and Emulsi-Phos 990. These specially developed phosphate blends permit the optimum combination of desirable processing and end product properties, such as viscosity, melt spread, body and hardness. Table D on the next page describes the phosphates for process cheese manufacturing.

Table C - Phosphate Usage in Meat, Poultry and Seafood Products

Application Summary	Phosphates	Method
Meat		
Ham, Bacon, Corned Beef, Roast Beef, Pastrami	Nutrifos 088, BC, B-90 or B-75	injection, vacuum tumbling 0.4-0.5% by weight
Frozen Hamburger Patties and Ground Beef Patties (Cooked or Frozen)	Nutrifos 088 or STP Powder	dry addition 0.2-0.4% by weight
Cooked Sausage	Nutrifos 088, BC, SK STP Powder or B-90	dry addition 0.15-0.35% by weight
Frankfurters, Bologna, Luncheon Meats	Nutrifos H-30, BC, SK, SAPP NL, Nutrifos 088	dry addition 0.15-0.35% by weight
Reduced Sodium Products	Nutrifos SK, TKPP	injection, tumbling, dry addition 0.15-0.5% by weight
Poultry		
Whole Turkeys 0.5% by weight	Nutrifos 088 or B-90	injection, tumbling
Turkey Hams, Pastrami, Corned Beef	Nutrifos 088, B-90, B-75, or BC	injection, tumbling 0.5% by weight
Restructured Poultry, Patties, Rolls, Nuggets, Cooked Sausage	Nutrifos 088, B-90 or STP Powder	dry addition 0.15-0.35% by weight
Ground Chicken or Turkey	Nutrifos 088 or B-90	dry addition 0.15-0.35% by weight
Frankfurters, Bologna, Luncheon Meats	Nutrifos H-30, SAPP NL, Nutrifos 088, BC, SK	dry addition 0.2-0.3% by weight
Reduced Sodium Products	Nutrifos SK, TKPP	injection, tumbling, marinades, dry addition 0.15-0.5% by weight
Seafood		
Fish Fillets	Katch, Nutrifos 088 or B-90	injection, dipping or tumbling to achieve 0.4-0.5% by weight
Shrimp Deshelling	Nutrifos 088, BC or B-90	dipping fresh shrimp in a 5-7% solution
Shrimp for Freezing or Cooking	Nutrifos 088, BC or B-90	dipping fresh shrimp in a 5-7% solution
Scallops	Nutrifos 088 or B-90	dipping fresh scallops in a 5-7% solution
Surimi	Nutrifos L-50, TSPP or TKPP	dry addition 0.1-0.5% by weight
Canned Tuna or Crab	SAPP NL	dry addition 0.3-0.5% by weight
Salmon for Canning	Nutrifos 088	dipping fillets in 3-5% solution
Reduced Sodium Products	Nutrifos SK, TKPP	injection, tumbling, marinades dry addition 0.15-0.5% by weight or dipping in 5-7% solution

properties. Whipped toppings, for example, usually can incorporate a greater amount of air and water during whipping, and they have greater overrun, superior stand-up, and, depending on the type of fat used, superior eating quality.[339,342,345]

The phosphates found most useful in whipped-topping formulations are DSP, DKP, and TSPP at levels of 0.025–1.0% of the complete liquid base prior to whipping. The levels of ingredients in typical, liquid, non-dairy whipped-topping formulas are presented in Table 21. Dry whipped toppings are prepared with similar ratios of the ingredients used in the liquid toppings; concentrates containing 30–50% solids are formed, then spray-dried and instantized.

TABLE 21
Ingredient Levels in Typical Whipped-topping Formulas[a]

Ingredients	*% of Total Weight*
Vegetable fat	24.0–35.0
Protein	1.0–6.0
Sucrose	6.0–15.0
Corn-syrup solids	0–5.0
Gum stabilizers	0.1–0.8
Lipid-type emulsifiers	0.3–1.1
Stabilizing salts	0–0.15
Water	To make 100%

[a] Data from references 331, 339, and 342–345.

Imitation Sour Cream, Sour-cream Dressings, and Chip Dips Replacements for fermented cream products are produced in considerable and growing quantities for the consumer market in the United States. These non-dairy products contain vegetable fat, protein (either soy protein or sodium caseinate), gum stabilizers, stabilizing salts, flavorings, acids to provide tartness, and often coloring agents, as well as imitation or real bacon chips, chives, spices, and other natural flavoring agents.[331,339,346,347] The stabilizing phosphate salts again are used to cause the proteins to form the properly dispersed, protective films about the fat globules and to prevent syneresis.

Imitation Ice Cream or "Frozen Desserts" Replacements for frozen dairy products are prepared by combining vegetable fat, either soy protein or sodium caseinate, emulsifiers, gum stabilizers, stabilizing salts, sugar, bodying agents, and the proper flavors and colors to produce products that resemble ice cream so closely that it is often difficult to distinguish between the natural and imitation products. Phosphate salts are used in most of these products to stabilize the protein system, as in other imitation or non-dairy products.[348,349]

Imitation Cheese, Cream Cheese, and Cheese Spreads Replacements for all types of dairy cheese products also can be prepared from non-dairy products, as well as from filled dairy products.[350,351] The proper formulation can result in products that, when properly processed, will resemble the natural product in all characteristics, including flavor and nutritional properties. The phosphates, including the mono-, di-, and tribasic orthophosphates, pyrophosphates, and polyphosphates, are useful in improving the physical characteristics of the proteins; the phosphates also form complexes with the proteins to provide the

Phosphates for the Meat, Poultry and Seafood Industries

Nutrifos® 088 sodium tripolyphosphate (STP) is an extremely fast-dissolving, multi-purpose phosphate for all meat, poultry and seafood applications. It is economical to use and provides most all the functions of more expensive phosphate blends. Nutrifos 088 is versatile. It is well-suited for injection use (hams, poultry and fish fillets), in solution (marinades, fish and shellfish), for dry addition (sausage, meat toppings), and for tumbling.

Nutrifos BC combines the high performance of STP with the ability to dissolve concurrently with salt. Usual STP procedure requires phosphate dissolution before the addition of sodium chloride. With Nutrifos BC this requirement is no longer necessary. Nutrifos BC dissolves rapidly and completely in combination with salt, potentially shortening preparation time. Nutrifos BC is ideal for prepackaged marinades and blends containing spices, salt and other ingredients.

Nutrifos B-90 is a blend of STP and the more soluble sodium hexametaphosphate (SHMP). Nutrifos B-90 is ideal when increased solubility or water softening are desired. It has a marked advantage in highly concentrated pickles, like those for hams where the high solubility of SHMP allows a processor to keep more phosphate in solution. Due to its sequestration, Nutrifos B-90 will delay oxidative rancidity in processed meat, poultry and seafood. Nutrifos B-90 substantially reduces the risk of clogged needles.

Nutrifos B-75 is a blend of STP and SHMP developed for applications requiring extremely high solubility. It is formulated to dissolve in hard water and has tremendous compatibility with high solid brines, such as those used for preparing canned hams. It is ideal for products requiring a slow cure. Nutrifos B-75 will also improve overall sliceability in bacon and ham.

Nutrifos H-30 is a blend of polyphosphates specially formulated for emulsion meat and poultry products, such as hot dogs and bologna. It has a near neutral pH which favors rapid cured color development. This allows for faster processing with the potential for increased production. Nutrifos H-30 improves emulsion stability and helps control viscosity, which is important when pumping emulsions. It also ensures the characteristic bite associated with emulsion products. With Nutrifos H-30, the processor does not have to sacrifice yield in order to have maximal bind.

Nutrifos SK sodium potassium tripolyphosphate (SKTP) is a reduced sodium polyphosphate combining the benefits of phosphate functionality with high solubility and handling ease. Use of Nutrifos SK does not result in off flavors usually associated with potassium. Nutrifos SK is a cost-effective alternative for achieving reduced sodium in meat, poultry and seafood products while retaining the benefits of polyphosphate functionality.

Nutrifos L-50 is a powder blend of STP and tetrasodium pyrophosphate (TSPP) developed for the seafood analog industry. Through its unique ability to solubilize and extract protein, Nutrifos L-50 results in surimi with optimal gel strength. Nutrifos L-50 is added dry to the minced fish, which avoids additional moisture incorporation.

Katch® fish phosphate is a blend of sodium polyphosphates created for the fish and seafood industries. Katch maintains moisture levels by minimizing cook and thaw loss. It also works as a cryoprotectant to help extend shelf life in frozen products and delays the onset of oxidative rancidity in even the fattiest of fish species. This versatile blend can be used as a dip (fillets, shrimp, scallops), for injection applications, and in tumbling.

Sodium acid pyrophosphate (SAPP NL) is an acid phosphate frequently used as a dry ingredient to stabilize emulsions. SAPP NL favors color development and improves flavor and texture in hot dogs and luncheon meats.

Tetrasodium pyrophosphate (TSPP), a highly alkaline phosphate, is used when maximal protein solubilization is desired. However, TSPP use is limited by its low solubility, and it is primarily utilized in combination with other more soluble phosphates or in specialty applications.

Tetrapotassium pyrophosphate (TKPP), like TSPP, is a very alkaline phosphate. TKPP is suitable for applications requiring extremely high solubility (60%) and/or reduced sodium. TKPP is an excellent choices for specialized applications and pet foods.

proper dispersion so that the finished products will simulate the natural products.[351] This author is personally aware of experiments that have resulted in cheese products very similar to natural cheddar, natural Swiss, and natural cream cheeses. There is no reason to doubt that any type of natural cheese can be duplicated with synthetic, non-dairy products through proper formulation, including the use of phosphate stabilizing salts.

Margarine Even margarine seems to benefit from the addition of a phosphate. A Japanese patent disclosed that an oil-in-water-in-oil emulsion could be prepared by homogenizing a milk casein dispersion in a "trisodium polyphosphate solution" with hydrogenated oil to form a margarine product.[352] The phosphate, assumed to be STP, most likely caused proper dispersion of the protein and inactivated any interfering calcium or magnesium ions in the system.

Applications in Cheese Products

The literature that contains references to the applications of phosphates in cheese products is voluminous. The majority of uses of phosphates are in processed cheeses, although phosphates also have been found useful in the preparation of cottage and natural aged cheeses.

The initial steps in the manufacture of cheese products are similar for all types of cheeses including cottage cheese. Whole milk is usually used, although skim milk also can be used to produce low-fat cheeses. The pasteurized milk is treated with lactic-acid bacteria or with lactic or phosphoric acid, then usually with a protein-coagulating enzyme; this causes the formation of a protein "curd," an insoluble paste or coagulum of the milk casein with the milk fat entrapped inside the curd in the form of emulsified droplets. The subsequent handling and processing of the curd determines the type of cheese that will be produced.[30]

Cottage Cheese Cottage cheese is prepared by washing the loosely packed, freshly coagulated casein curd; creamed cottage cheese is prepared by mixing this curd with whole milk, which often contains food-grade acids, such as H_3PO_4.[353] Bristol and Martin[354] pre-acidified skim milk with H_3PO_4, or its mixture with citric acid, prior to the addition of lactic acid bacteria; the setting time of the cottage cheese curd was reduced by 44% compared to the conventional procedure. A method of continuous processing of cottage cheese has recently been developed and is being promoted in European countries; the method reduces labor, provides greater uniformity in the cheese, increases the yield of cheese from the milk, and yields more cheese per hour of operation, which results in a lower-cost cottage cheese curd.[355] The process involves direct acidification rather than inoculation with lactic-acid bacteria; among the acids used is H_3PO_4.

Natural Cheese The product termed *natural cheese* is produced by microbiological fermentation of milk curd. A number of steps are involved in the preparation of the curd in a process that requires a considerable amount of time.[28] The curd is finally compressed in forms in which it becomes a compact mass fitting the shape of the form. It is then aged for various periods of time to "ripen." The typical cheese flavor is developed by the fermentation of the curd during the ripening stage, and it is often caused by very specific cultures of

Cured Meat and Poultry

Incorporation of phosphates confers several benefits on bacon, ham, corned beef and cured poultry products. By decreasing moisture loss during processing, phosphates increase yields and give products that are more moist to eat. Keeping the moisture level up and partially dissolving fibrous protein make the products more tender. By sequestering metal ions, especially iron, phosphates inhibit development of rancidity during storage. Phosphates also extend shelf life by stabilizing the red color of cured meat and poultry.

Processed Meat and Poultry

Blending Nutrifos H30 or SAPP (sodium acid pyrophosphate) into the meat during the chopping operation will accelerate development of red color in wieners, bologna and similar emulsion products. These ingredients offer the potential of increased production in a plant that is operating at smokehouse capacity and is able to increase smokehouse temperature. Including phosphates also makes the emulsion more resistant to a drop in pH.

Adding sodium tripolyphosphate, sodium hexametaphosphate or tetrasodium pyrophosphate, either singly or in any combination, increases emulsion stability and reduces fat cook-out when the product is prepared for consumption.

Frozen Products

Meats, poultry, fish and other seafoods all benefit from treatment with phosphate solutions before they are frozen.

Addition of phosphate:

- Inhibits development of rancidity during storage
- Decreases loss of protein-containing juices at thawing
- .Reduces shrinkage when the product is cooked

The result is a cooked product that is juicier, more tender and better flavored.

Shrimp

Phosphates can help the seafood processor by making the shells of shrimp easier to remove, thereby increasing the meat yield of the deshelling operation. STP or a blend of STP and SHMP is added to the boiling water, and the shells are removed with high-pressure water jets.

Canned Seafood

Addition of SAPP to albacore tuna during canning decreases or prevents formation of troublesome struvite crystals. Phosphates will also inhibit white protein curd formation in canned salmon.

Reformed and Restructured Products

In production of frozen products, such as restructured steaks, shrimp shapes, formed poultry parts, meat loaves, sectioned and formed roasts, turkey and chicken rolls, and fish blocks, phosphate solubilizes the protein that binds the pieces together and aids in moisture retention.

For surimi production and seafood analog manufacturing, Nutrifos polyphosphates have been found especially useful as cryoprotectants and binding aids.

bacteria or mold. Phosphates have been found to be beneficial in a number of the steps involved in the manufacture of natural cheese.[28,219,356-376]

Kielsmeier[356] significantly shortened the time necessary to prepare cheese curd for compression into forms by adding a calcium-complexing phosphate, such as TSPP, to the milk, along with a bacterial culture and rennet. The mixture was allowed to react for 10-20 minutes, after which it was acidified with a food-grade acid, such as lactic acid or H_3PO_4, to lower the pH to 5.4-5.5. If a firmer curd was desired, the calcium salts could be added along with the acid during the latter part of the process. The curd formed by this process could be compressed into forms and aged. The process could feasibly lend itself to continuous cheese processing because of the shortened time involved. Edam cheese was improved by the addition of MCP to more rapidly reduce the pH of the milk and to form a harder curd.[357]

The interest in a continuous process for the production of cheese curd is very high, since it would involve less labor and less time to age the cheese. The processes that have thus far been proposed involve the use of food-grade acid, such as H_3PO_4. This acid has been found to increase yields, decrease moisture, and increase the calcium level of the cheese.[358,359]

The rennet coagulation time of milk can be stabilized by the addition of polyphosphate, probably through the formation of calcium and magnesium complexes, since these ions are essential for milk coagulation by rennet.[356,360-364] Orthophosphates have no effect on the rennet coagulation time,[360,361,363] while polyphosphates are more effective than other calcium- and magnesium-complexing agents, such as EDTA.[219,362]

A number of investigators[365-373] have treated the milk used to develop starter cultures for cheese with either orthophosphates or pyrophosphates to prevent the growth of bacteriophage, which attacks the bacterial cultures necessary for proper fermentation and flavor development of the cheese. The orthophosphate salts appear to be more effective than the polyphosphates in the binding of calcium and in preventing its use as a nutrient for bacteriophage growth. The preferred process calls for the sterilization of milk and of solutions of the phosphates;[373] the phosphate solution is then aseptically added to the sterile milk, and the milk-phosphate mixture is reheated and then inoculated with the proper cheese-producing strain of bacteria.

Waters[374] has reported that periodic washing of the rinds of curing cheeses with a saturated solution of DSP prevents the growth of mold, rind rot, bacteria, and cheese mites when the cheeses are aged at humidities greater than 95%. Schulz[375] prevented spoilage of cheese surfaces by immersing the cheese block or wheel in a 20% aqueous solution of SAPP heated to 90°C, or by rubbing the surface with SAPP and subsequently heating it to 100°C in a steam tunnel for a short time. The process develops a stable, airtight, edible rind similar to process cheese. Soaking the press cloths used to wrap the surfaces of rindless cheeses in a 2% solution of sodium tetrapolyphosphate at pH 6.26 prevents adhesion of the press cloth during curing of the cheese.[376]

Pasteurized Process Cheese Products Pasteurized process cheese products are prepared by blending cheeses of various ages with water, sodium chloride, and emulsifying salts. The process involves heating the blended ingredients to 160-170°F with agitation to melt the mixture into a smooth, plasticized, fluid mass. The molten mixture is then formed into loaves of the proper size

Meat, Poultry and Seafood Applications of Solutia Phosphates

Polyphosphates are primarily used in meat, poultry and seafood products to provide protection from moisture loss during processing. In general, processors utilize sodium tripolyphosphate (STP), which can be used alone or in blends with sodium hexametaphosphate (SHMP). Alkaline polyphosphates, like STP, are believed to increase the local pH and onic strength surrounding the protein. These changes allow the protein to uncoil exposing sites, which increases the protein's capacity to bind water. During cooking or thawing, the protein will release significantly lower quantities of moisture, therefore increasing total product yield. The increase n water-binding capacity results in:

- Reduced moisture loss during cooking
- Improved yield following cooking
- Reduced moisture loss during thawing
- Increased tenderness
- Improved cooked flavor
- Reduced freezer burn
- Increased binding between muscle pieces

Other functions of polyphosphates include:

- pH adjustment and buffering
- Sequestration of multivalent cations to inhibit oxidative rancidity
- Stabilization of the color of cured products
- Emulsion stabilization and/or viscosity reduction
- Emulsification of fat and protein

United States Department of Agriculture (USDA) regulations generally allow addition of phosphate ingredients up to 0.5% by weight of the finished product. In the following sections, specific phosphates are recommended for particular applications.

and shape, or it is chilled in thin sheets or ribbons for cutting into sliced cheese.[28,30] J.L. Kraft obtained the initial patent for the preparation of a "sterilized cheese" in 1916.[377-380] Garstin[381] first used phosphate salts as emulsifiers for cheese processing in order to prevent fat separation. Most process cheeses prepared in the United States contain either DSP or an alkaline SALP, although these are sometimes combined with each other or with additional salts, such as TSP or sodium citrate. Recent reports indicate that the cyclic sodium tetrametaphosphate, but not trimetaphosphate,[382] and a starch-phosphate[383] can also function as cheese emulsifiers.

The adverse effects of rework (salvage) cheese can be overcome by the use of a combination of a lipid-type surface-active agent and phosphate-emulsifying salts.[384] In addition to their functions as buffers that adjust and maintain the pH in an optimum range, these phosphate salts also contribute highly desirable and essential effects to the physical properties of the cheese proteins, leading one to believe that their functions are more than just maintaining an optimum pH.[22,28,30,110,111,384-386] The federal standards of identity for pasteurized process cheese allow the addition of up to 3% of any one, or any combination, of the allowed emulsifying salts based on the weight of the pasteurized process cheese.[387] H_3PO_4 is also allowed, along with other food-grade acids, as an acidifying agent for pasteurized process cheese. Bolanowski and Ziemba[388] have recently described a continuous process for the manufacture of pasteurized process cheese.

There have been numerous investigations of the emulsifying systems and their effects on the properties of pasteurized process cheese.[23,27,28,378-400] These investigations have demonstrated a number of functions for the emulsifying salts, such as buffering the process-cheese system at the optimum pH for proper dispersion of the protein. The emulsifying salts also interact with the calcium present in the system, possibly to precipitate some of it, but also undoubtedly to form cross-links through the calcium ions between the protein molecules. Furthermore, they seem to interact with the protein molecules at the surfaces of fat droplets to prevent coalescing and thus prevent loss or bleeding of fat from the cheese. The emulsifying salts also appear to increase the water-holding capacity of the protein in order to prevent or at least inhibit water loss. Several investigators have shown that sodium citrate is not as effective on cheese as the phosphates.[23,28,399,400]

When polyphosphates are used as cheese-emulsifying salts, as is quite common in European countries, they are rapidly hydrolyzed to ortho-, pyro-, and tripolyphosphate units.[401] Slower but definite hydrolysis of very-long-chain sodium polyphosphates (Graham's salt) has also been reported by Scharpf and Kichline,[402] who have proposed these compounds for use in process cheese in this country. One of the major disadvantages to the use of DSP and TSP as emulsifying salts in some pasteurized process cheeses has been their tendency to initiate the appearance of crystals on the surface of the cheese; this is especially true of the packaged, sliced cheeses. These crystals have been identified as calcium tartrate crystals by Blanchard,[404] calcium citrate crystals by Morris and co-workers,[406] and DSP by others.[28]

The use of the sodium orthophosphates as emulsifying salts also results in the development of less acceptable flavor with aging.[27,110] Cheese emulsified with the SALP systems appears to retain a richer, "cheesy" flavor for a

Other Bakery Applications

Frosting and icing rely upon phosphates for pH adjustment and stabilization. Calcium phosphates are also used in gum-based systems to give proper gelling and thickening.

Dough conditioners, also known as dough improvers or yeast foods, often include MCP to optimize dough pH and to provide calcium in yeast-raised products. One dough conditioner employs a high level of dicalcium phosphate anhydrous. Monoammonium phosphate in a dough conditioner can buffer the pH and provide nitrogen.

Yeast production sometimes utilizes phosphoric acid to adjust the pH of growth media. Diammonium phosphate, monoammonium phosphate, monopotassium phosphate and dipotassium phosphate are sometimes used to provide nourishment to the yeast.

Breakfast cereals and pasta have shorter cooking times and richer, creamier color with the addition of DSP. Use of DSP also decreases processing time for ready-to-eat cereals. The use of DSP is permitted by the FDA Standards of Identities found in the CFR Title 21.

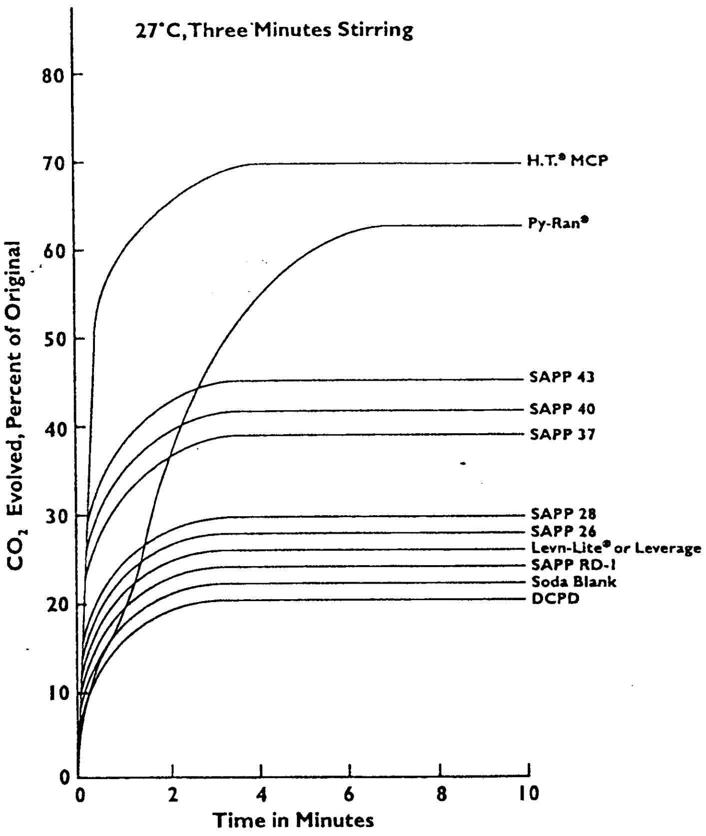
Starches, modified by addition of phosphate groups, exhibit several desirable properties, which include resistance to freeze-thaw breakdown, greater clarity, higher water-binding capacity, and high viscosity without gel formation.

Dough Rate of Reaction

The selection of the leavening acid is based upon the rate of release of carbon dioxide in your dough or batter mixture. The rate of leavening action is the key to a successful application. Solutia manufactures and markets a diverse line of leavening acids with varying reaction rates. The baker or formulator can select the right product for their particular "critical zone"... the point in the preparation process where it is desired to have the necessary gas released. The Dough Rate of Reaction test is used as a guide because it shows typical reaction curves for leavening acids.

Figure 1 demonstrates the leavening rates of various leaveners as characterized by the DRR test. The soda blank curve includes all the ingredients minus the leavening acid. These tests were conducted at 27°C with three minutes of stirring. Note that increase in temperature, stir time and other ingredients will impact the final rate of reaction. In general, higher temperatures accelerate the rate of reaction.

Figure 1 – **Typical Dough Rates of Reaction**



3

significantly longer period. The same emulsifying systems are now being used in cheese spreads[407] and low-fat or fat-free process cheeses.[408,409]

Phosphate Applications in Egg Products

A number of phosphate applications for improving the processing and functional properties of eggs have been reported in the literature;[410-424] examples are discussed in the following paragraphs. Their functions include complexing undesirable metal ions, buffering to optimum pH values, improving foam volume and stability, and inhibiting enzyme activity, microbiological organisms, and fat oxidation.

Applications in Shell Eggs

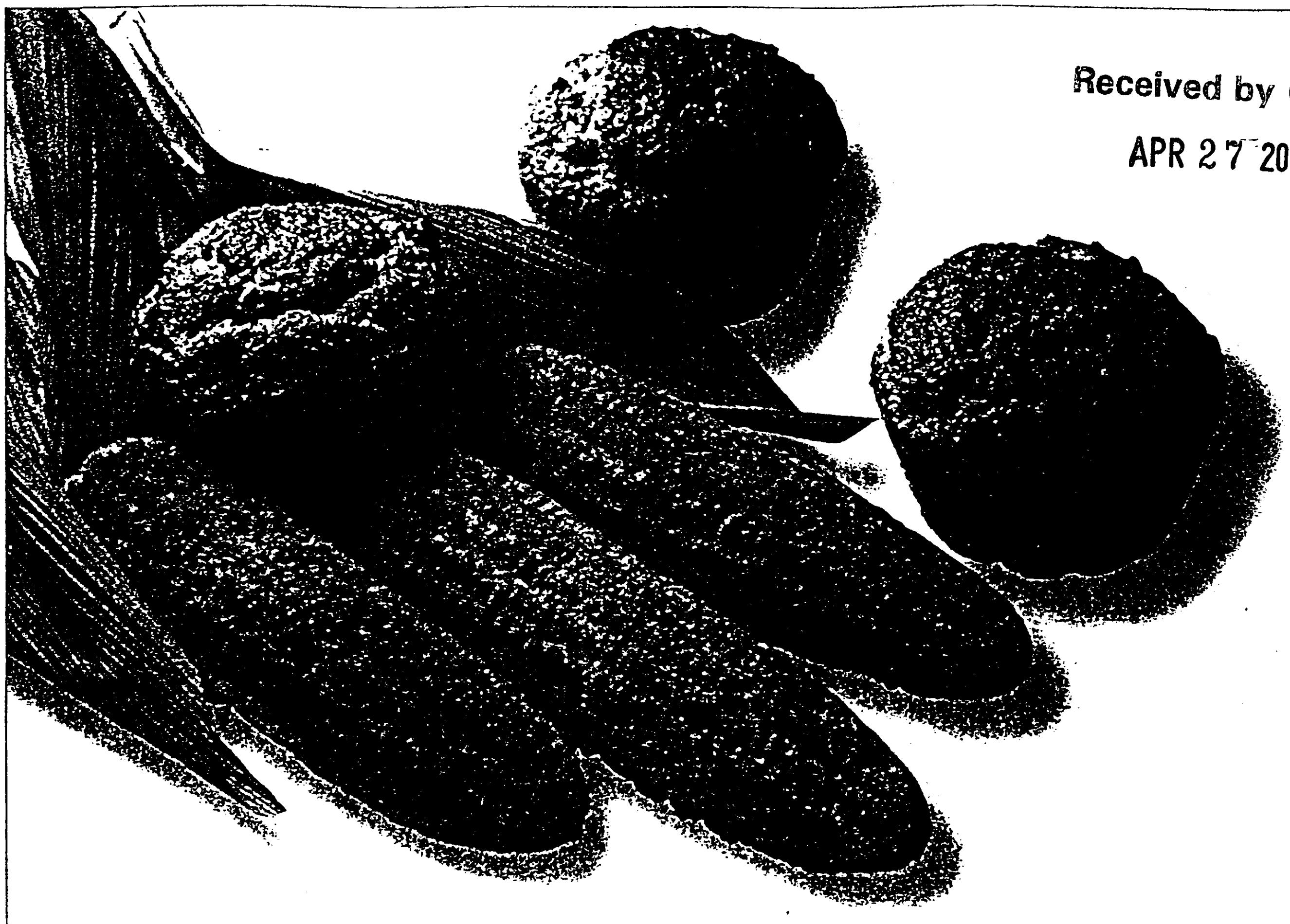
Pikarr[410] discovered that iron in the wash water used to clean soiled shell eggs contributes to more rapid spoilage, even when it is present in very low quantities. The addition of an iron-complexing acid to the wash water was found to prevent the formation of an iron-conalbumin complex that was responsible for the increased rate of spoilage. The effects of the acids were increased by the addition of small quantities of sodium, potassium, or ammonium orthophosphates or SAPP to the wash solution. Preferred complexing acids were citric, H_3PO_4, glutamic, acetic, and tartaric acids in order of decreasing effectiveness.

Applications in Whole-egg Products

Chin and Redfern[411] discovered that the addition of H_3PO_4, polyphosphoric acid, or any one of their alkali-metal or ammonium salts would prevent the formation of a disagreeable, muddy-brown color upon exposure of whole eggs or egg yolk to air. As a result, the federal standards for whole-egg products have been revised to allow the addition of up to 0.5% MSP or MKP for color preservation.[412]

Liquid egg products, particularly if frozen products are thawed, undergo proteolytic action and coagulation. Hall[413] reported that the addition of a polyphosphate, preferably with a chain length above three, stabilized the eggs against this enzymatic action.

Bellamy[414] prepared a concentrated whole-egg product having superior whipping properties and foam stability by separating the egg white from the egg yolk; he then added SAPP to the egg whites and allowed the mixture to ferment with natural organisms until the pH had been lowered to 6.3-6.5. The egg whites then were concentrated to one-quarter of their original volume and reconstituted with the equivalent quantity of egg yolk that had been previously removed. Lewis and co-workers[294] discovered that the addition of STP or SHMP to dried, whole eggs improved their whipping properties and stabilized them against deterioration during storage. STP gave the greater improvement, being especially noticeable in improving the foaming properties of dried, whole eggs when stored at room temperature for 3 months. Controls stored a similar period of time would not foam at all, as shown in Tables 22 and 23.



Stabil-9® combines SALP with anhydrous monocalcium phosphate for "double action": the early release of carbon dioxide by anhydrous monocalcium phosphate and the heat-triggered release by SALP in the oven. Available in regular and high calcium grades, Stabil-9 is used primarily in self-rising flours and biscuit mixes, where its properties permit long storage life of the dry mix. Furthermore, batters and doughs containing Stabil-9 retain satisfactory leavening action even when held for hours or days in the refrigerator. Stabil-9 gives finer grain to cakes. Other uses include self-rising corn meal and muffin mixes.

Pan-O-Lite®, a blend of SALP and monocalcium phosphate monohydrate, works well in pancake, waffle and cake mixes. It is used in cakes that do not contain high-aerating emulsifiers. Batter made with Pan-O-Lite resists thickening and loss of leavening power during storage under refrigerated or room temperature conditions, so this leavening agent is particularly appropriate for refrigerated pancake batters.

H.T.® MCP (monocalcium phosphate monohydrate) reacts rapidly with baking soda, so it is well suited for use in double-acting baking powders and in products that require double action, such as cake and pancake mixes. MCP's spherical particles make it a free-flowing compound that lends itself to use in phosphated flours.

Py-Ran® (anhydrous monocalcium phosphate) is stabilized by a coating that protects against premature leavening action by slowing dissolution and the subsequent reaction with baking soda. Consequently, Py-Ran has excellent leavening characteristics in self-rising and phosphated flours, self-rising corn meal, cake and pancake mixes, and household baking powder.

DCPD (dicalcium phosphate dihydrate or duohydrate) is useful in bakery products with a high set temperature, such as high sugar cakes. It begins to react with baking soda when the batter or dough temperature rises to about 135°F-140°F.

Adipic Acid is a white crystalline powder that's ideal for multiple food applications. In many food applications, adipic acid is preferred because of its non-hygroscopisity, which means dry products containing adipic acid have a longer storage life under humid conditions.

Leverage (dimagnesium phosphate) is a heat-activated leavening agent that provides no leavening action before baking. It provides a consistent leavening rate for greater control in batters and dough. Leverage produces finished products which are moist and tender.

hosphates for the Bakery Industry

(sodium acid pyrophosphate) leavening acids plied in several grades which have different rates tion with baking soda. In general, the grades of Solutia ngredients are designated by a number related to the Rate of Reaction (DRR), which is expressed as the tage of available carbon dioxide released in 8 minutes standardized test conditions.

RD-1 and SAPP 26 are the slowest reacting Their primary use is in products that require a long tion cycle, long bench tolerance or long storage life. For ated doughs, the low rates of carbon dioxide gas tion provide tolerance to process variation, yet the dioxide is released at the right time to ensure that pressure is produced in the container.

28 is an all-purpose leavening phosphate. Its delayed ease is especially suited to institutional and commercial of large batches, where extended mixing and forming ire necessary. The low reaction rate is stabilized by a Solutia process. Doughnut applications employ SAPP 28 bination with faster reacting SAPPs. SAPP 28 is also the manufacture of baking powders, either alone or in ation with MCP.

37, SAPP 40 and SAPP 43 provide rapid. rates of reaction over long periods, making them larly useful in cake and doughnut mixes.

These agents combine well with slower leavening acids to accommodate variation in other ingredients. In a balanced leavening system using any grade of SAPP, the final pH is typically 7.2 to 7.6.

SALP (sodium aluminum phosphate and blends) offers consistency in leavening rate throughout dough or batter storage and use. It also provides desired batter thickness, baking tolerance, and increased crumb whiteness and resiliency. SALP is an ideal leavening agent for prepared mixes.

Solutia's three SALP products are Levn-Lite, Stabil-9 and Pan-O-Lite leavening agents.

Levn-Lite® is SALP. Its major leavening action takes place only when the product is heated. Levn-Lite is used in cake, pancake and waffle mixes, where it helps ensure good volume. In cake formulations, it is employed with high-aerating emulsifiers. Levn-Lite has application in frozen and refrigerated products and in some commercial baking powders.

TABLE 22
Effect of Polyphosphates and Storage on Foam Volume of Whole-egg Meringues

Egg Type	*Storage Time, weeks*	*Storage Temperature, °C*	*Polyphosphate Used*	*Optimum Phosphate in Dried Egg, %*	*Max Volume Increase, %*
Fresh	None	—	—	—	560
Dried No. 1	None	—	None	—	200
	None	—	Hexametaphosphate	2.3–3.0	330
	None	—	Tripolyphosphate	1.3–2.0	360
Dried No. 2	None	—	None	—	220
	None	—	Tripolyphosphate	1.5	380
	13	4	None	—	220
	13	4	Tripolyphosphate	1.5	380
	13	25	None	—	0
	13	25	Tripolyphosphate	1.5	160

Source: Lewis, M. A., Marcelli, V., and Watts, B. M., 1953, *Food Technol.* 7:261, Table 3.

TABLE 23
Effect of Polyphosphates on Whipping Ability of Whole, Dried Egg in Sponge Cake

Egg Type	*Polyphosphate in Dried, Whole Egg*	*Weight of 1 Cup of Batter, g*	*Volume of Cake from 175 g of Batter, ml*
Fresh		62	980
Dried—4% Moisture	None	117	435
	2.9% hexametaphosphate	90	660
	4.6% hexametaphosphate	97	645
	1.5% tripolyphosphate	84	710
Dried—4.5% Moisture	None	110	525
	2.3% hexametaphosphate	81	815
	1.5% tripolyphosphate	74	895

Source: Lewis, M. A., Marcelli, V., and Watts, B. M., 1953, *Food Technol.* 7:261, Table 4.

Tongur[415] found that blending powdered, whole eggs with a combination of ascorbic acid and TSPP inhibited the oxidation of the fats in the dried eggs.

Sourby and co-workers[416] developed a process for sensitizing *Salmonella* to lower-processing temperatures by adding SHMP and a soluble calcium salt to the eggs prior to pasteurization. The process involves the use of 0.5% SHMP, 0.5% calcium chloride, and a pasteurization temperature of 130–135°F. The pasteurized whole-egg products were reported to have superior functional properties to those of whole eggs pasteurized by other available processes.

Bakery Applications of Solutia Phosphates

Solutia food phosphates find many uses in baking:

- Leavening acidulants
- Dough conditioners
- Mineral supplementation
- pH and buffering

The phosphates used include ingredients tailored to meet the home and commercial baker's specific leavening acid requirements. In addition to their role as the most commonly used acidulants for chemical leavening formulas, the phosphates also play an important part in bread and roll production. Food phosphates contribute to bread production directly in dough improvers and yeast foods, as well as indirectly as acidifiers in the production of yeast.

In every baking application, you will find Solutia phosphate ingredients uniformly high in quality and reliable in their functionality. You can depend on Solutia to supply expert advice when you encounter a challenge in formulating or processing.

Leavening

In baking, the phosphates function as leavening acids, which react with sodium bicarbonate, baking soda, to release carbon dioxide gas. The amount of gas and the rate of gas production determine the main effects of leavening. Table B below shows leavening uses of Solutia phosphates.

Exact levels of the phosphates needed to obtain a balanced leavening system can be calculated by use of the Neutralizing Value (NV), defined as the parts of baking soda neutralized by 100 parts of the leavening acid. See "Properties for Solutia Food Phosphates" in Table G on pages 30-31 for the NV of specific phosphates.

Table B – Leavening Applications of Solutia Phosphates

Product	**Sodium Bicarbonate (%)**	**Leavening Acids (To Neutralize)**
Baking Powders	30 - 40	H.T. MCP, Py-Ran, SAPP 28, Levn-Lite, Adipic Acid, Leverage
Biscuit Mixes	1.5 - 2.0	Stabil-9, Levn-Lite, SAPP 28
Breading Batter Mixes	0.0 - 2.0	SAPP 40, Levn-Lite, Pan-O-Lite, SAPP 28
Cake Doughnut Mixes	0.5 - 1.0	SAPP 40, SAPP 28, Levn-Lite, Py-Ran, SAPP 26, SAPP 37, SAPP 43, Leverage
Cake Mixes-Angel	1.5 - 2.0	H.T. MCP, Py-Ran, SAPP 40, Levn-Lite
Cake Mixes-Layer	0.6 - 1.0	Levn-Lite, Pan-O-Lite, SAPP, DCPD, Py-Ran, Leverage
Cookie Mixes	0.0 - 0.7	Stabil-9, SAPP RD-1, Levn-Lite
Crackers	0.5 - 1.8	H.T. MCP, Py-Ran, SAPP 28
Frozen Biscuit Doughs	1.5 - 2.0*	Levn-Lite, SAPP 28, SAPP 26, Leverage
Frozen Cake Batter	0.6 - 1.25	Levn-Lite, Pan-O-Lite, SAPP 28, H.T. MCP, DCPD, Leverage
Frozen Pancake Batter	1.7 - 2.2*	Pan-O-Lite, Levn-Lite, DCPD, Leverage
Hush Puppy Mixes	1.5 - 2.0	SAPP 28, SAPP 40, Py-Ran, Stabil-9
Muffins	1.5 - 2.0	Stabil-9, Pan-O-Lite, SAPP 28, DCPD, Leverage
Pancake Mixes	1.5 - 2.0	Pan-O-Lite, Levn-Lite, H.T. MCP, Py-Ran, SAPP 40, SAPP 28
Pizza Mixes	0.3 - 1.2	Pan-O-Lite, Levn-Lite, SAPP 28, DCPD, Leverage
Refrigerated Dough	2.0 - 2.5*	SAPP RD-1, SAPP 26, Levn-Lite, Leverage
Self-Rising Corn Meal	1.5 - 2.0	Py-Ran, Stabil-9, Levn-Lite, H.T. MCP
Self-Rising Flour	1.2 - 1.5	Stabil-9, Py-Ran, SAPP 28
Waffle Mixes	1.5 - 2.0	Pan-O-Lite, Levn-Lite, H.T. MCP, Py-Ran, SAPP 40, SAPP 28, Leverage

* % of solids

Kohl and Ellinger[417] reported that the addition of the peroxyhydrates of the alkali-metal salts of phosphates, sulfates, or carbonates to whole eggs was even more effective in the destruction of *Salmonella* and other microorganisms during pasteurization of the egg products.

Applications in Egg Whites

The federal standards for all egg products have been amended to require them to be free of *Salmonella*.[412] Thus, most eggs used in food preparation have been treated by pasteurization or some other method to eliminate *Salmonella*. Pasteurization invariably increases whipping time and reduces foam stability and viscosity of egg whites. Therefore, much interest has been shown in foam whipping aids and stabilizing agents. Kothe[418] increased the tolerance of egg whites to overbeating by the addition of sufficient MSP to reduce the pH of the egg whites to approximately 8.0. Finucane and Mitchell[419] found that the addition of approximately 2.5% SHMP to dried egg white significantly improved the whipping properties and foam stabilities. Finucane[420] extended this work and found that by adding partially hydrolyzed soy protein and SHMP to dried egg white, he could prepare an angel food cake mix in which all of the ingredients could be included in a single mixing stage instead of the two stages normally required.

Chang[421] and Chang and co-workers[422] demonstrated that SHMP stabilized the heat-labile protein conalbumin, which causes the development of turbidity in pasteurized eggs while they are in the process of being pasteurized. The process reduced the foaming ability of the treated egg whites somewhat, but this was restored upon the addition of a whipping agent, triacetin. A further advantage to the process was a significantly increased tolerance in the SHMP-treated egg whites to the presence of small quantities of egg yolk introduced during the breaking operation.

Kohl and co-workers[423,424] reported a pasteurization process for liquid egg whites based on the sensitization of even the most heat-resistant types of *Salmonella* at pasteurization temperatures of 125–130°F with approximately 3 minutes holding time. This treatment was also reported to contribute residual microbiological inhibition in the pasteurized eggs so that bacteria that survived the pasteurization process or were introduced by recontamination decreased in numbers even after thawing and holding the egg whites at 75°F for 72 hours.

Phosphate Applications in Fats and Oils

Various phosphates have been found useful in the processing and the applications of fats and oils in foods.[425-497] The phosphates have been found to aid in the extraction of fats and oils, in their refining, in stabilization of fat against flavor deterioration, and in obtaining stable fat and oil emulsions.

Applications in Oil Extraction

The ability of the phosphates, particularly the polyphosphates, to solubilize and disperse protein should be useful in fat and oil extraction. The phosphates

Table A – Functions of Solutia Food Phosphates

Function	Phosphate Ingredients	
Esterification	■ Sodium Trimetaphosphate	
Flow Conditioner	■ Tricalcium Phosphate	
Leavening Agent	■ Leverage® ■ Diammonium Phosphate ■ Dicalcium Phosphate Dihydrate ■ H.T. Monocalcium Phosphate Monohydrate ■ Levn-Lite Sodium Aluminum Phosphate ■ Pan-O-Lite	■ Stabil-9 ■ Monoammonium Phosphate ■ Monopotassium Phosphate ■ Monosodium Phosphate ■ Py-Ran Anhydrous Monocalcium Phosphate ■ Sodium Acid Pyrophosphate
Mineral Supplement	■ Dicalcium Phosphate ■ H.T. Monocalcium Phosphate Monohydrate ■ Mag-nificent® Source of Magnesium	■ Calcium Pyrophosphate ■ Tricalcium Phosphate
Nutrient	■ Diammonium Phosphate ■ Monoammonium Phosphate ■ Monopotassium Phosphate	■ Phosphoric Acid ■ Mag-nificent
Protein Modifier	■ Dicalcium Phosphate ■ Disodium Phosphate ■ Emulsi-Phos 440, 660 and 990 ■ H.T. Monocalcium Phosphate Monohydrate ■ Katch Fish Phosphate ■ Monosodium Phosphate ■ Nutrifos 088 ■ Nutrifos B-75 ■ Nutrifos B-90 ■ Nutrifos H-30 ■ Nutrifos L-50	■ Nutrifos SK ■ Nutrifos STP Powder ■ Py-Ran Anhydrous Monocalcium Phosphate ■ Sodium Acid Pyrophosphate ■ Sodium Hexametaphosphate ■ Sodium Potassium Tripolyphosphate ■ Sodium Tripolyphosphate ■ Tetrapotassium Pyrophosphate ■ Tetrasodium Pyrophosphate ■ Trisodium Phosphate
Sequestrant	■ Sodium Acid Pyrophosphate ■ Sodium Hexametaphosphate ■ Sodium Potassium Tripolyphosphate	■ Sodium Tripolyphosphate ■ Tetrapotassium Pyrophosphate ■ Tetrasodium Pyrophosphate
Stabilizer	■ Disodium Phosphate ■ Sodium Hexametaphosphate ■ Sodium Potassium Tripolyphosphate ■ Sodium Tripolyphosphate	■ Tetrapotassium Pyrophosphate ■ Tetrasodium Pyrophosphate ■ Trisodium Phosphate

should also be useful in breaking up lipo-protein complexes, thereby increasing oil yields. Rousseau[425] reported that yields of olive oil were increased 1.5–3.0% over those of untreated controls when the olives were treated with 2% of a mixture of 3 parts TSPP and 1 part sodium bicarbonate prior to grinding. Rousseau's findings appear to support the previous statements.

Applications in Processing Fats and Oils

Crude fats and oils as obtained from animal or vegetable matter contain a considerable number of impurities, which include free fatty acids, phosphatides, mucilaginous and proteinaceous materials, and similar contaminants. Crude fats and oils are refined by two methods—alkali refining and acid refining.

Alkali Refining The alkali-refining process for fats and oils involves the treatment of fats and oils with an alkali, such as sodium hydroxide, at temperatures and for times that vary with the desired results. The alkali treatment forms soaps from any free fatty acids present and from the lecithin and other phosphatides. Sterols are saponified in order to make them soluble in the aqueous solution. All of these impurities can be removed with the aqueous phase.

A disadvantage to the alkali-refining process is that the formation of soaps causes the formation of emulsions with a portion of the oil; therefore, refining losses of 2% or greater can be expected from this process. The addition of levels of phosphate salts ranging from 0.05% to a maximum of 1.0% has been reported by several investigators to significantly reduce refining losses to less than 1%.[426–429]

Acid Refining Acid refining of fats and oils usually involves the addition of sulfuric, hydrochloric, or chromic acids to the fats and oils. The results obtained can be controlled by adjusting the proportion of acid to oil, diluting the acid with water or other solvents, and varying the temperature of the reaction. The process usually results in a controlled, low level of residual free fatty acids remaining in the refined fat or oil.

Several investigators have reported advantages to the use of H_3PO_4 as the acid of choice in acid refining.[430–441] Some of the refining processes involve combinations of the acid and MSP, DSP, or TSP[433,434,437–439] or ammonium phosphates.[440] A process used to prepare a common, commercial, bakery shortening involves the deliberate, controlled hydrolysis of some of the fat to form free fatty acids by treating the refining mixture with alkali and by subsequently neutralizing with acid to produce 2–10% free fatty acids having no less than 16 carbon atoms in their molecules. The phosphoric-acid refining process has been reported to eliminate the formation of sulfonated triglycerides, to solubilize protein and mucilaginous materials, to hydrolyze phosphatides, and to greatly improve the odor, flavor, and stability against rancidity of the treated fats and oils.

Other Refining Applications Irmen[442] refined soft fats and liquid oils by treating them with phosphate salts and with higher alcohols and waxes. The result was a hardened fat that required no hydrogenation for use as shortening. Beck and Klein[443] refined highly flavored and colored crude oils by percolating them or filtering them through a bed of granular TCP. The refined oils provided colorless, bland, flavorless fats and oils for use in frying and other similar

Table A - Functions of Solutia Food Phosphates

Function	Phosphate Ingredients
Acidulant	■ Adipic Acid ■ H.T.® Monocalcium Phosphate Monohydrate ■ Levn-Lite® Sodium Aluminum Phosphate ■ Monoammonium Phosphate ■ Monopotassium Phosphate ■ Monosodium Phosphate ■ Pan-O-Lite® ■ Phosphoric Acid ■ Py-Ran® Anhydrous Monocalcium Phosphate ■ Sodium Acid Pyrophosphate ■ Stabil-9® ■ Leverage® Heat Activated Leavener
Absorbent	■ Disodium Phosphate ■ Tricalcium Phosphate
Alkalinity	■ Diammonium Phosphate ■ Disodium Phosphate ■ Emulsi-Phos® 440, 660 and 990 ■ Katch® Fish Phosphate ■ Nutrifos® 088 ■ Nutrifos BC ■ Nutrifos B-75 ■ Nutrifos B-90 ■ Nutrifos H30 ■ Nutrifos L-50 ■ Nutrifos SK ■ Nutrifos STP Powder ■ Sodium Potassium Tripolyphosphate ■ Sodium Tripolyphosphate ■ Tetrapotassium Pyrophosphate ■ Tetrasodium Pyrophosphate ■ Trisodium Phosphate
Buffering Agent	■ Adipic Acid ■ Diammonium Phosphate ■ Disodium Phosphate ■ H.T. Monocalcium Phosphate ■ Monoammonium Phosphate ■ Monopotassium Phosphate ■ Monosodium Phosphate ■ Phosphoric Acid ■ Sodium Acid Pyrophosphate ■ Sodium Hexametaphosphate ■ Sodium Potassium Tripolyphosphate ■ Sodium Tripolyphosphate ■ Tetrapotassium Pyrophosphate ■ Tetrasodium Pyrophosphate ■ Trisodium Phosphate
Coagulant	■ Adipic Acid ■ Phosphoric Acid ■ Sodium Acid Pyrophosphate ■ Sodium Hexametaphosphate ■ Sodium Potassium Tripolyphosphate ■ Sodium Tripolyphosphate ■ Tetrapotassium Pyrophosphate ■ Tetrasodium Pyrophosphate
Dispersing Agent	■ Sodium Acid Pyrophosphate ■ Sodium Hexametaphosphate ■ Sodium Potassium Tripolyphosphate ■ Sodium Tripolyphosphate ■ Tetrapotassium Pyrophosphate ■ Tetrasodium Pyrophosphate
Emulsifying Agent	■ Disodium Phosphate ■ Emulsi-Phos 440, 660 and 990 ■ Monopotassium Phosphate ■ Monosodium Phosphate ■ Sodium Hexametaphosphate ■ Sodium Acid Pyrophosphate ■ Sodium Hexametaphosphate ■ Sodium Potassium Tripolyphosphate ■ Sodium Tripolyphosphate ■ Tetrapotassium Pyrophosphate ■ Tetrasodium Pyrophosphate ■ Tetrasodium Phosphate

processes. Toxic alkaloids were reported to be removed by use of 1% manganese dioxide, aeration, and then treatment with 1-1.5% H_3PO_4.[444] TSPP and similar alkali-metal salts were reported to aid in the removal of sterol-containing contaminants of fats and oils.[445] Copper, iron, nickel, and tin in lard were effectively deactivated as oxidation catalysts by phosphoric, citric, tartaric, or ascorbic acids and several of the fatty acid esters of ascorbic acid.[446,447]

Bleaching After a crude fat or oil is refined to remove its impurities, it must be bleached to remove the coloring materials typical of crude fats and oils. Eckey[448] reported that combinations of H_3PO_4 and bleaching clays were preferable in bleaching fats and oils, although sulfuric and metaphosphoric acids could also be used. Other bleaching processes utilize the following treatments:

1. treating with H_3PO_4 and hydrogen peroxide at 60–70°C for 0.5–1.5 hours,[449]
2. treating the fat or oil with H_3PO_4, $H_4P_2O_7$, or any of their acidic salts plus an inorganic silicone acid or its salt while air is bubbled through it,[450]
3. bleaching the fat or oil with TSPP in a solution of hydrogen peroxide,[451]
4. adding acids, especially H_3PO_4, to acid clays that are then used to decolorize the fats or oils,[452]
5. treating the fat or oil with an alkali metal carbonate and H_3PO_4, and later adding a solution of hydrogen peroxide.[453]

Loury[454] reported that he was able to precipitate contaminating metallic salts and to hydrolyze mucilages by treating fats and oils prior to bleaching with dilute H_3PO_4.

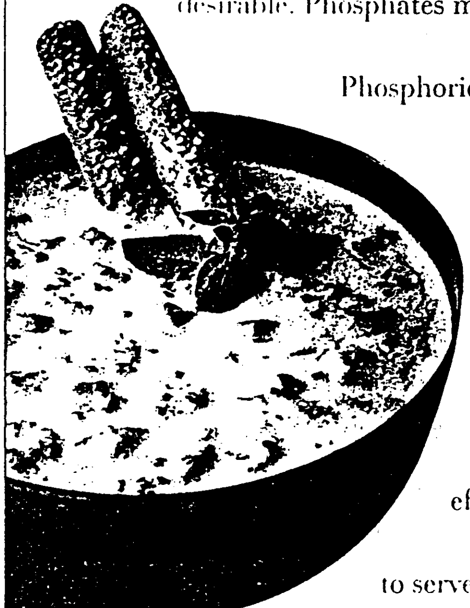
Rearrangement Rearrangement, or interesterification, requires the use of sodium methylate as a catalyst. This catalyst must be destroyed before further processing of the fat or oil can be accomplished. H_3PO_4 was found useful for this purpose with subsequent removal of the acid and inactivated catalyst by neutralization with sodium compounds and by washing.[455,456]

Hydrogenation Phosphoric acid has been used to remove nickel catalysts from hydrogenated fats and oils.[457] Hydrogenated vegetable oils lost the hydrogenation odors and stabilized against odor and flavor reversion by treatment of the hydrogenated fats with H_3PO_4 and a neutral bleaching earth and bubbling air through them at elevated temperatures.[458] H_3PO_4 also has been used in nonselective hydrogenation processes of fats and oils.[459]

Monoglyceride Preparation Monoglycerides are prepared by (1) treating a fat or oil with additional glycerine dissolved in caustic soda, (2) heating, and (3) agitating the mixture until all the glycerine has been esterified by transfer of fatty acids from the triglycerides of the fat. Such compositions, containing mono- and diglycerides, must again be bleached to remove undesirable colored compounds. This can be accomplished by treating the mixture with filter clays and H_3PO_4.[460] It is also necessary to neutralize the sodium hydroxide used as a catalyst; a combination of H_3PO_4 and glycerol has been used to accomplish this neutralization.[461]

Other Processing Applications The presence of glyceride polymers causes foaming, discoloration, and development of off-odors in frying fats. The

Phosphates are well-established ingredients for many food products. Their strength and versatility are founded on their multifunctional and diverse properties. Individual phosphates also are capable of providing more than one functionality. The phosphates furnish a means to control many texture, appearance and flavor problems. Baked products leavened with phosphates exhibit excellent texture, color, volume and lightness. In process cheese products, phosphates provide the meltability and smooth mouthfeel that is so desirable. Phosphates make processed meat more juicy and tender. Phosphoric acid enhances the clean, sparkling flavor of beverages.



Solutia food phosphates meet or exceed the standards established in the Food Chemicals Codex. In addition, specific products meet U.S. Pharmacopeia and/or National Formulary standards for pharmaceutical use. Solutia provides phosphates which are consistent and effective. With these phosphorus-based ingredients comes our commitment to serve your information needs on the functions of phosphates in food. At Solutia, you have direct access to a team of technologists. With Solutia phosphates and know-how, you can achieve even greater quality and profitability for your food products.

polymers can be removed by treating a fat or oil with a combination of phosphoric acid and bleaching clay.[462] Mixtures of filter aids and H_3PO_4 could be used by processors of fried foods to filter their frying fats after each day's use; such filtering could provide additional protection against these polymers in the frying oils.

Applications in Fat Antioxidant Systems

The phosphates have been reported to inhibit the oxidation of unsaturated fatty acids in both dry fat systems and aqueous fat systems.[431–493]

Dry Fat Systems Dry fat systems containing no moisture, as in refined fats and oils, have been stabilized against oxidative rancidity by saturation with H_3PO_4 alone or in combination with its acidic salts and often with the addition of tocopherol or one of the poly-substituted benzene-ring compounds.[431,448,463,464] According to Calkins[465] dry fat and oil systems are saturated by approximately 0.0002% H_3PO_4. This is an insufficient quantity of the acid to provide synergistic activity with 0.02% of antioxidant quinone compounds. However, the stability of the system was dramatically increased as the level of H_3PO_4 was increased from 0.009–0.09% in the presence of the same level of quinone. Calkins suggested that the H_3PO_4 forms an addition compound with the quinone, which can then diffuse in greater quantity throughout the fat system; it, therefore, can undergo exchange reactions with free radicals formed during the initial stages of formation of peroxide compounds in the unsaturated fatty acids. The phosphorylated fatty-acid-peroxide compound then splits off H_3PO_4 to regenerate the unsaturated bond instead of undergoing the usual cleavage of the bond to form aldehydes and other oxidative rancidity by-products.

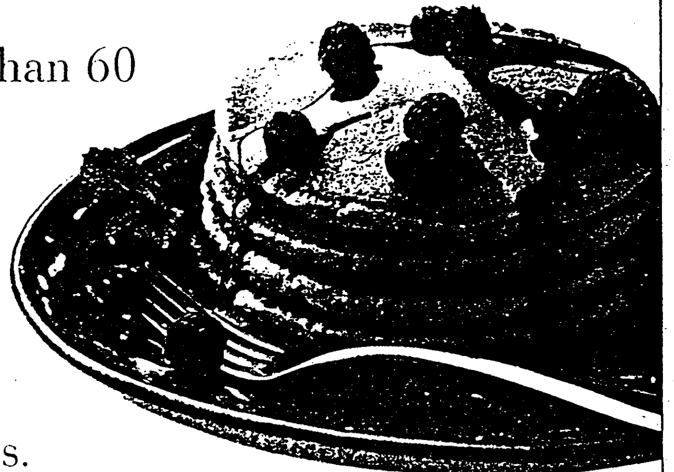
Investigators at the American Meat Institute Foundation[466–468] and several others [469–472] have confirmed the synergistic activity of H_3PO_4 with BHA, BHT, propyl gallate, and similar common organic antioxidants to inhibit the oxidation of fats and oils. Privett and Quackenbush[472] reported that H_3PO_4 has a "sparing action" on organic antioxidants in fat and oil systems and that the organic compounds also exhibit a "sparing action" on the H_3PO_4. They also demonstrated that H_3PO_4 prevents the estimation of fatty-acid-peroxide because it interacts with the peroxide at the temperatures used in accelerated stability tests.

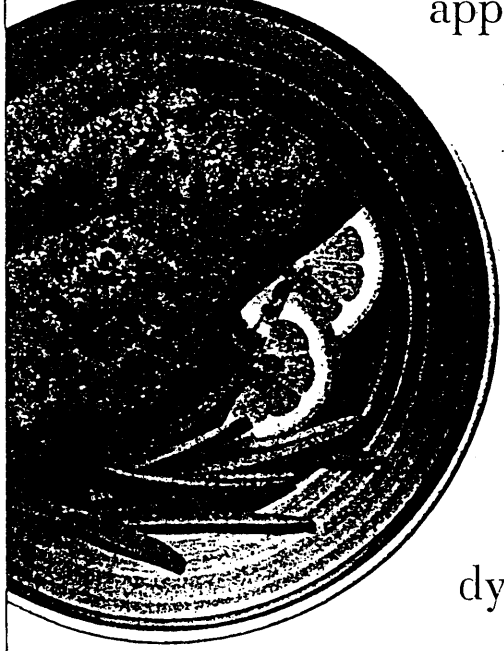
Several patents have been issued based on the synergistic effect of H_3PO_4 with organic antioxidants in dry fat systems.[473–482] Kuhrt[483,484] has reported that the amino acid glycine, H_3PO_4, and their salts increase the stability of dry fat systems against oxidative rancidity from 3–30 times over that of untreated controls.

Aqueous Fat Systems Aqueous fat systems contain both fat and water, and they may contain a number of other ingredients. Watts and her co-workers[485] observed that baked goods leavened with baking powders containing SAPP were more stable toward development of rancid flavors and odors than those leavened with baking powders containing other phosphate acids. SAPP was later confirmed to exhibit synergism with tocopherols naturally present in lard. Watts and co-workers also confirmed that the antioxidant activity exhibited by the SAPP was not due to the binding of copper alone, as had been suggested by Lea.[486] Watts[487] and Watts and her co-workers[488–490] later demonstrated that orthophosphates were ineffective synergists for antioxidant activity of organic antioxidants; the polyphosphates exhibited

Phosphates for Every Application

We're Solutia, formerly the chemical businesses of Monsanto Company. For more than 60 years, we've been producing food phosphates that apply to your applications.

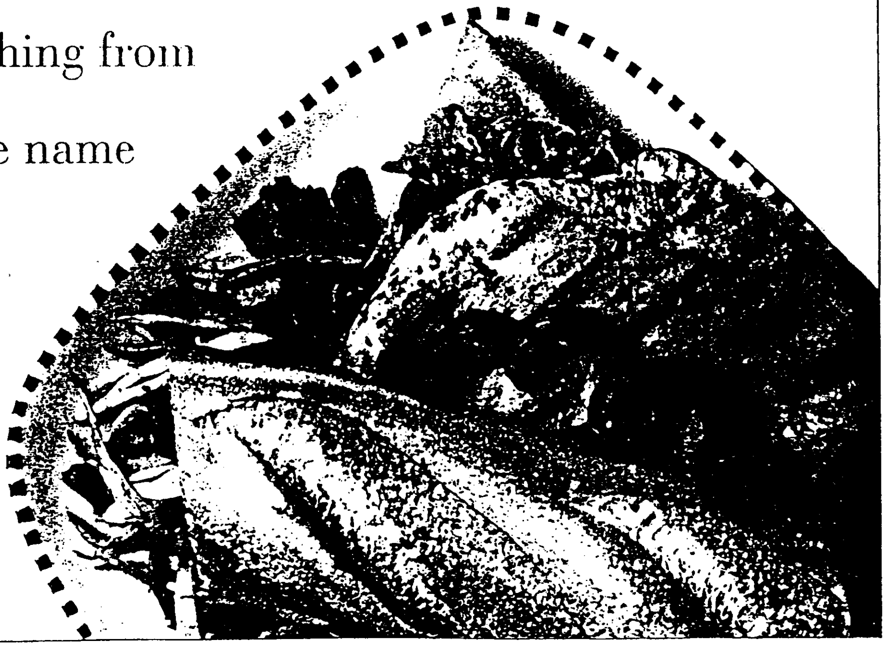




Your formulas.

And your manufacturing processes.

We begin by tailoring innovative solutions that fit the specific needs of our customers. Then we design dynamic new products. So whether you use food phosphates in anything from cakes to hams, we're the name to remember for new creative solutions.



SOLUTIA

increasing antioxidant activity with increasing chain length in the presence of such organic antioxidants. Citrate also had some antioxidant activity, but compared only with the STP and shorter-chain phosphates in its activity. Citrates, pyrophosphates, and STP doubled antioxidant activity in the presence of fat systems, while longer-chain polyphosphates, such as hexametaphosphate and Maddrell's salt, increased activity by 6-12 times. Lehmann and Watts[488] studied the antioxidant activity of several phosphates and citric and ascorbic acids by themselves as well as in the presence of various organic antioxidants. As shown in Table 24, the synergistic activity of the phosphates with the organic compounds varies according to the compound tested. The work of Watts and her co-workers has led to two patented applications for phosphates as antioxidants and as synergists for antioxidants in aqueous fat systems, food products, and pharmaceutical preparations.[489,490]

TABLE 24
Synergistic Effects of Phosphates with Various Primary Antioxidants in Aqueous Lard Systems

Synergist Used[b]	*Days to Turn Rancid at 45°C*[a]					
	Plain Lard	*Lard and 0.005% Tocopherol*	*Lard and 0.005% NDGA*	*Lard and 0.005% BHA*	*Lard and 0.005% Propyl Gallate*	*Lard and 0.005% Lauryl Gallate*
Buffer	2	4	5	22	11	6
Ascorbic acid	< 1	< 1	23	1	< 1	< 2
Citric acid	3	12	20	66	15	16
DSP	2	7	11	43	7	6
STP	3	12	21	48	18	16
SHMP	7	—	34	57	28	21
Maddrell's salt	8	—	31	64	28	27

Source: Lehmann, B. T., and Watts, B. M., 1951, *J. Amer. Oil Chem. Soc.* *28*:475; with permission.

[a] Time required for half bleaching of carotene.

[b] Concentration = 0.1% in pH 7.5 borate buffer.

Ozawa and Ota[491] demonstrated that condensed phosphates increased the preservative effects of a number of "antiseptics" added to boiled fish meat; hexametaphosphate was most effective. The effects, however, could be eliminated by the addition of calcium.

Holman[492] patented the use of a thin film of MSP or MKP around the metal exterior of the pouring spouts of cans; this thin film prevented formation of oxidative rancidity by-products that could form on the spout and contaminate the fat or oil poured from the can.

Mahon and Chapman[493] reported that citric acid, H_3PO_4, glycine, and EDTA were ineffective as acidic synergists in increasing the shelf-life of pie crusts. These authors apparently did not test the longer-chain polyphosphates or polyphosphoric acids for this application. Further evidence of practical applications of the phosphates as synergists and antioxidants in food systems

Our commitment to you.

Solutia has been providing the food industry with food phosphates for over 60 years. At Solutia, our goal is to help you obtain the most efficient utilization of phosphate ingredients – by providing you with high-quality phosphates for your specific applications. Our commitment to supply our customers with quality ingredients, service and assistance is ensured by using statistically proven Total Quality Methods and manufacturing resource planning (MRP II) for manufacturing, customer service, research and delivery. When developing and manufacturing food products, it's important to use only the most consistent and effective ingredients. Ingredients coupled with dependable technical assistance make Solutia a leader in the food phosphate industry. Our team of experienced technologists wants to work with you in support of your product development and in support of the use of our ingredients. Solutia is your partner in product development and delivery.

That's our promise to you.

Table of Contents

will be discussed in subsequent sections in this chapter, particularly in the section on applications in meats.

Applications in Oil and Water Emulsions

Phosphates have been reported to increase the stability of emulsions against separation. van Hees[494] reported that a combination of polyphosphate and pyrophosphate stabilized dispersions of fats and oils with an aqueous phase for "a long time without separation of the fat from the water." A Spanish patent reported that the addition of a phosphate salt to mayonnaise increased the stability of its emulsion.[495] Mitchell[496] reported that the stability of an aqueous peanut-butter suspension was improved by the addition of sufficient DSP to raise the pH of the aqueous phase to 6.6–6.8. Vincent[497] reported a similar stabilizing effect of phosphates on comminuted peanuts when the pH was buffered to remain between 6.5–7.0. These emulsion stabilization applications may depend on buffering capacity to produce the optimum pH for maximum protein-film dispersion to stabilize the system against separation into aqueous and fat phases.

Phosphate Applications in Fruit and Vegetable Products

Table 1 has shown that fruits and vegetables contain significant levels of phosphorus. Investigators have demonstrated that phosphorus exists in the plant tissues and juices as phosphoric acid and phosphate anions at levels as high as 2.7% of dihydrogen phosphate anion in some citrus fruits.[498–500] In spite of these high levels of phosphate and phosphoric acid, phosphates have significant functions as food ingredients in vegetable and fruit processing. They provide stabilization against microbiological spoilage, oxidative rancidity, vitamin loss, and loss of color; they also increase and optimize tenderization or firming of fruit and vegetable tissues and thickness or viscosity of juices and purées.

Applications as Inhibitors of Microbiological Spoilage

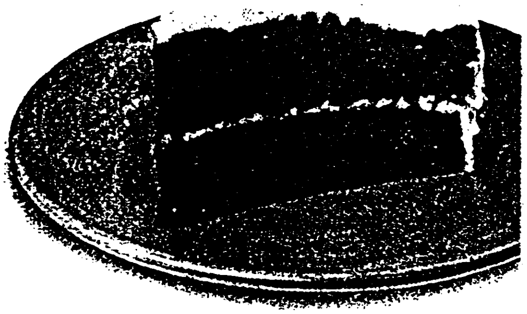
Surface Applications Although some surface applications for phosphates in fruits utilize their ability to act as detergents in the removal of spray materials and the natural waxy coatings of the fruits,[501] other surface applications utilize their ability to act as microbiological inhibitors and as synergists for other preservatives. Bates[502] found that by immersing fruits in a solution of TSP or DSP and drying them so that a film of the phosphate remains, particularly in surface cuts, scratches, or abrasions, the decay of the fruits was delayed for a significant period of time. Rippey[503] preferred a 50-50 combination of TSP and sodium carbonate to reduce the attack of molds on the surfaces of fruits and the spread of mold from one fruit to another. Kalmar[504] applied the surface preservative sodium orthophenylphenate to the surface of fruits in the presence of TSPP, TSP, or sodium carbonate, or a combination of these, at pH values of 10–11.5. Kalmar[505] further reported that combinations of sodium hypochlorite and a buffer composed of DSP and sodium carbonate at a pH of 10.2–11.5 also prevented spoilage of fruit surfaces from blue and green molds.

Smith and Krause[506] prevented the growth of bacteria and enzymatic browning by treating the surfaces of peeled, raw potatoes with a solution of

ASTARIS™
Quality Products. Exceptional Response.

ASTARIS LLC
P.O. Box 411160
622 Emerson Road
St. Louis, Missouri 63141-1160

314-983-7500
www.astaris.com



food phosphat

H_3PO_4, propylene glycol, sodium benzoate, and sodium metabisulfite. Brandt[507] significantly extended the shelf-life and protected fruits and vegetables against microbiological spoilage by dipping them in solutions of $H_4P_2O_7$ at ambient temperatures. The treatment preserved the original colors of the fruits and vegetables and prevented certain types of discoloration, such as the after-cooking darkening of potatoes. When $H_4P_2O_7$ was used alone, mold growth was inhibited only at concentrations above 0.5%. However, combinations of $H_4P_2O_7$ at levels below 0.5% combined with benzoic acid were highly effective. The microbiological preservation could not be explained as being due to the low pH, since buffered solutions were equally effective and often were required when the food was adversely affected by low pH values. Post and co-workers[508] found that polyphosphates were highly effective in preventing mold growth on the surface of fresh cherries if the fruit was dipped in a 10% solution of sodium tetrapolyphosphate; SHMP, STP, and TSPP were also effective, but their effectiveness decreased in the order given. The polyphosphates were believed to interfere with germination of the fungal spores in some unknown way. Although some spores eventually germinated, they produced weak mycelial growth. Similar effects were observed by Kohl and Ellinger.[103]

Applications in Fruit and Vegetable Juices Kohl and Ellinger[509] demonstrated through microbiological and taste tests that the shelf-life of apple cider treated with a combination of SHMP and either sodium benzoate or potassium sorbate was more than doubled when compared with the same lot of cider treated with the benzoate or sorbate alone. SHMP used by itself was less effective than when used in combination with another compound. The same effect on shelf-life was demonstrated with other fruit and vegetable juices.

Applications as Antioxidants

Combinations of SAPP or citric acid with a mixture of BHA and BHT were shown by Deobald and co-workers[510] to retard the development of off-flavors from oxidative rancidity in sweet-potato flakes. TSPP was reported[511] to extend the shelf-life of dried vegetables when they were dipped into a solution of the phosphate prior to blanching and drying. Although Rhee and Watts[512] found that STP failed to inhibit the activity of lipoxidase in model systems containing pea or soybean lipoxidase, STP was found to be a very effective antioxidant in slurries prepared from the peas themselves. BHA and gallic acid and its esters were less effective when used in treating the peas, but they were highly effective in the artificial systems; the authors were unable to explain the differences in effect.[512]

Molsberry[513] found that the flavor and the texture of frozen mushrooms were retained by treatment with a "sealing mixture" of approximately 1 part sodium sulfate, 1 part DSP, and 2 parts sodium bisulfite in water. The oxidation of ascorbic acid was prevented, and this important vitamin was preserved in model systems and in sugared and non-sugared citrus juices by SHMP[514] and by metaphosphoric acid.[515]

Applications in Stabilizing Fruit and Vegetable Colors

Hall[516] preserved the natural red colors of tomatoes, ketchup, and all types of red berries, their preserves, and juice products by adding 0.1–0.4% of one of the polyphosphates to the fruits prior to cooking. All of the polyphosphates—

MC Corporation
ood Phosphates Marketing
735 Market Street
hiladelphia PA 19103

from pyrophosphates through the long-chain potassium and sodium metaphosphates—were effective. The longer-chain polyphosphates were more effective than those with shorter chains.

Nelson and Finkle[517] discovered that treatment of apple slices with a mildly alkaline solution resulted in the methylation of *o*-diphenolic compounds and subsequently prevented them from being substrates for the enzymatic reaction that causes development of a brown color on the surface of the exposed apple tissue. Bolin and co-workers[518] developed a commercial process based on Nelson and Finkle's work that inhibited the development of a brown surface color and maintained a very crisp texture and a preferred flavor in treated apple slices as compared to those produced by present commercial processes.

The bright-green color of vegetables intended for canning or freezing has been preserved when they were treated with a DSP buffer system that maintained a pH of 6.8–7.0.[110] Fleischman[519] reported that buffering vegetable purées with orthophosphates at pH 8.0 in the presence of magnesium carbonate increased the production of green chlorophyllide in vegetable purées and thus stabilized their green color. Taste panels preferred the flavor of the treated vegetable purées over untreated controls.

The presence of as little as 1 ppm iron and 0.1 ppm copper in fruit or vegetable tissues has been reported sufficient to catalyze the oxidation of *o*-diphenolic compounds to produce tissue discoloration. Most fruit and vegetable tissues normally contain higher levels of each metal. Combinations of sulfites, such as sodium sulfite, with a mixture of SAPP and TSPP to maintain optimum pH for the sulfite reaction have been reported to control enzymatic discoloration of raw fruit and vegetable tissues.[27]

The blackening of raw and cooked potato tissues due to the oxidation of *o*-diphenolic compounds in the presence of iron and other heavy metals has been one of the most extensively investigated discoloration reactions in fruit and vegetable processing.[27,28,30,110,111,520–528] Raw, peeled potatoes have often been treated with sulfur dioxide or with sodium bisulfite in acidic solution (to provide sulfur dioxide) to inhibit the enzyme that catalyzes this reaction. Michels[520] reported that by treating the raw, peeled potatoes with polymerized phosphoric acids and calcium or magnesium ions, the blackening of the raw tissues was inhibited.

The after-cooking darkening of potatoes, which also is a reaction involving the oxidation of *o*-diphenolic compounds, requires the presence of iron to catalyze this enzymatic reaction. Juul[522–523] was apparently the first to discover that SAPP was highly effective in sequestering any iron present in potato tissue and therefore prevented the after-cooking darkening when the potatoes had been dipped or cooked in a solution of the phosphate. Smith and his co-workers[521,524–526] extensively studied the use of SAPP to prevent after-cooking darkening, confirming that this was a highly effective treatment. EDTA also was reported to perform the same function.[521] However, because the treatment with SAPP is generally less costly and fully as effective, it is in general use in the potato-processing industry. Smith and Davis[525] reported that gray or black discolorations in cooked-potato tissues could be eliminated if the cooked potatoes were dipped in a solution of SAPP at 40°F. A complete bibliography of the literature on this topic has been published recently by Talley and co-workers.[527]

Table 3

Phosphates in Dairy Products

Dairy Product	Phosphate Used	Function	Recommended Phosphate Level (% weight)
Process Cheese			
Melting	DSP DUO, TSPX	emulsifier, protein stabilizer	2.0
Non-melting	STPP, SHMP		2.0
Cheese Powder	DSP	protein stabilizer	1.5–2.5
Instant Pudding	TSPP, DSP	protein coagulant	2.5–3.0
Cheesecake Filling Mix	TSPP, MCPM	protein coagulant	1.5
UHT Beverage	DSP, SHMP	protein stabilizer	0.1–0.5
Evaporated and Condensed Milk	DSP	protein stabilizer	0.02–0.1
Lowfat Milk Powder	DSP	dispersant	2% max based on solids
Coffee whitener	DKP, TKPP, DSP, STPP	dispersant, protein stabilizer	
Liquid			0.1–1.0
Powder			1.0–2.0
Whipped Toppings	DSP, DKP, TSPP	protein stabilizer	0.02–1.0
Whey Processing	SHMP	protein dispersant	0.1–0.5
Ice Cream, Frozen Dairy Desserts	DSP, TSPP, SHMP	protein stabilizer, emulsifier	0.1–0.2

Technical Service

Our experienced technical staff is available to assist you in your product development efforts. Please call 1-800-848-3362 to obtain prompt and reliable technical service from our phosphate specialists.

The levels and type of phosphate to be used differ greatly depending on the product. FMC can provide the technical expertise to assist you with your formulation changes.

Federal Regulations

FMC food-grade sodium, potassium, and calcium phosphates comply with Food Chemicals Codex specifications and are classified as GRAS (Generally Recognized As Safe) by the U.S. Food and Drug Administration. In pasteurized process cheese and related products, phosphates may be added to a maximum of 3.0% of the weight of the finished product. Lowfat milk may contain up to a maximum of 2.0% phosphates based on the weight of the solids. The amount of phosphates that can be added to most other dairy products is limited to good manufacturing practice. A summary of phosphate functions and sugested use levels in various dairy products is provided in Table 3.

Inhibition of discoloration and retention of the original bright-orange color of sweet-potato flakes and of canned and frozen sweet potatoes have been accomplished by treating them with SAPP or a combination of SAPP and TSPP.[523,528] MSP and longer-chain polyphosphates have been shown to be much less effective for this treatment.

Applications in Obtaining Optimum Texture

Kertesz[529] discovered the influence of the calcium ion in the firming and tenderization of fruit or vegetable tissues and in the control of the viscosity of purées and juices. The calcium ion reacts with the pectic acid (polygalacturonic acid) that is formed upon the demethoxylation of natural pectin in the fruit or vegetable cell wall. This reaction is also responsible for gelling of fruit juices during preparation of preserves, jams, and jellies.[28] Proper control of the calcium ion can be highly beneficial in the processing of fruits and vegetables. The introduction of soluble calcium salts can increase firmness of tissues of whole fruits and vegetables, while the precipitation or complexing of calcium can tenderize tissues or prevent gelation of fruit and vegetable pectins.[28]

Pectin Gels Pectin is normally extracted from apple pomace or the peels of citrus fruits by heating these materials with acid. Many housewives are familiar with the necessity for pectin in the preparation of fruit preserves. As reviewed by Kertesz,[529] natural pectins in the cell walls of fruits and vegetables become demethoxylated by the enzymes in the tissues when the cell walls are broken. Gels are formed when the resulting pectic acid reacts with calcium. The yield of pectin during its extraction from the source material is significantly increased by the addition of SHMP to the fruit pulp to sequester calcium ion and prevent the formation of calcium pectate; pectin yields have been reported to be increased as much as 25%, and the extraction time has been decreased by as much as 50%.[530-536] The effectiveness of polyphosphates was found to increase with increasing chain lengths from pyrophosphate to SHMP.

The polyphosphates have been found to be highly effective in obtaining optimum characteristics in pectin gels. An excellent review of the chemistry and uses of pectin has been published by Woodmansee[536] and contains a good bibliography for further study. Numerous reports and patents describe the useful applications of various types of phosphates in the control of pectin gel formation for use in the production of pectin materials for home canning, the commercial production of preserves, jams, and jellies, and the preparations of a number of other dessert gels.[531,535-543] Waller and Baker[535] reported that polyphosphates are rapidly hydrolyzed to orthophosphate, which then is capable of entering phosphorylation reactions with pectin to form cross-linked chains throughout the entire gel system. SHMP again was found to be more effective than sodium tetrapolyphosphate, and the shorter-chain polyphosphates were decreasingly effective.

Because it is naturally present in many fruit and vegetable juices, H_3PO_4 has often been used to provide optimum tartness and pH for setting of pectin gels. It has the added advantage that its effectiveness is not diminished by heat.[27,28,110,111]

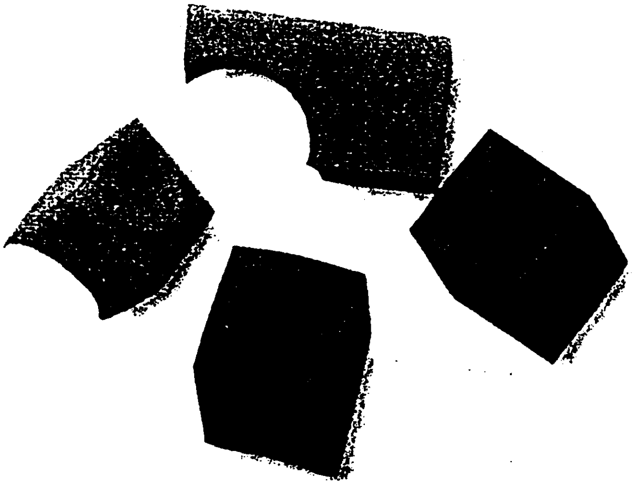
Tomato Products Studies have shown that the phosphates have many beneficial applications in the processing of tomato products.[544-547] SHMP, added to the tomato fruit prior to cooking, has produced more viscous tomato

Table 2

Standards of Identity for Pasteurized Process Cheese and Related Products*

Type	Ingredients	Fat Content (minimum)	Moisture (maximum)	pH (minimum)
Cheese	Natural cheese, emulsifying salts, water, coloring, other optional ingredients	47% of solids (Swiss, 43%) (Gruyere, 45%)	43% (Colby, 40%) (Swiss, 44%) (Limburger, 51%)	5.3
Cheese food	Natural cheese, emulsifying salts, water, salt, coloring, spices or flavorings, other optional ingredients	23%	44%	5.0
Cheese spread	Natural cheese, emulsifying salts, water, salt, coloring, hydrocolloids (0.8%, max.), sweetening agent, spices or flavorings, other optional ingredients	20%	60%	4.0

*21 Code of Federal Regulations Chapter 1 (4-1-91 Edition)



sauces,[544] aided in the viscosity control of tomato purées,[546] and increased the yields of juice obtained from tomato pulp.[545] The addition of SHMP to tomato pulp has increased the viscosity of juice extracted from it;[531-545] the addition of H_3PO_4 has been used to improve viscosity of tomato juice, tomato purée, and similar products in a recently proposed improved hot-break process.[547]

Potato Texture SAPP was used by Smith and Davis[548] to improve the mealiness and other textural properties of potato products. Cole[549] improved the textural characteristics of dehydrated potato products by cooking them in buffered water maintained at a pH of 6–8 with mixtures of MSP and DSP or their potassium equivalents. The ability of phosphates to improve mealiness of potato products has been reviewed by Kintner and Tweedy[550] and Smith.[521] Textural characteristics have been improved in direct relation to the amount of SAPP added. This is probably due to formation of small quantities of phosphorylated amylopectin, which prevents rupture of the starch granules due to increased hydrogen bonding between the phosphorylated starch molecules.

Tenderization Many fruits and vegetables have tough skins that grow increasingly tough as they become too mature. The toughness of fruit and vegetable skins has been shown to increase in direct proportion to increasing content of calcium. This may be natural calcium or that introduced through the use of hard water in blanching the fruits and vegetables. The addition of STP or SHMP to the water used in processing fruits and vegetables decreases the toughness of the skins of peas, lima beans, snap beans, corn,[27,110,111,551,552] and plums.[553,554] This author has also noted the significant tenderization of the skins of broccoli by applying SHMP to the blanching water; in fact, the broccoli can be tenderized to the point that it is unacceptably tender for eating. Treatment of the fruits or vegetables with SHMP has been shown to have no effect on sugar or vitamin-C levels or to upgrade poor-quality vegetables.[551]

Neubert and Carter[553] demonstrated that the toughness of the skins of Italian prune plums is directly proportional to the level of calcium in the skins, as shown in Figure 3. The calcium content of the water used in processing, as well as the natural calcium content of the skins, contributed to increasing toughness. The addition of SHMP at levels above 0.5% tenderized the skins and also softened the flesh of the plums. An increase in the calcium content of the syrup also contributed to toughening of the skins, as demonstrated in Figure 3. SHMP added to salt brine increased the penetration of the salt into the shells of peanuts, allowing processors to prepare salted peanuts inside the shells.[111] A combination of SHMP and papain increased the penetration of syrup into cherries that are being sweetened, and it shortened the time of the process.[555]

Firming Tissues The studies of Loconti and Kertesz[556] have shown that calcium salts are definitely involved in the firming of the tissues of tomatoes through their ability to form calcium pectates. Calcium salts also have been shown to be effective in firming peeled apple slices used for freezing and canning[557] and in the firming of snap beans.[558] The addition of soluble calcium salts, such as MCP, calcium chloride, calcium sulfate, or calcium citrate for the firming of canned tomatoes, potatoes, green or red sweet peppers, lima beans, and carrots, has been approved in the federal standards for these vegetables.[559] In 1969 a temporary approval was granted for the addition of soluble calcium salts to canned sweet potatoes for similar purposes.[560]

964. Andres, P., 1940, *Z. Wirtschaftsgruppe Zuckerind. 90*:228; 1941, *Chem. Abstr. 35*:4987.
965. Neumann, M. W., 1940, *Arch. Suikerind. Nederland Ned.-Indie 1*:51; 1940, *Chem. Abstr. 34*:4604.
966. Saha, J. M., and Jain, N. S., 1954, *Sugar 49(3)*:38; 1954, *Chem. Abstr. 48*:5533.
967. Chemische Werke Albert and Sueddeutsche Zucker A.-G., Belgian Patent 611,251, 1962; 1962, *Chem. Abstr. 57*:14042h.
968. Barrett, E. P., Brown, J. M., and Olech, S. M., 1951, *Ind. Eng. Chem. 43*:639.
969. Barrett, E. P., 1952, *Sugar Ind. Technicians 1952*:9 pp.; 1952, *Chem. Abstr. 46*:9331.
970. Kubala, S., 1952, *Cukoripar 5*:229; 1953, *Chem. Abstr. 47*:11775.
971. Kortschak, H. P., 1942, *Hawaii. Plant. Rec. 46*:105.
972. Jung, E. V. (Knapsack Aktiengesellschaft), U.S. Patent 3,347,705, 1967.
973. Cummings, A. B. (Johns-Manville Products Corp.), Canadian Patent 421,985, 1944.
974. Fowler, A. P., 1936, *Proc. Cuban Sugar Tech. Assoc. 10*:52.
975. Sanchez, P., and Ehrhert, E. N. (Sucro-Blanc, Inc.), U.S. Patent 2,216,753, 1940.
976. Isbell, H. S. (Government of the United States), U.S. Patent 2,421,380, 1947.
977. Vincent, G. P. (Mathieson Alkali Works, Inc.), U.S. Patent 2,430,262, 1947.
978. Andresen, V. V. J., U.S. Patent 1,732,492, 1929.
979. Yasuo, I., 1955, *Sugar J. 18(5)*:29.
980. Schongart, H. A., 1959, *Z. Zuckerind. 9(1)*:10.
981. Gupta, S. C., and Ramaiah, N. A., 1965, *Indian Sugar 14*:719; 1965, *Chem. Abstr. 63*:18435f.
982. Moss, H. V., 1934, *The Canner 79(6)*:18; 1934, *Chem. Abstr. 28*:7054.
983. White, J. R., and Dunn, J. A. (Lever Bros. Co.), U.S. Patent 2,225,894, 1940.
984. Nelson, T. J., 1949, *Food Technol. 3*:347.
985. Mead, M. W. (National Grain Yeast Corp.), U.S. Patent 2,075,127, 1937.
986. Byk, H. (Chemische Werke, Charlottenburg), German Patent 247,809, 1910.
987. Epstein, A. K., and Harris, B. R., U.S. Patent 2,075,807, 1937.
988. Martin, G. D. (Monsanto Chemical Co.), U.S. Patent 2,247,280, 1941.
989. Nyrop, J. E., British Patent 640,241, 1950.
990. Harris, B. R., U.S. Patent 2,177,983, 1939.
991. Katzman, M. (Emulsol Corp.), U.S. Patent 2,243,868, 1941.
992. Thurman, B. H. (Refining, Inc.), U.S. Patent 2,271,409, 1942.
993. *Ibid.*, U.S. Patent 2,272,616, 1942.
994. Pader, M., and Gershon, S. D. (Lever Bros. Co.), U.S. Patent 3,224,883, 1965; 1967, *Chem. Abstr. 67*:2295g.
995. *Ibid.*, U.S. Patent 3,224,884, 1965.
996. Katzman, M. B. (Emulsol Corp.), U.S. Patent 2,176,078, 1939.
997. Thompson, J. E. (Procter & Gamble Co.), U.S. Patent 3,458,323, 1969.
998. Cunningham, F. E., Kline, L., and Lineweaver, H. (United States of America), U.S. Patent 3,328,175, 1967.
999. Gumbmann, M. R., Gagne, W. E., and Williams, S. N., 1968, *Toxicol. Appl. Pharmacol. 12*:360.
1000. Curtin, J. H., and Gagolski, J. (Colonial Sugar Refining Co., Ltd.), U.S. Patent 3,375,168, 1968.
1001. Toy, A. D. F. (Colonial Sugar Refining Co., Ltd.), U.S. Patent 3,428,624, 1969.
1002. Stauffer Chemical Company, Netherlands Patent Application No. 6,608,960, 1966; British Patent No. 1,139,684 (1969).
1003. Tucker, J. W., and Toy, A. D. F. (Colonial Sugar Refining Co., Ltd.), Canadian Patent 825,087, 1969.
1004. Colonial Sugar Refining Co., Ltd., Japanese Patent 21,383 ('69), 1969.
1005. Kyowa Hakko Kogyo Co., Ltd., Japanese Patent 13,486 ('70), 1970; 1971, *Food Sci. Technol. Abstr. 3*:1H58.

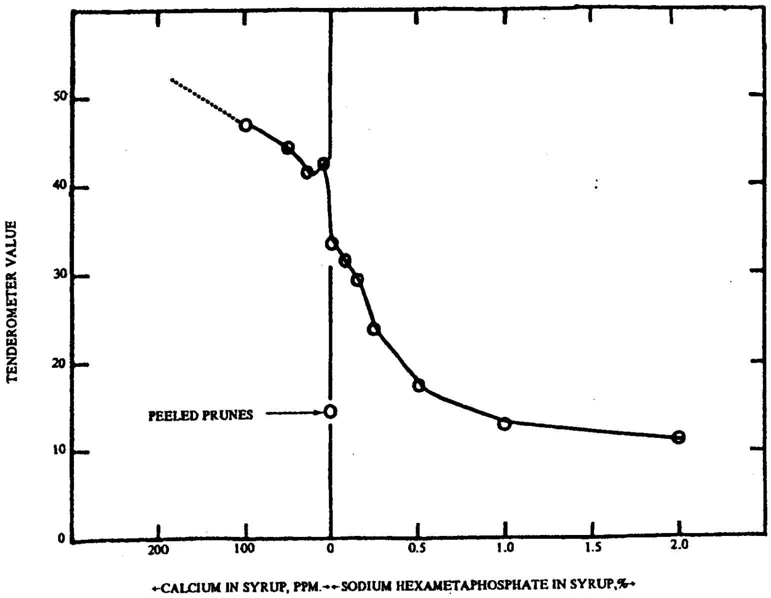


Fig. 3. Effect of addition of calcium and sodium hexametaphosphate on texture of canned Italian prunes. (Source: Neubert, A. M., and Carter, G. H., 1954, *Food Technol.* 8:518; with permission.)

Miscellaneous Applications

Dakin[561] reported that pyrophosphates and other compounds retarded softening of cabbage tissue due to the oxidation of cellulose to form pectic materials. Takeda Chemical Industries[562] found that either EDTA or polyphosphates softened salted pickles if added prior to brining. DSP or TSP also has been reported necessary in production of imitation or fabricated potato chips.[563]

Phosphate Applications in Gums and Gels

The vegetable gums, like pectin, are long-chain, high-molecular-weight polysaccharides or mixtures of polysaccharides that are capable of interacting as polyelectrolytes; therefore, they are capable of interacting with other polyelectrolytes, particularly the long-chain polyphosphates. Gums often are used as stabilizers and thickeners in food processing. Some merely swell when hydrated and, therefore, increase viscosity of the food system, while others form thick rubbery gels. Glicksman has published excellent reviews of the properties and uses of the various vegetable gums in *Advances in Food Research*[564] and Chapter 7 of this handbook. The phosphates are capable of modifying and improving the physical characteristics of gums such as agar, alginates, carrageenan, guar, and locust bean. A review of phosphate interactions with gums has been published by Sand and Sodano.[29]

Applications in Agar Gel Systems

Agar has been used in foods in the Orient for centuries, and it is commonly used as a stabilizer in the manufacture of chiffon pies, meringues, icings, and

915. Neukom, H. (International Minerals & Chemicals Corp.), U.S. Patent 2,824,870, 1958.
916. *Ibid.,* U.S. Patent 2,865,762, 1958.
917. Ferrara, L. W., U.S. Patent, 2,865,763, 1958.
918. Neukom, H., U.S. Patent 2,884,412, 1959.
919. Kodras, R., U.S. Patent 2,971,954, 1961.
920. Sietsema, J. W., and Trotter, W. C., U.S. Patent 2,993,041, 1961.
921. Schierbaum, F., and Boerner, O., East German Patent 36,806, 1965; 1965, *Chem. Abstr. 63*:3150f.
922. Felton, G. E., and Schopmeyer, H. H. (American Maize Products Co.), U.S. Patent 2,328,537, 1943.
923. Wetzstein, H. L., and Lyon, P., U.S. Patent 2,754,232, 1956.
924. Kerr, R. W., and Cleveland, F. C., Jr. (Corn Products Co.), U.S. Patent 2,801,242, 1957.
925. *Ibid.,* U.S. Patent 2,852,393, 1958.
926. *Ibid.,* U.S. Patent 2,938,901, 1960.
927. Gramera, R. E., Heerema, J., and Parrish, F. W., 1966, *Cereal Chem. 43*:104.
928. Deutsche Maizena Werke G.m.b.H., German Patent 1,109,500, 1961.
929. Ogawa, H., Japanese Patent 5,017 ('70), 1970; Chiyoda Kagako Kogyosho Co., Ltd., Japanese Patent 5018 ('70), 1970; 1970, *Food Sci. Technol. Abstr. 2*:9M798, 9M799.
930. Anon., 1961, *Fed. Reg. 26*:188; *ibid.*, 1964, *29*:14403; *ibid.*, 1964, *29*:15256; *ibid.*, 1967, *32*:8359.
931. Baikow, V. E., 1956, *Sugar 51*:39; 1956, *J. Sci. Food Agr. 7*:ii.
932. Taussig, C. W., and Roland, A. C. (Applied Sugar Laboratories, Inc.), U.S. Patent 2,249,920, 1941; British Patent 525,014, 1940.
933. Cummins, A. B., 1942, *Ind. Eng. Chem. 34*:398.
934. Wright, A., *ibid.*, 425.
935. Boyd, R., Canadian Patent 422,170, 1944.
936. Bliss, L. R., 1948, *Int. Sugar J. 50*:205; 1948, *Chem. Abstr. 42*:8502.
937. Cook, H. A., and Kilby, M., 1948, *Rep. Hawaiian Sugar Technol. 6*:195; 1950, *Chem. Abstr. 44*:7076.
938. Bojorquez, M. O., Jasso, J. deJ. U., and Acosta, J., July 1951, *Bol. Azucar. (Mex.) 2*:23; 1951, *Sugar Ind. Abstr. 13*:182.
939. Black, R. F., and Zemenek, L., 1952, *Sugar Ind. Technicians 1952*:9 pp.; 1952, *Chem. Abstr. 46*:9331.
940. Ishigaki, H., 1953, *Sci. Rep. Hyogo Univ. Agr., Ser. Agr. Chem. 1*:15.
941. N.V. Algemeene Norit Mfg., German Patent 1,008,219, 1957.
942. Zemanek, L. A., 1959, *Publ. Tech. Papers Proc. Ann. Meeting Sugar Ind. Technicians 18*(Sect. VI):1.
943. Delfos, J. J. (N.V. Algemeene Norit Maatschappij), U.S. Patent 2,964,428, 1960.
944. Payet, P. R., French Patent 1,230,842, 1960.
945. Bennett, M. C., and Ragnauth, J. M., 1960, *Int. Sugar J. 62*:13, 41.
946. de Sornay, P., 1915, *Bull. Soc. Chim. Maurice 6*:41; 1916, *Chem. Abstr. 10*:1109.
947. Schulmann, V., 1938, *Listy Cukrovar 56*:501; 1938, *Chem. Abstr. 32*:8813.
948. Klopfer, V., U.S. Patent 2,243,381, 1941.
949. Anon., 1942, *Food Ind. 14(2)*:104.
950. Alvarex, A. S., 1942, *Rev. Ind. Agr. Tucuman 32*:127.
951. Bollaert, A. R., and Halvorsen, G. G. (Great Lakes Carbon Corp.), U.S. Patent 2,470,332, 1949.
952. Golovin, P. V., and Gerasimenko, A. A., U.S.S.R. Patent 116,101, 1958.
953. Golovnyak, Y. D., Kartashov, A. K., and Kurilenko, O. K., *Izv. Vyssh. Uchebn. Zaved. Pishch. Tekhnol. 1962(5)*:78; 1964, *Chem. Abstr. 60*:4321f.
954. Skorobogat'ko, N. I., 1963, *Sakh. Prom. 37(5)*:41; 1963, *Chem. Abstr. 59*:6599g.
955. Muehlpforte, H., 1963, *Zuckererzeugung 7(4)*:106; 1964, *Chem. Abstr. 60*:10909g.
956. Onanchenko, L. I., 1966, *Sakh. Prom. 40(2)*:11; 1966, *Chem. Abstr. 64*:14399f.
957. Katana, A. I., 1966, *Sakh. Prom. 40(12)*:12; 1967, *Chem. Abstr. 66*:77201m.
958. Golubeva, A. D., Kartashov, A. K., Limanskaya, A. Y., and Verchenko, L. M., 1969, *Sakh. Prom. 43(10)*:55; 1970, *Food Sci. Technol. Abstr. 2*:6L394.
959. Bird, M., 1928, *Facts About Sugar 23*:139; 1928, *Planter Sugar Mfr. 80*:143.
960. Ruping, H., German Patent 617,706, 1935.
961. Spengler, O., and Todt, F., 1941, *Z. Wirtschaftsgruppe Zuckerind. 91*:87.
962. Loewy, K., 1943, *Rev. Bras. Quim. 15*:105; 1943, *Chem. Abstr. 37*:6921.
963. Gururaja, J. S., and Ray, P. K., 1946, *Indian Sugar 7*:127.

toppings. It is also frequently used in preparing confectionery gums and gels.[28,564]

Since agar is composed of at least two polymeric electrolytes, the phosphates should be useful in improving its gelling characteristics. Apparently only Sergeeva[565] has studied the beneficial effects of DSP upon a gel composed of agar, sugar, and molasses for use in preparing orange and lemon slices. She demonstrated that the gelling strength of the agar gel was significantly increased by the addition of 0.12–0.3% DSP.

Applications in Alginate Gel Systems

The basic component of alginate gels is believed to be alginic acid, a powerful, anionic polyelectrolyte that reacts readily with cationic polyelectrolytes such as the polyphosphates. Although alginic acid is insoluble, its sodium, potassium, and ammonium salts are very soluble and are used in foods.

The soluble alginic acid salts react with the di- or trivalent metal ions to form insoluble salts of the metal alginate. If the reaction is too rapid, grainy, discontinuous gels or even precipitates are formed. If the rate is too slow, the gel formation will require too long a period to be practical, and the resulting gel may be too soft. It is, therefore, necessary to prepare a system in which a slow, uniform rate of release of the metal ion is obtained. The calcium ion is usually the preferred metal ion for preparation of alginate gels. Glicksman[564] has discussed the conditions required for obtaining optimum alginate food gels.

As would be expected from its calcium content, milk forms gels with alginic acid. It is necessary to first obtain complete dispersion of the soluble alginate throughout the milk before gelling begins. This was accomplished by Lucas,[566] who added TSP to sodium alginate, and by Steiner,[567,568] who used combinations of SHMP and a difficultly soluble calcium salt, such as TCP, to control body and texture of ice cream, chocolate milk, and other dairy products, as well as fruit jams and jellies, jellied salads and broths, water-gelled desserts, and candied jellies. Steiner's most successful system included a soluble alginate salt, a difficultly soluble calcium salt, a gel-retarding agent, such as SHMP, and a weakly acidic compound, such as glucono-Δ-lactone. Roland[569] reported a process for controlling viscosity and stabilizing suspended particles in food systems by first adding TSPP, STP, or long-chain polyphosphates to an aqueous suspension of the metal ion, such as milk, which contains calcium; the alginate salt is then added to the product. Gibsen[570] reported that a combination of sodium alginate, sodium carbonate, a calcium salt, and a buffering agent, such as TSPP, could be used in preparing instant-milk-pudding mixes. He later reported the preparation of smooth, firm, cold-water-soluble dessert gels by combining (1) a slightly soluble dibasic acid, such as adipic or fumaric acid, with (2) sodium alginate, (3) a slowly soluble calcium salt, such as TCP or DCP, and (4) a gel-retarding sequestering agent, such as SHMP.[571]

Rocks[572] prepared cold-water-soluble dessert gels that required only the slowly soluble calcium salts, such as DCP and TCP, and a weak acid; Rocks' formula eliminated the use of a calcium sequestering agent. Hunter and Rocks[573] prepared a sodium phosphoalginate from a wet paste of sodium alginate and TSP, which could then be dried and utilized for preparation of milk puddings. Merton and McDowell[574] prepared instant, cold-water-soluble dessert gels from a four-component system composed of the soluble alginate,

872. Beckel, A. C., DeVoss, L. I., Belter, P. A., and Smith, A. K. (U.S. Department of Agriculture), U.S. Patent 2,444,241, 1948.
873. Beckel, A. C., Belter, P. A., and Smith, A. K. (U.S. Department of Agriculture), U.S. Patent 2,445,931, 1948.
874. Glabe, E. F., Goldman, P. F., Anderson, P. W., Finn, L. A., and Smith, A. K., 1956, *Food Technol. 10*:51.
875. Norris, F. A., and Johnson, D. C. (Swift & Co.), U.S. Patent 3,155,524, 1964.
876. Pintauro, N. D., Reynolds, J. M., and Newman, K. R. (General Foods Corp.), U.S. Patent 3,147,125, 1964.
877. Burnett, R. S., and Gunther, J. K. (Central Soya Co., Inc.), U.S. Patent 2,489,173, 1949.
878. Sevall, H. E., and Schaeffer, R. P. (The Borden Co.), U.S. Patent 2,588,419, 1952.
879. Patterson, B. A., U.S. Patent 2,716,606, 1955.
880. Gunther, R. C. (Gunther Products, Inc.), U.S. Patent 2,844,468, 1958; Canadian Patent 565,025, 1958.
881. Sutton, W. J. L. (Monsanto Chemical Co.), U.S. Patent 2,929,715, 1960.
882. Clausi, A. S., Common, J. L., and Horti, H. M. (General Foods Corp.), U.S. Patent 2,954,299, 1960; Canadian Patent 600,649, 1960.
883. Mancuso, J. J., and Common, J. L. (General Foods Corp.), U.S. Patent 2,965,493, 1960.
884. Mitchell, W. A., and Seidel, W. C. (General Foods Corp.), U.S. Patent 2,968,565, 1961.
885. Block, H. W. (General Foods Corp.), U.S. Patent 2,983,617, 1961.
886. Downey, H. A., U.S. Patent 3,018,183, 1962.
887. Grettie, D. P., and Tiemstra, P. J. (Swift & Co.), U.S. Patent 3,490,920, 1970.
888. Schwartz, C. (Hall Laboratories, Inc.), U.S. Patent 2,215,137, 1940.
889. Horvath, A. A. (Hall Laboratories, Inc.), U.S. Patent 2,429,579, 1947.
890. Albright and Wilson, Ltd., British Patent 600,933, 1948.
891. Rane, L., and Newhouser, L. R. (Government of the United States), U.S. Patent 2,726,235, 1955.
892. Nitschmann, H., Rickli, E., and Kistler, P., 1959, *Helv. Chim. Acta 42*:2198; 1959, *Chem. Abstr. 54*:12227i.
893. Keil, H. L., Hagen, R. F., and Flawe, R. W., German Patent 1,111,917, 1961; *ibid.*, German Patent 1,133,228, 1962.
894. Fukamachi, C., and Watanabe, T., 1962, *Nippon Shokuhin Kogyo Gakkaishi 9*:19; 1963, *Chem. Abstr. 59*:13264a.
895. Waugh, D. F. (National Dairy Research Laboratories, Inc.), U.S. Patent 2,744,891, 1956.
896. Consolazio, G. A., and Moses, R. E. (General Foods Corp.), U.S. Patent 3,153,030, 1964.
897. Wegner, H., 1957, *Starke 9*:196.
898. Winkler, S., 1960, *Starke 12*:34.
899. Palasinski, M., and Bussek, J., 1964, *Roczniki Technol. Chem. Zywnosci 10*:47;1964, *Chem. Abstr. 61*:9658c.
900. Palasinski, M., 1964, *Zeszyty Nauk. Wyzszej Szkoly Rolniczej Krakowie Rolnictwo 11(21)*:65; 1965, *Chem. Abstr. 62*:15342e.
901. Nara, S., Maeda, I., and Tsujino, T., 1964, *Nippon Nogei Kagaku Kaishi 38*:356; 1965, *Chem. Abstr. 63*:5881c.
902. Knyaginichev, M. I., and Komarov, V. I., *Izv. Vysshikh Uchebn. Zavedenii Pishchevaya Tekhnol. 1966(1)*:41; 1966, *Chem. Abstr. 64*:13286h.
903. Kuhl, H., 1937, *Muhlenlab 7*:95; 1937, *Chem. Abstr. 31*:8979.
904. Nutting, G. C., 1952, *J. Colloid Sci. 7*:128.
905. Bowen, W. S., U.S. Patent 2,185,368, 1940.
906. Rozenbroek, M. D. (N.V. Chemische Fabriek Servo), Netherlands Patent 59,843, 1947.
907. Kunz, W. B. (American Viscose Corp.), U.S. Patent 3,030,667, 1962.
908. Fredrickson, R. E. C. (A. E. Staley Mfg. Co.), U.S. Patent 3,003,894, 1961.
909. Osman, E. M., 1967, in *Starch: Chemistry and Technology*, R. L. Whistler and E. F. Paschall, Eds., Academic Press, p. 177.
910. Whistler, R. L., 1971, *Cereal Sci. Today 16(2)*:54, 73.
911. Hamilton, R. M., and Paschall, E. F., 1967, in *Starch: Chemistry and Technology*, R. L. Whistler and E. F. Paschall, Eds., Academic Press, p. 351.
912. Evans, J. W. (American Maize Products Co.), U.S. Patent 2,806,026, 1957.
913. Kerr, R. W., and Cleveland, F. C., Jr. (Corn Products Co.), U.S. Patent 2,884,413, 1959.
914. *Ibid.*, U.S. Patent 2,961,440, 1960.

TCP, a carbonate, and citric acid. Hunter[575] prepared chiffon pie fillings from sodium alginate, skimmed-milk powder, and SHMP. Miller and Rocks[576] prepared high-bloom-strength gels by combinations of sodium alginate, calcium carbonate, STP, and adipic acid.

Andrew and MacLeod[577] described a number of applications for alginate in food processes. They reported that the thickening of a canned product could be delayed until after the can had been filled by use of a low-viscosity sodium alginate and a slowly soluble calcium salt. They also reported that fruit- or vegetable-flavored particles could be prepared by depositing a combination of sweetening agents, coloring, flavoring, and sodium alginate by drops into a calcium chloride bath. Other applications for alginates were also proposed.

Applications in Carrageenan Gel Systems

Carrageenan, like algin, is a strongly charged, anionic polyelectrolyte of high molecular weight; it is also extracted from seaweeds. The extract contains five or more distinct fractions, each differing in properties. It forms complexes with proteins and other long-chain molecules, such as polyphosphates, to form gels and sols. Glicksman[564] has reviewed the chemical and physical properties and applications of carrageenan in food products; only a few will be mentioned here, as they are also discussed in Chapter 7.

Unlike algin, calcium inhibits the gelling of some fractions of carrageenan. Stoloff[578,579] used soluble phosphate salts, particularly the polyphosphates, to sequester calcium ions from milk and tap water to prepare stable chocolate milk and water gels. Zabik and Aldrich[580] reported that the rate of shear appeared to have a more significant influence on the viscosity of carrageenan–potassium salt gels than the presence of differing anions due to the type of potassium salt used.

Sand and Sodano[28] reported that the addition of low levels of polyphosphates to milk-gelling systems containing carrageenan reduces and often completely eliminates syneresis.

Applications in Other Gum Gel Systems

Guar and locust-bean gums were used by Weinstein[581] in preparing ice cream stabilizers. SHMP was added to the system to prevent the denaturation of the proteins by the gums added to the stabilizers. Green and co-workers[582] reported the preparation of multi-phased food products in which the levels of calcium ion necessary for preparation of proper gelling were controlled by means of complexing agents, such as TSP, TSPP, STP, or SHMP. Lauck and Tucker[233] and Marcus[583] prepared hydrated gels of calcium orthophosphate by combining a soluble calcium compound, such as calcium chloride, and DSP or TSP.

Phosphate Applications in Meat Processing

Meat has been a highly accepted portion of the human diet for centuries. The production, processing, and preservation of meat to maintain maximum palatability have been of major concern in the technology of meat processing. The palatability of meat is judged largely by its color in the raw and prepared states, its tenderness when eaten, and its flavor. Each characteristic is directly

827. Ueoka, Y., Oka, H., Suemitso, H., and Sugimoto, T., 1966, *Nippon Shokuhin Kogyo Gakkaishi 13*:475; 1967, *Chem. Abstr. 67*:2233k.
828. Takei, M., and Takahashi, T., 1961, *Tokaiku Suisan Kenkyusho Kenkyu Hokoku 30*:105; 1962, *Chem. Abstr. 57*:14248g.
829. Ichisugi, T., Kuroda, K., and Ikawa, K., 1965, *Hokusuishi Geppo 22*:273, 319; 1965, *Chem. Abstr. 63*:10576c.
830. Mathen, C., 1968, *Fish. Technol. 5(2)*:104; 1970, *Food Sci. Technol. Abstr. 2*:5R167.
831. Jones, R., 1969, *Fish. Ind. Res. 5*:83.
832. Sjöstrom, L. B. (Arthur D. Little, Inc.), U.S. Patent 2,446,889, 1948.
833. Tarr, H. L. A., Gardner, L. J., and Ingram, P., 1969, *J. Food Sci. 34*:637.
834. Zipser, M. W., and Watts, B. M., 1961, *Food Technol. 15*:318.
835. Greig, R. A., Emerson, J. A., and Fliehman, G. W., 1969, *Fish. Ind. Res. 5*:2.
836. Hempel, H. (Gorton-Pew Fisheries Co.), U.S. Patent 2,397,547, 1946.
837. Aktieselskabet Protan and Helberud, O., Norwegian Patent 86,681, 1955; 1950, *Chem. Abstr. 50*:7348a.
838. Uchiyama, H., and Amano, K., 1959, *Bull. Jap. Soc. Sci. Fish. 25(7–9)*:531.
839. Ozawa, T., Nagaoka, S., and Aragaki, M., 1963, *Shokuhin Eiseigaku Zasshi 4*:332, 339; 1964, *Chem. Abstr. 60*:13788h.
840. Levin, R. E., 1967, *J. Milk Food Technol. 30*:277.
841. McFee, E. P., and Peters, J. A. (Gorton-Pew Fisheries Co., Ltd.), U.S. Patent 2,554,625, 1951.
842. Kreidl, E. L., and McFee, E. P. (Gorton-Pew Fisheries Co., Ltd.), U.S. Patent 2,555,236, 1951.
843. McFee, E. P., and Swaine, R. L., 1953, *Food Eng. 25(12)*:67, 190, 192.
844. Yamada, H., 1961, *Nippon Suisan Chuo Kenkyusho Hokoku 9*:78; 1963, *Chem. Abstr. 58*:11895f.
845. Kelch, F., and Buhlmann, X., 1958, *Fleischwirtschaft 10*:325.
846. Pacheco, G., and Echaniz, J. S., 1953, *Brasil-Medico 67(2)*:43.
847. Pacheco, G., and Dias, V. M., 1954, *Mem. Inst. Oswaldo Cruz Rio de J. 52(2)*:405.
848. Heiligman, F., Desrosier, N. W., and Broumand, H., 1956, *Food Res. 21*:63.
849. Williams, O. B., and Hennessee, A. D., 1956, *Food Res. 21*:112.
850. Wollmann, E., Veterinary Medical Dissertation, Munich, Germany, 1957; abstracted in 1959, *Fleischwirtschaft 11(4)*:291.
851. Post, F. J., Krishnamurty, G. B., and Flanagan, M. D., 1963, *Appl. Microbiol. 11*:430.
852. Gould, G. W., *Fourth International Symposium Food Microbiology*, Swedish Institute for Food Preservation Research, Goteborg, Sweden, 1964, p. 17; 1967, *Chem. Ind. 1967*:234.
853. Irani, R. R., and Callis, C. F., 1962, *J. Amer. Chem. Soc. 39*:156.
854. Irani, R. R., and Morgenthaler, W. W., 1963, *ibid. 40*:283.
855. Nowakowska-Waszczuk, A., 1965, *Acta Microbiol. Polon. 14*:207; 1965, *Chem. Abstr. 63*:7367b.
856. Gray, G. W., and Wilkinson, S. G., 1965, *J. Gen. Microbiol. 39*:385.
857. Hamilton-Miller, J. M. T., 1965, *Biochem. Biophys. Res. Commun. 20*:688.
858. Brown, M. R. W., and Richards, R. M. E., 1965, *Nature 207*:1391.
859. Burkard, G., Weil, J. H., and Ebel, J. P., 1965, *Bull. Soc. Chim. Biol. 47*:561; 1965, *Chem. Abstr. 63*:10218f.
860. Tomiyama, T., Kitahara, K., Shiraishi, E., and Imaizumi, K., *Fourth International Symposium on Food Microbiology*, Swedish Institute of Food Preservation Research, 1964, Goteborg, Sweden, p. 261.
861. Kooistra, J. A., and Troller, J. A. (Procter & Gamble Co.), U.S. Patent 3,404,987, 1968.
862. Vishniac, W., 1950, *Arch. Biochem. 26*:167.
863. Brock, R. D., 1952, *J. Aust. Inst. Agr. Sci. 18*:41.
864. Fuld, E., 1902, *Beitr. Chem. Physiol. Path. 2*:155; quoted in Horvath, ref. 237.
865. Ferrel, R. E., Olcott, H. S., and Fraenkel-Conrat, H., 1948, *J. Amer. Chem. Soc. 70*:2101.
866. Braginskaya, F. I., and El'piner, I. E., 1963, *Biofizika 8*:34; 1963, *Chem. Abstr. 58*:12792c.
867. Council of Scientific and Industrial Research, Indian Patent 45,580, 1953; 1953, *Chem. Abstr. 47*:6576c.
868. Hall, L. A. (Griffith Laboratories, Inc.), U.S. Patent 2,477,742, 1949.
869. Ferrel, R. E., and Olcott, H. S. (U.S. Department of Agriculture), U.S. Patent 2,522,504, 1950.
870. Mohammad, A., Mecham, D. K., and Olcott, H. S., 1954, *J. Agr. Food Chem. 2*:136.
871. Knight, J. W., 1965, *The Chemistry of Wheat Starch and Gluten and Their Conversion Products*, Leonard Hill, p. 92.

such as alkali-metal metaphosphates (particularly sodium acid pyrophosphate and amino polycarboxylic acids, such as EDTA) will complex the magnesium and also prevent the formation of this compound. Attempting to extract the magnesium compounds with water, either by rinsing, washing, or boiling the seafood in ordinary water, is not sufficient to remove the quantity of magnesium necessary to prevent formation of struvite crystals. McFee and Peters recommended the use of SHMP, ammonium metaphosphate, STP, or the potassium salts equivalent to the same products, and EDTA for these purposes. In a later patent Kreidl and McFee[842] recommended the addition of 0.5–1.5% of a sodium polyphosphate compound, such as SHMP, to the liquid used in preparing the canned seafood product to prevent the formation of the struvite crystals during its shelf-life. Quantities of the soluble, alkali-metal phosphate as low as 0.25% were found to be effective, based on the total moisture content of the canned seafood.

Later McFee and Swaine[843] reported that SHMP added to the liquid of the canned product was the most practical method for preventing the formation of struvite crystals in such canned seafoods as lobster, shrimp, crab, and flaked fish, such as pollack, cod, and haddock. They reported five advantages to the use of SHMP, as follows:

1. SHMP is a neutral salt; therefore, it does not create acidic or alkaline flavors in the canned product.
2. As a GRAS compound, SHMP is safe for use in all food products.
3. SHMP can be applied either in solution or in the dry form with equivalent results.
4. SHMP can be mixed with the food before canning, or it can be added to the cans during their filling.
5. A very small quantity of SHMP is necessary to prevent the formation of struvite, thus making it very economical in use.

The authors reported that canned seafoods containing SHMP had a shelf-life of three–four years.

Yamada[844] reported that the minimum quantities of SHMP required to prevent the formation of struvite in canned king crab meat ranged between 0.13–0.22% of the total product. Jones[831] reported that adding 0.25–0.35% of SAPP to king crab meat inhibited the formation of struvite in canned products containing salt during the observed storage period of one year.

Phosphates as Microbiological Inhibitors

The applications of the phosphates as microbiological inhibitors in various types of food products have been reviewed in several sections of this chapter. There are, however, a number of references to food applications for polyphosphates as microbiological inhibitors, and these will be reviewed in the following discussion.

Applications as Inhibitors of Bacterial Growth

General Inhibitory Effects Kelch and Buhlmann[845] reported that commercial mixtures of phosphates normally used in curing meat products (Curafos and Fibrisol, manufactured by J.A. Benckiser) act as microbiological inhibitors of

783. Akiba, M., Motohiro, T., and Tanikawa, E., 1967, *J. Food Technol. 2*:69.
784. Spinelli, J., Pelroy, G., and Miyauchi, D., 1968, *Fish. Ind. Res. 4*:37.
785. Ravesi, E. M., and Anderson, M. L., 1969, *Fish. Ind. Res. 5*:175.
786. Kuusi, T., and Kytokangas, R., 1970, *Maataloustieteellinen Aikak. 42(1)*:30; 1970, *Food Sci. Technol. Abstr. 2*:11R378.
787. Meyer, A. (Calgon, Inc.), U.S. Patent 2,735,777, 1956.
788. Yamaga, M., Morioka, K., and Kawakami, T., 1961, *Reito 36*:904; 1962, *Chem. Abstr. 57*:7758d.
789. Sen, D. P., and Lahiry, N. L., 1964, *Food Technol. 18*:1611.
790. Miyauchi, D., Spinelli, J., Pelroy, G., and Steinberg, M. A., Winter, 1967-68, *Isot. Radiat. Technol. 5(2)*:136; 1969, *Commer. Fish. Abstr. 22(3)*:7.
791. Sen, D. P., Visweswarish, K., and Lahiry, N. L., 1960, *Food Sci. (Mysore) 10*:144; 1962, *Chem. Abstr. 56*:1812a.
792. Garnatz, G., Volle, N. H., and Deatherage, F. E. (Kroger Grocery & Baking Co.), U.S. Patent 2,488,184, 1949.
793. MacCallum, W. A., Chalker, D. A., Lauder, J. T., Odense, P. H., and Idler, D. R., 1964, *J. Fish. Res. Board Can. 21*:1397; 1965, *Chem. Abstr. 62*:8310.
794. Tanikawa, E., 1963, *Adv. Food. Res. 12*:367.
795. Okamura, K., Matsuda, T., and Yokoyama, M., 1958-1959, *Bull. Jap. Soc. Sci. Fish. 24*:545; 1959, *Chem. Abstr. 53*:14376e.
796. *Ibid.*, 1958-1959, *Nippon Suisangaku Kaishi 24*:821; 1959, *Chem. Abstr. 53*:15411g.
797. *Ibid.*, 1958-1959, *Nippon Suisan Gakkaishi 24*:978, 986; 1960, *Chem. Abstr. 54*:15750a.
798. Okamura, K., 1960, *Nippon Suisan Gakkaishi 26*:600; 1961, *Chem. Abstr. 55*:14749b.
799. *Ibid.*, 1961, *27*:48.
800. *Ibid.*, 1961, *27*:52.
801. *Ibid.*, 1961, *27*:58.
802. Miyake, M., Hayashi, K., and Noda, H., 1963, *Mie Kenritsu Daigaku Suisangakubu Kiyo 6(1)*:39; 1965, *Chem. Abstr. 63*:8960f.
803. Akiyama, N., 1961, *Hokkaido-Ritsu Eisei Kenkyushoho 12*:113; 1965, *Chem. Abstr. 62*:15348c.
804. Anon., 1968, *Commer. Fish. 7(1)*:19; 1968, *Commer. Fish. Abstr. 21(11)*:13.
805. Seagran, H. L., 1958, *Food Res. 23*:143.
806. Albright and Wilson (Mfg.), Ltd., British Patent 916,208, 1961.
807. Mahon, J. H. (Hagan Chemicals & Controls, Inc.), U.S. Patent 3,036,923, 1962.
808. Anon., 1962, *Food Eng. 34(9)*:106.
809. Tanikawa, E., Akiba, M., and Shitamori, A., 1963, *Food Technol. 17*:1425.
810. Mahon, J. H., and Schneider, C. G., 1964, *Food Technol. 18*:117.
811. Boyd, J. W., and Southcott, B. A., 1965, *J. Fish. Res. Board Can. 22*:53.
812. Swartz, W. E. (Calgon Corporation), Canadian Patent 847,280, 1970.
813. Sutton, A. H., paper presented before the *FAO Technical Conference on the Freezing and Irradiation of Fish*, Madrid, September 4-8, 1967; reviewed in Anon., 1968, *Food Mfr. 43(1)*:26.
814. Sutton, A. H., and Ogilvie, J. M., 1968, *J. Fish. Res. Board Can. 25*:1475.
815. Miyauchi, D. T., Spinelli, J., Pelroy, G., and Stoll, N., 1965, AEC Accession No. 29583, Report No. TID-22515, U.S. Government Printing Office; 1966, *Nucl. Sci. Abstr. 20*:3600.
816. Spinelli, J., and Weig, D., November 1968, *Canner/Packer 137(12)*:28; 1968, *Commer. Fish. Abstr. 22(4)*:1.
817. Anon., April 1969, *Quick Frozen Foods 31*:146.
818. *Ibid.*, 150.
819. Anon., 1968, *Food Eng. 40(2)*:11.
820. Barnett, H. J., Nelson, R. W., and Dassow, J. A., 1969, *Fish. Ind. Res. 5*:103.
821. Dyer, W. J., Brockerhoff, H., Hoyle, R. J., and Fraser, D. I., 1964, *J. Fish. Res. Board Can. 21*:101.
822. Love, R. M., 1965, *Rep. Progr. Appl. Chem. 50*:292.
823. Anon., 1964, *Torry Research Station Annual Report*, p. 13; quoted in ref. 822.
824. Okamura, K., 1960, *Nippon Suisan Gakkaishi 26*:60; 1961, *Chem. Abstr. 55*:6720c.
825. Okamura, K., Kodama, M., Sonada, H., and Yamada, J., 1966, *Nippon Suisan Gakkaishi 32*:80; 1967, *Chem. Abstr. 67*:10497q.
826. Tanikawa, E., Motohiro, T., and Akiba, M., paper presented before the *FAO Technical Conference on the Freezing and Irradiation of Fish*, Madrid, September 4-8, 1967; reviewed in Anon., 1968, *Food Mfr. 43(1)*:26.

certain food-spoilage microorganisms when tested in optimum nutrient media for these microorganisms. The Curafos used in these experiments contained 15% TSPP, 70% STP, and 15% SHMP; Fibrisol contained 25% SAPP, 15% TSPP, 10% SHMP, and 50% NaCl. Each of the phosphate mixtures was tested against the various organisms at levels of 0.3%, 0.5%, and 1.0%; controls containing no phosphates were included in the tests. The media containing the inoculations of microorganisms with and without the phosphates were heated to 50°C, 55°C, 60°C, 65°C, and, in the case of sporulating bacteria, 75°C and 80°C. *Staphylococcus aureus* and *Streptococcus faecalis* were inhibited or destroyed by all levels of phosphate and at all temperatures tested from 50°C through 65°C, but they grew rampantly at each temperature in the absence of the phosphates. The *S. faecalis* grew in the unheated media containing all levels of phosphate, while only the 0.3% and 0.5% Fibrisol-containing media supported the growth of *S. aureus* without heating. All levels of Curafos prevented growth of *S. aureus* with or without heating. Growth of the spore forms of *Bacillus subtilis* was inhibited with and without heating in the presence of 0.5% and 1.0% Curafos. *B. subtilis* spores were able to germinate and grow, although with limited success, in the presence of 0.3% Curafos and with increasing success with time in the presence of the Fibrisol at all levels. The vegetative forms of *B. subtilis* were strongly inhibited by the presence of 0.5 and 1.0% Curafos with and without heating; they grew to a limited extent after 5 days or more incubation in the presence of 0.3% Curafos. Although they were capable of growing after prolonged incubation in the presence of 0.3% and 0.5% Fibrisol, they did not grow in the presence of 1.0% Fibrisol with heating. The organisms could grow with prolonged incubation in the presence of all levels of Fibrisol when the medium was not heated. Spores of *Clostridium sporogenes* had difficulty germinating in the presence of 0.5 and 1.0% Curafos, but they could grow, especially after prolonged incubation, in the presence of all levels of Fibrisol with and without heating. *C. bifermentans* had considerable difficulty growing in the presence of all levels of Curafos with any degree of heating; it could grow after prolonged incubation in the presence of 0.3%, but growth was completely inhibited in the presence of 0.5 and 1.0% Curafos without heating. Growth occurred, although it required prolonged incubation, at 0.3 and 0.5% levels of Fibrisol with and without heating; growth was completely inhibited with and without heating in the presence of 1.0% Fibrisol.

The effects of orthophosphates as lytic agents for various bacteria have been studied and reviewed by Pacheco and Echaniz[846] and Pacheco and Dias.[847] TSP·$12H_2O$ was found to be the most effective lytic agent in concentrations of 0.001–0.1 mol solutions. MSP·H_2O, DSP·$2H_2O$, and DKP·H_2O were also found to be effective against *Salmonella typhosa*, *Escherichia coli*, and *Staphylococcus aureus*. Lytic action of the phosphates is puzzling, since the orthophosphates have been demonstrated to be essential to the growth of microorganisms[102,103]; they are particularly essential to spore germination of some of the spore-forming bacteria, as determined by Heiligman and coworkers.[848]

Williams and Hennessee[849] reported that spores of *Bacillus stearothermophilus* had greater heat resistance at phosphate concentrations of mol/120 or lower than in distilled water or in solutions with higher phosphate concentrations. Their work offers an explanation of the inhibiting effects of the higher

732. Flesch, P., and Bauer, G., French Patent 1,446,678, 1966.
733. Haynes, R. D. (Monsanto Chemical Company), U.S. Patent 2,868,654, 1959.
734. Bickel, W. (Johann A. Benckiser G.m.b.H.), German Patent 1,074,380, 1960.
735. Chemische Fabrik Budenheim, A.G., British Patent 831,132, 1960.
736. Elder, E. V., Jr. (Hooker Chemical Corp.), U.S. Patent 3,104,978, 1963.
737. Sair, L., and Donahoo, W. P. (Griffith Laboratories, Inc.), U.S. Patent 3,139,347, 1964.
738. Sair, L. (Griffith Laboratories, Inc.), U.S. Patent 3,231,392, 1966.
739. Mahon, J. H. (Calgon Corporation), U.S. Patent 3,401,046, 1968.
740. Murphy, L. W., and Jones, R. L., British Patent 862,109, 1961.
741. Beerend, R. F., and Needle, H. C. (Basic Food Materials, Inc.), U.S. Patent 3,192,055, 1965.
742. Takeda Chemical Industries, Ltd., French Patent 1,386,675, 1965.
743. deFremery, D., and Pool, M. F., 1960, *Food Res. 25*:73.
744. deFremery, D., 1963, *Proceedings Meat Tenderness Symposium*, Campbell Soup Company, p. 99.
745. deFremery, D., 1966, *J. Agr. Food Chem. 14*:214.
746. Wells, G. H., May, K. N., and Powers, J. J., 1962, *Food Technol. 16*:137.
747. Klose, A. A., Campbell, A. A., and Hanson, H. L., 1963, *Poult. Sci. 42*:743.
748. Mahon, J. H., 1962, *Poult. Processing Market. 68(8)*:16, 24, 26.
749. Mahon, J. H., 1962, *Food Eng. 34(11)*:108,113.
750. Mahon, J. H. (Calgon Corporation), U.S. Patent 3,104,170, 1963; Belgian Patent 614,742, 1962; Canadian Patent 691,480, 1963; Netherlands Patent Appl. No. 6,613,628, 1967.
751. Froning, G. W., 1965, *Poult. Sci. 44*:1104.
752. Froning, G. W., 1966, *Poult. Sci. 45*:185.
753. Dodge, J. W., and Stadelman, W. J., 1959, *Food Technol. 13*:81.
754. May, K. N., Helmer, R. L., and Saffle, R. L., 1962, *Poult. Sci. 41*:1665.
755. Klose, A. A., Campbell, A. A., and Hanson, H. L., 1962, *Poult. Sci. 41*:1655.
756. Spencer, J. V., and Smith, L. E., 1962, *Poult. Sci. 41*:1685.
757. Baker, R. C., and Darfler, J., 1968, *Poult. Sci. 47*:1590.
758. Schwall, D. V., Rogers, A. B., and Corbin, D. (Armour & Co.), U.S. Patent 3,399,063, 1968.
759. Schwall, D. V., and Rogers, A. B. (Armour & Co.), U.S. Patent 3,285,753, 1966; British Patent 1,198,670, 1970.
760. *Ibid.*, U.S. Patent 3,413,127, 1968.
761. Schnell, P. G., Vadehra, D. V., and Baker, R. C., 1970, *J. Can. Inst. Food Technol. 3(2)*:44.
762. Vadehra, D. V., and Baker, R. C., 1970, *Food Technol. 24*:766, 775.
763. Schlamb, K. F. (Calgon Corporation), U.S. Patent 3,499,767, 1970.
764. Mountney, G. J., and Arganosa, F. C., 1962, *Poult. Sci. 41*:1668.
765. Schermerhorn, E. P., and Stadelman, W. J., 1962, *Poult. Sci. 41*:1680.
766. Monk, J. A., Mountney, G. J., and Prudent, I., 1964, *Food Technol. 18*:226.
767. Shermerhorn, E. P., and Stadelman, W. J., 1964, *Food Technol. 18*:101.
768. Mahon, J. H. (Calgon Corporation), U.S. Patent 3,462,278, 1969; Netherlands Patent Appl. No. 6,613,627, 1967.
769. Montemayor, E., Vadehra, D. V., and Baker, R. C., quoted in Vadehra and Baker, ref. 762.
770. Hudspeth, J. P., and May, K. N., 1967, *Food Technol. 21*:1141.
771. Marion, W. W., and Forsythe, R. H., 1962, *Poult. Sci. 41*:1663; *ibid.*, 1964, *J. Food Sci. 29*:530.
772. Thomson, J. E., 1964, *Food Technol. 18*:1805.
773. Jimenez, A. V., Fernandez, R. P., and Girauta, M. E., 1961, *Symposium Substances Etrangeres Aliments* (No. 6, Madrid, 1960), p. 530; 1963, *Chem. Abstr. 59*:3256e.
774. Melnick, D., Perry, G. A., and Lawrence, R. L. (Corn Products Company), U.S. Patent 3,065,084, 1962.
775. Kraft, A. A., and Ayres, J. C., 1961, *Appl. Microbiol. 9*:549; *ibid.*, 1964, *J. Food Sci. 29*:218.
776. Tomiyama, T., Kitahara, K., Shiraishi, E., and Imaizumi, K., *Fourth International Symposium on Food Microbiology* (Gotborg, Sweden, 1964), p. 261.
777. Elliott, R. P., Straka, R. P., and Garibaldi, J. A., 1964, *Appl. Microbiol. 12*:517.
778. Linko, R. R., and Nikkila, O. E., 1961, *J. Food Sci. 26*:606.
779. Kuusi, T., Nikkila, O. E., and Kytokangas, R., 1965, *Valt. Tek. Tutkimuslaitos Tiedotus Sar. I Puu 4(78)*:1; 1966, *Chem. Abstr. 64*:20525a.
780. Nikkila, O. E., Kuusi, T., and Kytokangas, R., 1967, *J. Food Sci. 32*:686.
781. Scheurer, P. G., 1968, *J. Food Sci. 33*:504.
782. Love, R. M., and Abel, G., 1966, *J. Food Technol. 1*:323.

concentrations, such as mol/15 reported in the earlier literature, which they reviewed.

Wollmann[850] studied the effects of various salts, including sodium pyrophosphate, SHMP, and Fibrisol (a commercial phosphate curing-salt mixture), on the heat resistance of *Erysipelthrix rhusiopathiae*, *Salmonella typhimurium*, and *Mycobacterium tuberculosis*. The salts were tested at 0.5% concentrations at various temperatures in order to determine their ability to inhibit the growth of or to completely kill the bacteria. *E. rhusiopathiae* was completely inhibited by sodium pyrophosphate and potassium iodide, while Fibrisol and sodium citrate were less effective; SHMP and sodium citrate caused an increase in heat resistance of the organisms. Only sodium pyrophosphate and potassium iodide were effective upon the addition of 0.2% sodium chloride to the medium. *S. typhimurium*, although significantly affected by all of the salts investigated, was most affected by sodium pyrophosphate and potassium iodide. However, the addition of 0.2% sodium chloride completely overcame the effects of all of the salts, including the sodium pyrophosphate and potassium iodide. The heat resistance of *M. tuberculosis* was lowered only by sodium pyrophosphate and potassium iodide. Fibrisol initially also lowered the heat resistance, but its effect was overcome by the addition of sodium chloride.

Post and co-workers[851] studied the effects of SHMP on pure cultures and wild cultures of bacteria. The authors reported that concentrations of 0.1% SHMP were effective in preventing the growth of most gram-positive bacteria when added to the media in which they were grown. Gram-negative bacteria were capable of growing at concentrations of SHMP as high as 10%. However, some gram-negative bacteria, such as *Pseudomonas fluorescens*, were lysed when SHMP contacted the cells. This lysis was inhibited or prevented by the addition of sodium chloride or magnesium sulfate. Growth of the gram-positive *Sarcina lutea* could occur in the presence of SHMP levels that normally prevented growth if magnesium sulfate was added to the medium. The authors speculated that SHMP interfered with the metabolism of divalent cations, especially with the magnesium ion, and thus inhibited cell division and caused the loss of the cell-wall integrity.

Gould[852] reported that concentrations of 0.2–1.0% SHMP, containing only small amounts of ortho-, pyro-, or tripolyphosphate, prevented the normal germination and growth of bacteria spores. The higher concentrations prevented growth before the rupture of the spore wall and thus prevented the development of the spores into vegetative cells. Although the spore germination was not inhibited at the lower concentrations, the vegetative cells were distorted, failed to develop in the normal manner, and did not multiply. The effect of SHMP at pH 6 was 1.5 to 2 times as great as it was at pH 7.

Kohl and Ellinger[102] obtained a number of foreign patents on the application of medium-chain-length polyphosphates, averaging in chain length from 16–100 and preferably between 16–34, as microbiological inhibitors in numerous food products. The medium-chain-length polyphosphates were found to be more effective than the SHMP previously reported in the literature. The activity of the polyphosphates increased as the chain length increased from 16 through the high 20's; it then began to decrease in effectiveness as the chain length increased. Certain bacteria were effectively inhibited in growth or completely

685. Mahon, P., Hogue, D., Leeking, P., Lim, E., and Fenton, F., 1956, *Food Technol. 10*:265.
686. Gisske, W., 1958, *Fleischwirtschaft 10*:21.
687. Schoch, W. S. (Armour & Company), U.S. Patent 2,824,809, 1958.
688. Watts, B. M., 1957, *Proceedings 9th Research Conference*, American Meat Institute, p. 61.
689. Wasserman, M. (Meat Industry Suppliers, Inc.), U.S. Patent 2,812,261, 1957.
690. Suri, 1961, *Fleischwirtschaft 13*:403.
691. Siedlecki, E., 1964, *Gospodarka Miesna 16(1)*:7; 1965, *Chem. Abstr. 62*:1009h.
692. Lauck, R. M., and Tucker, J. W. (Stauffer Chemical Company), U.S. Patent 3,118,777, 1964.
693. Savic, I., Suvakov, M., Nikolic, J., and Korolija, S., 1965, *Technol. Mesa 6(10)*:274, 278; 1966, *Chem. Abstr. 64*:14868h.
694. Swift, C. E., Weir, C. E., and Hankins, O. G., 1954, *Food Technol. 8*:339.
695. Szent-Gyorgyi, A. G., 1952, *Proceedings Fourth Research Conference*, American Meat Institute, p. 22.
696. Szent-Gyorgyi, A. G., 1960, in *Proteins of the Myofibril in Structure and Function of Muscle*, G. H. Bourne, Ed., Vol. II, Academic Press, p. 1.
697. Schleich, H., and Arnold, R. S. (Baxter Laboratories, Inc.), U.S. Patent 3,037,870, 1962.
698. Maas, R. H., and Olson, F. C. (Oscar Mayer & Co., Inc.), U.S. Patent 3,075,843, 1963.
699. Leeking, P., Mahon, P., Hogue, D., Lim, E., and Fenton, F., 1956, *Food Technol. 10*:274.
700. Frank, S. S., M.S. Thesis, Cornell University, 1955.
701. Swift, C. E., and Ellis, R., 1956, *Food Technol. 10*:546.
702. Volovinskaya, V. P., Rubashkina, S. S., Solov'ev, V. I., and Dyklop, V. K., *Tr. Vses. Nauchno.-Issled. Inst. Myasn. Prom-st.' 1958(8)*:78; 1960, *Chem. Abstr. 55*:18822a.
703. Volovinskaya, V. P., Rubashkina, S. S., Poletaev, T., Kel'man, B., and Merkulova, V., 1959, *Myasnaya Ind. S.S.S.R. 30(4)*:48; 1961, *Chem. Abstr. 55*:9712f.
704. Rupp, V. R., Brockmann, M. C., and Nickolson, L. W. (Hygrade Food Products Corp.), U.S. Patent 2,937,094, 1960; Canadian Patent 594,779, 1960.
705. Zeller, M., 1961, *Dsch. Lebensm.-Rundsch. 57*:205.
706. Grau, R., 1961, *Fleischwirtschaft 13*:183.
707. Rongey, E. H., and Bratzler, L. J., 1966, *Food Technol. 20*:1228.
708. Mahon, J. H., and Schneider, C. (Calgon Corporation), Canadian Patent 788,939, 1968; Netherlands Appl. No. 6,600,579, 1966.
709. Keller, H., 1955, *Fleischwirtschaft 7*:15.
710. Sherman, P., 1961, *Food Technol. 15*:87.
711. Pfaff, W., British Patent 881,397, 1961.
712. Zipser, M. W., and Watts, B. M., 1967, *J. Agr. Food Chem. 15*:80.
713. Evans, J. B., 1954, *Proceedings Research Report to Industry*, American Meat Institute Foundation, p. 12.
714. Bickel, W. (Calgon, Inc.), U.S. Patent 2,735,776, 1956.
715. Wollmann, E., 1959, *Fleischwirtschaft 11*:291.
716. Peat, M. R. (Wm. J. Strange Co.), U.S. Patent 2,925,344, 1960.
717. Gorsica, H. J. (B. Heller & Co.), U.S. Patent 3,008,832, 1961.
718. Hall, L. A. (Griffith Laboratories, Inc.), U.S. Patent 2,145,417, 1939.
719. *Ibid.*, U.S. Patent 2,668,771, 1954.
720. Hall, L. A., and Kalchbrenner, W. S. (Griffith Laboratories, Inc.), U.S. Patents 2,770,548 and 2,770,551, 1956.
721. Hall, L. A. (Griffith Laboratories, Inc.), U.S. Patent 2,770,549, 1956.
722. Hall, L. A., and Griffith, C. L. (Griffith Laboratories, Inc.), U.S. Patent 2,770,550, 1956.
723. Chemische Fabrik Budenheim A.G., British Patent 754,406, 1956.
724. Huber, H., and Vogt, K. (Chemische Werke Albert), U.S. Patent 2,852,392, 1958; British Patent 696,617, 1953.
725. Barnett, H. W. (Canada Packers, Ltd.), U.S. Patent 2,903,366, 1959.
726. Barth, W. (Franziska Therese Barth, geb. Wegerl), German Patent 1,041,338, 1961.
727. Miyake, M., and Noda, H. (Tanabe Seiyaku Co., Ltd.), Japanese Patent 9134, 1961; 1962, *Chem. Abstr. 56*:6437a.
728. Chemische Fabrik Johann A. Benckiser G.m.b.H., British Patent 897,682, 1962.
729. Buchholz, K. (Johann A. Benckiser G.m.b.H.), U.S. Patent 3,032,421, 1962.
730. Oliver, R. J., and Voegeli, M. M. (Swift & Co.), U.S. Patent 3,028,246, 1962.
731. Pfrengle, O. (Chemische Fabrik Budenheim Rudolf A. Oetker K.G.), German Patent 1,181,030, 1964.

TABLE 35
Effect of Polyphosphate Chain Length on Inhibition of Growth of *S. aureus*

Phosphate Additive	*Chain Length*	*Turbidity (Measure of Growth)*	*Bacterial Count per ml (by Plating)*[a]			*Per Cent Bacteria Surviving*		
			24 hr	*5 days*	*10 days*	*24 hr*	*5 days*	*10 days*
Na_2HPO_4 + KH_2PO_4		Heavy turbid	est. 10^{8+}	10^{8+}	10^{8+}	100^{+}	100^{+}	100^{+}
Sodium acid pyrophosphate + tetrasodium pyrophosphate		Turbid	2×10^{6}	10^{8+}	10^{8+}	30	100^{+}	100^{+}
Sodium tripolyphosphate		Clear	2×10^{5}	2×10^{3}	50	3	0.03	0.001
Sodium polyphosphate	12	Clear	10^{5}	20	20	2	0.000 3	0.000 3
	16	Clear	4×10^{3}	0	0	0.06	0	0
	18	Clear	4×10^{3}	0	0	0.06	0	0
	34	Clear	2×10^{3}	0	0	0.03	0	0
	37	Clear	2×10^{3}	100	40	0.03	0.002	0.001
NaCl (control)		Heavy turbid	10^{8}	10^{8}	10^{8}	100^{+}	100^{+}	100^{+}

Source: Kohl, W. F., and Ellinger, R. H. (Stauffer Chemical Company), British Patent 1,154,079, 1969; reprinted by permission. See also reference 102.

[a] The initial bacterial count was 6×10^{6}.

633. Wismer-Pedersen, J., 1965, *J. Food Sci. 30*:85.
634. *Ibid.*, 91-97.
635. Popp, H., and Muhlbrecht, F. N., 1958, *Food Sci. 10*:399.
636. Watts, B. M., 1954, *Adv. Food. Res. 5*:1.
637. Fox, J. B., 1966, *J. Food Agr. Chem. 14*:207.
638. Hall, G. O. (Hall Laboratories, Inc.), U.S. Patent 2,513,004, 1950.
639. Brissey, G. E. (Swift & Company), U.S. Patent 2,596,067, 1952.
640. Chang, I., and Watts, B. M., 1949, *Food Technol. 3*:332.
641. Bendall, J. R., 1953, *Nature (Lond.) 172*:586.
642. Fukazawa, T., Hashimoto, Y., and Yasui, T., 1961, *J. Food Sci. 26*:331.
643. Giacino, C. (International Flavors & Fragrances, Inc.), U.S. Patent 3,394,015, 1968.
644. Keil, H. L., Hagen, R. F., and Flaws, R. W. (Armour & Company), U.S. Patent 2,953,462, 1960.
645. Kamstra, L. D., and Saffle, R. L., 1959, *Food Technol. 13*:652.
646. Carpenter, J. A., Saffle, R. L., and Kamstra, L. D., 1961, *Food Technol. 15*:197.
647. Voegeli, M. M., and Gorsica, H. J. (B. Heller & Company), U.S. Patent 3,154,421, 1964.
648. *Ibid.*, U.S. Patent 3,154,423, 1964.
649. Rust, M. E., Ph.D. Thesis, Kansas State University, 1963.
650. Allen, H. E. (H. E. Allen and A. G. McCaleb), U.S. Patent 2,140,781, 1938.
651. Mullins, A. M., Kelley, G. G., and Brady, D. E., 1958, *Food Technol. 12*:227.
652. Hopkins, E. W., and Zimont, L. J. (Armour & Company), U.S. Patent 2,999,019, 1961.
653. Williams, B. E. (Hodges Research and Development Corporation), U.S. Patent 3,006,768, 1961.
654. Komarik, S. L. (Griffith Laboratories, Inc.), U.S. Patent 3,147,123, 1964.
655. Brown, W. L., Denny, D., and Schmucker, M. L. (John Morrell & Co.), U.S. Patent 3,207,608, 1965.
656. Delaney, W. (Madison Laboratories, Inc.), U.S. Patent 3,188,213, 1965.
657. Huffman, D. L., Palmer, A. Z., Carpenter, J. W., and Shirley, R. L., 1965, *Quart. J. Fla. Acad. Sci. 28*:106; *ibid.*, 1969, *J. Animal Sci. 28*:443.
658. Miller, E. M., and Harrison, D. L., 1965, *Food Technol. 19*:94.
659. Hopkins, E. W., and Zimont, L. J. (Armour & Company), U.S. Patent 3,049,428, 1962.
660. Unilever, N. V., Netherlands Patent Appl. No. 6,506,834, 1965.
661. Brendl, J., Klein, S., Kocianova, M., 1967, *Sb. Vys. Sk. Chem.-Tech. Praze Potraviny 14*:49; 1967, *Chem. Abstr. 67*:115889x.
662. Tims, M. J., and Watts, B. M., 1958, *Food Technol. 12*:240.
663. Tarladgis, B. G., Younathan, M. T., and Watts, B. M., 1959, *Food Technol. 13*:635.
664. Chang, P., Younathan, M. T., and Watts, B. M., 1961, *Food Technol. 15*:168.
665. Ramsey, M. B., and Watts, B. M., 1963, *Food Technol. 17*:1056.
666. Zipser, M. W., Kwon, T., and Watts, B. M., 1964, *J. Agr. Food Chem. 12*:105.
667. Watts, B. M., 1961, *Proceedings Flavor Chemists Symposium*, Campbell Soup Company, p. 83.
668. Watts, B. M., Meat Products, 1962, *Lipids and Their Oxidation*, H. W. Schultz, Ed., Avi Publishing Company.
669. Savich, A. L., and Jansen, C. E. (Swift & Company), U.S. Patent 2,830,907, 1958.
670. Ziegler, J. A. (Griffith Laboratories, Inc.), U.S. Patent 3,073,700, 1963.
671. Jacoby, D., and Berhold, R. J. (Adolph's Food Products Mfg. Co.), U.S. Patent 3,469,995 (1969).
672. Bickel, W. (Johann A. Benckiser G.m.b.H.), U.S. Patent 3,029,150, 1962.
673. Fetty, H. J., U.S. Patent 3,216,827, 1965.
674. Sair, L., and Cook, W. H., 1938, *Can. J. Res. D16*:255.
675. Sherman, P., 1962, *Food Technol. 16*:91.
676. Swift, C. E., and Ellis, R., 1957, *Food Technol. 11*:450.
677. Zwanenberg's Fabrieken N.V., Netherlands Patent 62,273, 1948.
678. Sair, L., and Komarik, S. L. (Griffith Laboratories, Inc.), U.S. Patent 3,391,007, 1968.
679. Anon., February 1953, *Food Eng. 25*:214.
680. Bailey, M. E., Frame, R. W., and Naumann, H. D., 1964, *J. Agr. Food Chem. 12*:89.
681. Rahelic, S., Rede, R., and Jovicic, V., 1966, *Technol. Mesa 7(9)*:252; 1967, *Chem. Abstr. 67*:36667z.
682. Wilson, G. D., 1954, *Proceedings Research Report to Industry*, American Meat Institute Foundation, p. 32.
683. Fenton, F., Sheffy, B. E., Naumann, H. D., Wellington, G. H., Hogue, D., and Mahon, P., 1956, *Food Technol. 10*:272.
684. Wilson, G. D., *Natl. Provisioner*, 1954, *131*:112; as quoted in Fenton *et al.*, ref. 683.

killed by levels as low as 0.1%, while others required levels considerably higher, ranging from 1% to as high as 5%. *S. aureus* was very effectively killed by levels of 1% sodium polyphosphates with average chain lengths of 16–34, as shown in Table 35. The polyphosphates were found to be effective to varying degrees against different species of bacteria, as demonstrated in Table 36, which shows the effect of polyphosphate chain length upon the growth of *E. coli*.

TABLE 36

Effect of Polyphosphate Chain Length on Inhibition of Growth of *E. coli*

Phosphate Additive	*Amount of Additive, %*	*Growth of Initial Bacteria Population, %*		
		80/ml	*800/ml*	*8 000/ml*
Na_2HPO_4 + KH_2PO_4	1	100+	100+	100+
Sodium acid pyrophosphate + tetrasodium pyrophosphate	1	40	40	39
Sodium tripolyphosphate	1	1	1	3
Sodium polyphosphate 12	1	21	29	33
Sodium polyphosphate 16	1	19	28	32
Sodium polyphosphate 18	1	1	1	4
Sodium polyphosphate 34	1	25	35	32
Sodium polyphosphate 37	1	37	37	37
Potassium polyphosphate (1 000+) in 2% Vitrafos®	0.5	36	41	40
Potassium polyphosphate (1 000+) in 1% Vitrafos®	0.5	29	36	46
Potassium polyphosphate (1 000+) in 0.5% Vitrafos®	0.5	70	70	73
NaCl (control)	1	85	85	85
No additive		100%	100%	100%

Source: Kohl, W. F., and Ellinger, R. H. (Stauffer Chemical Company), British Patent 1,154,079, 1969; reprinted by permission. See also reference 102.

Effects of Metal Chelation Considerable speculation about the effects of polyphosphates as microbiological inhibitors centers on their ability to sequester the essential, nutritional mineral elements required for normal growth of microorganisms. The polyphosphates are excellent sequestering agents for calcium, magnesium, and iron, three of the most important of the essential metal ions.[853,854] The polyphosphates are capable of sequestering calcium in the presence of oxylate, an ability that increases as temperature increases within the pH range of 5–12. However, the ability to sequester calcium decreases with chain length as the pH changes; at pH values of 9.5 and higher, STP and TSPP were the most effective calcium and magnesium sequestrants. Magnesium, in particular, is important to the cell-wall integrity of some of the common food microorganisms.[855] By increasing or decreasing the level of magnesium in the media, *Lactobacillus* species can be changed from the typical rod forms to filamentous forms and vice versa. The number of the metal cations, as well as lipopolysaccharides, is apparently essential to the

581. Weinstein, B. (Crest Foods Company), U.S. Patent 2,856,289, 1958.
582. Green, J., Schuller, E. J., Rickert, J. A., and Borders, B. (General Foods Corp.), U.S. Patent 2,992,925, 1961.
583. Marcus, J. K., U.S. Patent 2,605,229, 1952.
584. Grau, R., 1958, *Kondensierte Phosphate in Lebensmitteln* (Symposium, 1957, Mainz), Springer-Verlag, p. 89.
585. Hamm, R., 1960, *Adv. Food Res. 10*:355.
586. Saffle, R. L., 1968, *Adv. Food Res. 16*:105.
587. Karmas, E., 1970, *Fresh Meat Processing*, Noyes Data Corporation.
588. American Meat Institute Foundation, 1960, *The Science of Meat and Meat Products*, W. H. Freeman and Company.
589. McLoughlin, J. V., 1969, *Food Manuf. 44(1)*:36.
590. Kotter, L., 1957, *Die Fleischwirtschaft 9*:697.
591. *Ibid.*, 1961, *13*:186.
592. Grau, R., Hamm, R., and Baumann, A., 1953, *Biochem. Z. 325*:1.
593. Bendall, J. R., 1954, *J. Sci. Food Agr. 5*:468.
594. Fukazawa, T., Hashimoto, Y., and Yasui, T., 1961, *J. Food Sci. 26*:541.
595. *Ibid.*, 550.
596. Yasui, T., Sakanishi, M., and Hashimoto, Y., 1964, *J. Agr. Food Chem. 12*:392.
597. Yasui, T., Fukazawa, T., Takahashi, K., Sakanishi, M., and Hashimoto, Y., *ibid.*, 399.
598. Klepacka, M., 1965, *Przem. Spozywczy 19(8)*:501; 1966, *Chem. Abstr. 65*:17596a.
599. Grau, R., Hamm, R., and Baumann, A., 1953, *Naturwissenschaften 40*:535.
600. Morse, R. E., October 1955, *Food Eng. 27(10)*:84.
601. Epstein, F. (First Spice Manufacturing Corp.), U.S. Patent 2,876,115, 1959.
602. Kotter, L., 1960, *Zur Wirkung Kondensierter Phosphate und Anderer Salze auf Tierisches Eiweiss*, M. & H. Schaper.
603. Hellendoorn, E. W., 1962, *J. Food Technol. 16(9)*:119.
604. Inklaar, P. A., 1967, *J. Food Sci. 32*:525.
605. Baldwin, T. T., and deMan, J. M., 1968, *J. Inst. Can. Technol. Aliment. 1*:164.
606. Turner, E. W., and Olson, F. C. (Oscar Mayer & Co., Inc.), U.S. Patent 2,874,060, 1959.
607. Saffle, R. L., and Galbreath, J. W., 1964, *Food Technol. 18*:1943.
608. Acton, J. C., and Saffle, R. L., quoted in Saffle, ref. 586.
609. Kotter, L., 1958, *Kondensierte Phosphate in Lebensmitteln* (Symposium, 1957, Mainz), Springer-Verlag, p. 99.
610. Hansen, L. J., 1960, *Food Technol. 14*:565.
611. Swift, C. E., Lockett, C., and Fryar, A. J., 1961, *Food Technol. 15*:468.
612. Hegarty, G. R., Bratzler, L. J., and Pearson, A. M., 1963, *J. Food Sci. 28*:663.
613. Carpenter, J. A., and Saffle, R. L., 1965, *Food Technol. 19*:1567.
614. Trautman, J. C., 1964, *Food Technol. 18*:1065.
615. Swift, C. E., 1965, *Proceedings of the Meat Industry Research Conference*, O. E. Kolari and W. J. Aunan, Eds., American Meat Institute Foundation, p. 78.
616. Ellinger, R. H., and Harkey, C. N., unpublished work, 1960.
617. Mahon, J. H., July 1961, *Proc. 30th Res. Conf. Amer. Meat Inst. Found. 64*:59.
618. Sherman, P., 1961, *Food Technol. 15*:79.
619. Depner, M., 1949, *Fleischwirtschaft 1*:252.
620. Hamm, R., 1955, *Naturwissenschaften 42*:394.
621. Hamm, R., 1955, *Fleischwirtschaft 7*:196.
622. *Ibid.*, 1956, *8*:266.
623. *Ibid.*, 340.
624. Hamm, R., 1957, *Z. Lebensm.-Unters. Forsch. 106*:281.
625. *Ibid.*, 1958, *107*:428.
626. Hamm, R., and Grau, R., 1958, *Z. Lebensm.-Unters. Forsch. 108*:280.
627. Hamm, R., 1959, *Natl. Provisioner 140(15)*:78.
628. Hamm, R., 1959, *Z. Lebensm.-Unters. Forsch. 110*:95.
629. Swift, C. E., and Berman, M. D., 1959, *Food Technol. 13*:365.
630. Wierbicki, E., Kunkle, L. E., and Deathrage, F. E., 1963, *Fleischwirtschaft 15*:404.
631. Swift, C. E., and Ellis, R., 1956, *Food Technol. 10*:546.
632. Wierbicki, E., Tiede, M. G., and Burrell, R. C., paper presented at the 19th Annual Meeting, Institute of Food Technologists, Philadelphia, May 17-21, 1959.

structural integrity of the cell walls of some of the *Pseudomonas* and *Alcaligenes* species of organisms, as the addition of EDTA at alkaline pH values effectively solubilizes their cell walls.[856] Sequestration of metal ion also appears to increase the permeability of the bacterial cell walls to compounds that can interfere with the growth of the organism.[857] The fact that EDTA inhibits the growth of organisms, as reported by Brown and Richards,[858] may provide support for the metal-chelation theory. However, factors other than metal-chelating ability appear to be involved in the microbiological inhibition. Clues might be found in the reports of Burkard *et al.*,[859] who indicated that polyphosphates are capable of interfering with or at least decreasing the acceptor activity of soluble RNA in yeast. According to these authors, if polyphosphates were eliminated from yeast RNA preparations, the acceptor activity of the RNA was usually satisfactory; if, however, polyphosphates were added to the purified RNA preparations, the acceptor activity was decreased in proportion to the amount of polyphosphate added.

Tomiyama *et al.*,[860] Ozawa *et al.*,[839] and others have studied the synergistic activity of the polyphosphates with various types of antibiotics in the preservation of foods. The polyphosphates have the ability to sequester metallic ions, which interfere with the antibiotic activity of the organic compounds. Kooistra and Troller[861] reported that the effect of organic preservatives, e.g., the edible acids and salts of propionic, sorbic, and benzoic acids with their methyl and ethyl esters, was potentiated by the addition of the phosphate, carbonate, chloride, pyrophosphate, and other edible salts of iron, manganese, zinc, tin, and silver. The polyvalent metal ion probably was slowly released to the solution and produced some type of potentiating effect on the microbiological activity of the organic salt.

Applications as Inhibitors of Yeast and Fungal Growth

The ability of STP to interfere with the fermentation of glucose from yeast was demonstrated by Vishniac.[862] He indicated that STP inhibited the enzyme hexokinase; if ATP or magnesium was added to the medium, the STP inhibition could be reversed. Vishniac suggested that the STP chelated the magnesium, which was essential to the activity of the hexokinase. Kohl and Ellinger[509] claimed that the longer-chain polyphosphates were even more effective in inhibiting yeast fermentation of fruit juices, such as apple cider. As is the case with general microbiological inhibition by medium-chain-length polyphosphates, the most effective range of chain lengths appears to be between 18–37. The degree of inhibition increases as the chain length increases from 3 through approximately 30, and then it decreases with increasing chain length.

The polyphosphates have been found to be effective inhibitors of the growth of fungi. Post and co-workers[508] reported that dipping fresh cherries in a 10% solution of SHMP, STP, TSPP, or sodium tetrapolyphosphate would inhibit or delay spoilage of the cherries by such fungi as *Penicillium expansum*, *Rhizopus nigricans*, and *Botrytis* species. Kohl and Ellinger[103] obtained patents in several foreign countries for the applications of medium-chain-length polyphosphates, including those having average chain lengths of 14–37 phosphate units, as inhibitors of fungal spoilage in beer and wine, refrigerated doughs, malt and other grain products, process cheese, fruits, meats, poultry, seafood, and vegetables.

530. Baker, G. L., and Woodmansee, C. W., 1944, *Fruit Prod. J. 23(6)*:164, 185.
531. Baker, G. L., and Gilligan, G. M., 1946, *Food Packer 27(6)*:56.
532. Baker, G. L., and Murray, W. G., 1947, *Food Res. 12*:129.
533. McCready, R. M., Shepherd, A. D., and Maclay, W. D., 1947, *Fruit Prod. J. 27*:36.
534. Woodmansee, C. W., and Baker, G. L., 1954, *Del. Agr. Exp. Sta. Tech. Bull.*, No. 305:5.
535. Waller, G. R., and Baker, G. L., 1953, *J. Agr. Food Chem. 1*:1213.
536. Woodmansee, C. W., 1967, *Del. Agr. Exp. Sta.*, Circular No. 5, University of Delaware.
537. Olsen, A. G., and Fehlberg, E. R. (General Foods Corp.), U.S. Patent 2,334,281, 1943.
538. Leo, H. T., and Taylor, C. C., U.S. Patents 2,483,548 and 2,483,549, 1949.
539. Leo, H. T., Taylor, C. C., and Lindsey, J. W., U.S. Patent 2,483,550, 1949.
540. Pedersen, K. (Kobenhavens Pektinfabrik V. Karl Pedersen), U.S. Patent 2,540,545, 1951.
541. Briccoli-Bati, M., Italian Patent 472,159, 1952.
542. Avoset Company, British Patent 748,402, 1956.
543. Leo, H. T., and Taylor, C. C., U.S. Patent 2,824,007, 1958.
544. Baker, G. L., and Gilligan, G. M., 1947, *Fruit Prod. J. 26(9)*:260, 279.
545. Morse, R. E., 1952, *Food Packer 33(6)*:30, 52.
546. Peters, G. L., Brown, H. D., Gould, W. A., and Davis, R. B., 1954, *Food Technol. 8*:220.
547. Wagner, J. R., and Miers, J. C., 1967, *Food Technol. 21*:920; Wagner, J. R., Miers, J. C., Sanshuck, D. W., and Becker, R., 1968, *Food Technol. 22*:1484.
548. Smith, O., and Davis, C. O., 1963, *Amer. Potato J. 40*:67.
549. Cole, M. S. (The Pillsbury Company), U.S. Patent 3,219,464, 1965.
550. Kintner, J. A., and Tweedy, E., 1967, *Food Technol. 21*:865.
551. Nielsen, J. P., Campbell, H., and Boggs, M., June 1943, *West. Canner Packer 35(7)*:49.
552. Holmquist, J. W., Schmidt, C. F., and Guest, A. E., 1948, *Canning Trade 70 (40)*:7, 20.
553. Neubert, A. M., and Carter, G. H., 1954, *Food Technol. 8*:518.
554. Anon., November 1955, *Food Eng. 27*:188.
555. Blakemore, S. M., U.S. Patent 3,307,954, 1967.
556. Loconti, J. O., and Kertesz, Z. I., 1941, *Food Res. 6*:499.
557. Powers, J. J., and Esselen, W. B., Jr., 1946, *Fruit Prod. J. 25(7)*:200, 217.
558. Van Buren, J. P., 1968, *Food Technol. 22*:790.
559. Anon., 1971, *Code of Federal Regulations, Title 21*, Parts 27, 51, 53, revised as of January 1, 1971, U.S. Government Printing Office.
560. Anon., September 15, 1969, *Food Chem. News 1969*:18.
561. Dakin, J. C., 1963, *Nature 199*:383.
562. Takeda Chemical Industries, Ltd., Japanese Patent 8619 ('70), 1970; 1970, *Food Sci. Technol. Abstr. 2*:11T414.
563. Peschardt, W. J., and Hume, S. R. (Wm. Steward and Arnold, Ltd.), West German Patent Appl. No. 1,280,646, 1968; 1969, *Food Sci. Technol. Abstr. 1(5)*:5J415.
564. Glicksman, M., 1962, *Adv. Food Res. 11*:110.
565. Sergeeva, Z. I., *Tr. Vses. Nauchno.-Issled. Inst. Konditersk. Prom-st.' 1960(15)*:150; 1962, *Chem. Abstr. 57*:3841e.
566. Lucas, H. J. (Kelco Company), U.S. Patent 2,097,228, 1937.
567. Steiner, A. B. (Kelco Company), U.S. Patent 2,441,729, 1948.
568. *Ibid.*, U.S. Patent 2,485,934, 1949.
569. Roland, C. T. (Hall Laboratories), U.S. Patent 2,665,211, 1954.
570. Gibsen, K. F. (Kelco Company), U.S. Patent 2,808,337, 1957.
571. *Ibid.*, U.S. Patent 2,918,375, 1959.
572. Rocks, J. K. (Kelco Company), U.S. Patent 2,925,343, 1960.
573. Hunter, A. R., and Rocks, J. K. (Kelco Company), U.S. Patent 2,949,366, 1960.
574. Merton, R. R., and McDowell, R. H. (Alginate Industries, Ltd.), U.S. Patent 2,930,701, 1960; British Patent 828,350, 1960.
575. Hunter, A. R. (Kelco Company), U.S. Patent 2,987,400, 1961.
576. Miller, A., and Rocks, J. K. (Kelco Company), U.S. Patent 3,266,906, 1966; Canadian Patent 811,682, 1969.
577. Andrew, T. R., and MacLeod, W. C., 1970, *Food Prod. Devel. 4(5)*:99.
578. Stoloff, L. S. (Seaplant Chemical Corp.), U.S. Patent 2,801,923, 1957.
579. Stoloff, L. S. (Seaplant Chemical Corp.), U.S. Patent 2,864,706, 1958.
580. Zabik, M. E., and Aldrich, P. J., 1965, *J. Food Sci. 30*:111.

Applications as Inhibitors of Viruses

Several applications of phosphates as inhibitors of viruses in dairy products have been reviewed in the section of this chapter on Phosphate Applications in Dairy Products. The uses of TSP to inhibit potato virus X and tobacco Mosaic virus have been reported by Brock.[863] The use of a 10 or 20% solution of TSP was found to be more effective than equivalent concentrations of Formalin, and the authors reported that the TSP solution was more effective if the treated inoculum containing the virus was held for 5 minutes prior to inoculating the plant. A 10% solution of TSP was found also to be an effective sterilizing agent for instruments and hands during experimental work with the viruses.

Phosphate Applications in Processing Food Protein

As proteins represent essential components of human and animal diets, their importance in proper nutrition has been well established. Phosphates have been shown to improve numerous characteristics of the proteins, so that they can be more useful in their intended applications. Combinations of orthophosphates are often used to obtain optimum pH values for desired protein characteristics. Less known, but equally important, in food applications are the interactions between proteins and the polymerized phosphates. Numerous specific interactions between proteins of cereals, dairy products, meats, and other protein constituents of food systems have been reviewed in the sections of this chapter dealing with those specific systems. Some of the general interactions between proteins and the polyphosphates also have been reported in the literature and should be reviewed here, since they can have important applications in any food system containing proteins.

The shorter-chain polyphosphates, such as pyrophosphate, tripolyphosphate, and tetrapolyphosphate, are usually quite specific and have been reviewed in the specific food systems. The interactions of the longer-chain polyphosphates, from hexametaphosphate to the very high-molecular-weight, highly polymerized polymetaphosphates, will be of major consideration in this section.

That polyphosphates interact with proteins has been known since the work of Berzelius in 1916; excellent reviews of his early work have been prepared by Horvath[237] and Leach.[239] Horvath reviewed works completed through 1945, while Leach concentrated on works beginning in the late 1930's through 1962.

Some of the very early research, such as that of Fuld in 1902,[864] indicated that the proportion of polyphosphate bound to the protein was determined by the quantity of basic amino acids, such as lysine, arginine, and histidine, present in the protein. The work of Briggs[234] and Perlmann[236] confirmed that the polyphosphates form very strong, non-ionizing, salt-like bonds with the basic groups of protein to such an extent that they mask the basic effects of the protein and shift the dissociation constant of the carboxyl groups to a lower pH region.

The interaction of the polyphosphates with proteins has resulted in the following: (1) precipitation and coagulation of egg white and ovalbumin, (2) precipitation of blood-serum proteins from dilute solutions, (3) precipitation of

484. *Ibid.*, U.S. Patents 2,681,281 and 2,681,283, 1954; U.S. Patents 2,701,769 and 2,701,770, 1955; British Patent 731,177, 1955.
485. Watts, B. M., Lehmann, B., and Goodrich, F., 1949, *J. Amer. Oil Chem. Soc. 26*:481.
486. Lea, C. H., 1950, *Rancidity in Edible Fats*, Chemical Publishing Company.
487. Watts, B., 1950, *J. Amer. Oil Chem. Soc. 27*:48.
488. Lehmann, B. T., and Watts, B. M., 1951, *J. Amer. Oil Chem. Soc. 28*:475.
489. Watts, B. M., and Moss, H. V. (Syracuse University), U.S. Patent 2,629,664, 1953.
490. Lehmann, B. T., and Watts, B. M. (Monsanto Chemical Company), U.S. Patent 2,707,154, 1955; Canadian Patent 538,129, 1957.
491. Ozawa, T., and Ota, A., 1965, *Shokuhin Eiseigaku Zasshi 6(1)*:10; 1965, *Chem. Abstr. 62*:16877g.
492. Holman, G. W. (The Procter & Gamble Company), U.S. Patent 2,871,130, 1959; German Patent 1,236,361, 1967.
493. Mahon, J. H., and Chapman, R. A., 1954, *J. Amer. Oil Chem. Soc. 31*:108.
494. van Hees, G.m.b.H., German Patent 919,779, 1954.
495. Modernas Aplicaciones de la Refrigeración Industrial, S.A., Spanish Patent 217,490, 1955.
496. Mitchell, J. H. (Stevens Industries, Inc.), U.S. Patent 2,511,119, 1950.
497. Vincent, J. F., U.S. Patent 2,511,136, 1950.
498. Langendorf, H., and Lang, K., 1961, *Z. Lebensm.-Unters. Forsch. 115*:400.
499. Benk, E., 1969, *Flussiges Obst 36*:468; 1970, *Food Sci. Technol. Abstr. 2*:5H511.
500. Diemair, W., and Pfeifer, K., 1962, *Z. Lebensm.-Unters. Forsch. 117*:209.
501. Laucks, I. F., Banks, H. P., and Rippey, H. F. (Laucks Laboratories, Inc.), U.S. Patent 1,732,816, 1929.
502. Bates, H. R. (Citrus Compound Corp.), U.S. Patent 1,774,310, 1930.
503. Rippey, H. F. (Laucks Laboratories, Inc.), U.S. Patent 1,935,599, 1933.
504. Kalmar, A. F. (Food Machinery Corp.), U.S. Patent 2,374,209, 1945.
505. Kalmar, A. F. (Food Machinery Corp.), U.S. Patent 2,374,210, 1945.
506. Smith, J. D., and Krause, H. J., U.S. Patent 2,700,613, 1955.
507. Brandt, K., German Patent 1,417,432, 1968.
508. Post, F. J., Coblentz, W. S., Chou, T. W., and Salunhke, D. K., 1968, *Appl. Microbiol. 16*:138.
509. Kohl, W. F., and Ellinger, R. H., Polyphosphates as Preservatives for Apple Cider, paper presented before the 30th Annual Meeting of the Institute of Food Technologists, San Francisco, California, May 26, 1970.
510. Deobald, H. J., McLemore, T. A., Bertoniere, N. R., and Martinez, J. A., 1964, *Food Technol. 18*:1970.
511. Maggi, A. G., Netherlands Patent Application No. 6,600,754, 1966; 1967, *Chem. Abstr. 66*:1740c.
512. Rhee, K. S., and Watts, B. M., 1966, *J. Food Sci. 31*:669.
513. Molsberry, C. C., U.S. Patent 3,342,610, 1967.
514. Hanada, S., Yokoo, Y., Suzuki, E., Yamaguchi, N., and Yoshida, T., 1959, *Eiyo Shokuryo 11*:306; 1963, *Chem. Abstr. 58*:2097f.
515. Feldheim, W., and Seidemann, J., 1962, *Fruchtsaft-Industrie 7*:166; 1962, *Chem. Abstr. 57*:14250c.
516. Hall, G. O. (Hall Laboratories, Inc.), U.S. Patent 2,478,266, 1949.
517. Nelson, R. F., and Finkle, B. J., 1964, *Phytochem. 3*:321.
518. Bolin, H. R., Nury, F. S., and Finkle, B. J., 1964, *Baker's Dig. 38(3)*:46.
519. Fleischman, D. L., 1969, *Diss. Abstr. Int. B, Sci. Eng. 30(2)*:696.
520. Michels, P. (Chemische Fabrik Johann A. Benckiser G.m.b.H.), German Patent 1,082,792, 1962; 1962, *Chem. Abstr. 56*:3872i.
521. Smith, O., 1968, *Potatoes: Production, Storing, Processing*, Avi Publishing Company, Inc.
522. Juul, F., Thesis, *I Kommission Hos Jul. Gjellerups Forlag*, Copenhagen, Denmark, 1949; 1950, *Amer. Potato J. 27*:32-37 (abstract); 1950, *Biol. Abstr. 24*:3610, 11938.
523. Stauffer Chemicals for Modern Potato Processing, Food Industry Release No. 5, Stauffer Chemical Company.
524. Smith, O., 1958, *Amer. Potato J. 35*:573.
525. Smith, O., and Davis, C. O., 1962, *Amer. Potato J. 39*:45.
526. Talburt, W. F., and Smith, O., 1967, *Potato Processing*, Avi Publishing Company, Inc.
527. Talley, E. A., *et al.*, 1969, *Amer. Potato J. 46*:302.
528. Hoover, M. W., 1963, *Food Technol. 17*:636.
529. Kertesz, Z. I., 1939, *The Canner 88(7)*:26.

gelatin-polyphosphate complexes from dilute solutions that are resistant to microbiological decomposition, (4) precipitation of milk proteins and especially casein, and (5) precipitation of various albumins and peptones from aqueous solutions.[237] In each case the reaction results in a flocculent precipitate that is composed of the protein-polyphosphate complex. The quantity of polyphosphate bound to the protein increases in direct proportion to the amount of polyphosphate in the solution; as this quantity is increased, the bound polyphosphate reaches a maximum, which is different for each protein investigated.[234-239]

In contrast to the reports that the polyphosphates were bound to the amino groups of the proteins, Ferrel and co-workers[865] indicated that the highly stable complex between protein and polyphosphate was due to the binding of ortho- and metaphosphoric acid groups to the hydroxyl groups of the amino acids in the proteins, e.g., serine, tyrosine, and threonine, and to a small extent to the phenol hydroxyl group of tyrosine. The authors reported that the complex, after complete removal of all soluble phosphate and other salts by dialysis, was stable to dilute acid and alkaline hydrolysis.

In seeking the reason for the separation of two polyphosphate fractions when yeast cells are partitioned with trichloroacetic acid, Katchman and Van Wazer[235] studied the coprecipitation and formation of complexes between egg albumin and polyphosphates of various chain lengths. The authors reported that the quantity of polyphosphate coprecipitated with the egg albumin, upon treating it with trichloroacetic acid, increased as the chain length of the polyphosphate increased. Approximately 25% of the added phosphorus was coprecipitated with egg albumin when the precipitating agent was a polyphosphate with an average chain length of 16; about 50% of the phosphorus was coprecipitated with egg albumin when treated with a phosphate glass having an average chain length of 85-130. Approximately 80% of the phosphorus of a polyphosphate with a chain length of 230 was coprecipitated with the egg albumin; 100% of the phosphorus of a Kurrol's salt with an average chain length of 1600 was coprecipitated with the egg albumin. It was also possible to separate the sodium phosphate glass with an average chain length of 16 from the Kurrol's salt by coprecipitation with the egg albumin in the presence of trichloroacetic acid. In each case the coprecipitates were complexes of the egg albumin with the polyphosphate.

Braginskaya and El'piner[866] indicated that the formation of protein-polyphosphate and protein-heparin complexes was pH dependent and that the complexes formed at active protein sites, which did not inhibit their enzymatic activity. The proteins studied were γ-globulin, lactalbumin, myosin, and polyalanine. Lyons and Siebenthal[238] determined that the differences in the binding of polyphosphates due to variations in chain length may be caused by the number of possible binding sites on the polyphosphate. The authors speculated that pyrophosphate may have only one possible binding site, while tripolyphosphate may have at least two different binding sites. Longer-chain polyphosphates probably have multiple sites for interaction with multiple sites on the proteins and for increased opportunity for the binding sites on the two compounds to match each other in space.

The variations in the complexing activity between polyphosphates of various chain lengths and the different proteins have been useful in a number

437. James, E. M. (Sharples Specialty Company), U.S. Patent 2,115,668, 1938.
438. Hempel, H. (Gorton-Pew Fisheries, Ltd.), U.S. Patent 2,226,036, 1941.
439. Clayton, B. (Refining, Inc.), U.S. Patent 2,292,822, 1942.
440. Mitani, M., U.S. Patent 3,008,972, 1961.
441. Coith, H. S., and Votaw, V. M. (The Procter & Gamble Company), U.S. Patents 2,061,121 and 2,061,122, 1936.
442. Irmen, P., British Patent 503,607, 1939.
443. Beck, T. M., and Klein, G. I. (Victor Chemical Works), U.S. Patent 2,214,520, 1940.
444. Roy, A. C., 1954, *J. Sci. Ind. Res. (India) 13B*:376.
445. Julian, P. L., and Iveson, H. T. (The Glidden Co.), U.S. Patent 2,752,378, 1956.
446. Morris, S. G., Myers, J. S., Jr., Kip, M. L., and Riemenschneider, R. W., 1950, *J. Amer. Oil. Chem. Soc. 27*:105.
447. Dron, D. W., and Lindsey, F. A. (De Laval Separator Co.), U.S. Patent 2,650,931, 1953.
448. Eckey, E. W. (The Procter & Gamble Company), U.S. Patent 1,982,907, 1934.
449. Lever Bros. and Unilever, Ltd., British Patent 577,879, 1946.
450. *Ibid.*, British Patent 612,169, 1948.
451. Kukn, K. (Kali-Chemi Aktiengesellschaft), British Patent 742,233, 1955; German Patent 1,012,014, 1957.
452. Tsuchiya, T., 1948, *J. Nippon Oil Technol. Soc. 1(3)*:24; *ibid.*, 1949, *2(2/3)*:1.
453. Koyama, R., Japanese Patent 2584 ('52), 1952.
454. Loury, M., 1955, *Rev. fr. Corps gras 2*:15.
455. Skau, E. L. (U.S. Department of Agriculture), U.S. Patent 2,684,377, 1954.
456. Van Akkeren, L. A., and Ast, H. J. (Swift & Co.), U.S. Patent 2,878,274, 1959.
457. Morris, C. E., and Khym, F. P. (Armour & Company), U.S. Patent 2,602,807, 1952.
458. Merker, D. R. (Swift & Co.), U.S. Patent 2,783,260, 1957.
459. *Ibid.*, U.S. Patent 2,862,941, 1958.
460. Richardson, A. S., and Eckey, E. W. (The Procter & Gamble Company), U.S. Patent 2,132,437, 1938.
461. Feuge, R. O., and Gros, A. T., 1950, *J. Amer. Oil Chem. Soc. 27*:117.
462. Van Akkeren, L. A. (Armour & Company), U.S. Patent 3,284,213, 1966.
463. Richardson, A. S., Vibrans, F. C., and Andrews, J. T. R. (The Procter & Gamble Company), U.S. Patent 1,993,181, 1935.
464. Musher, S. (Musher Foundation, Inc.), U.S. Patents 2,314,364 and 2,314,365, 1943.
465. Calkins, V. P., 1947, *J. Amer. Chem. Soc. 69*:384.
466. Kraybill, H. R., *et al.*, 1949, *J. Amer. Oil Chem. Soc. 26*:449.
467. Kraybill, H. R., and Beadle, B. W. (American Meat Institute Foundation), U.S. Patent 2,451,748, 1948.
468. Beadle, B. W., and Kraybill, H. R. (American Meat Institute Foundation), U.S. Patent 2,648,608, 1953.
469. Kring, P., 1950, *Dansk Tidskr. farm. 24*:211; abstracted in 1951, *J. Amer. Oil Chem. Soc. 28(3)*:123.
470. Morris, S. G., Gordon, C. F., Brenner, N., Meyers, J. S., Jr., Riemenschneider, R. W., and Ault, W. C., 1952, *J. Amer. Oil Chem. Soc. 29*:441.
471. Lips, H. J., 1952, *Food Canada 12(6)*:9, 12, 16.
472. Privett, O. S., and Quackenbush, F. W., *J. Amer. Oil Chem. Soc. 31*:225, 321.
473. Hall, L. A. (Griffith Laboratories, Inc.), U.S. Patent 2,511,803, 1950.
474. Magoffin, J. E. (Eastman Kodak Co.), U.S. Patent 2,607,746, 1952; British Patent 679,192, 1952; Canadian Patent 511,767, 1955.
475. Abe, Y., Japanese Patent 5323 ('53), 1953.
476. Gleim, W. K. T. (Universal Oil Products Company), U.S. Patent 2,694,645, 1954.
477. Sumiki, Y., and Tamura, S., Japanese Patent 8521 ('54), 1954.
478. Bentz, R. W. (Eastman Kodak Co.), U.S. Patent 2,772,243, 1956.
479. Mattil, K. F., and Sims, R. J. (Swift & Co.), U.S. Patent 2,759,829, 1956.
480. Brickman, A. W., Conquest, V., Madden, F. J., Filbey, E. T., and Oleson, W. B., British Patents 754,388 and 754,389, 1956.
481. Thompson, R. B. (Universal Oil Products Company), U.S. Patent 2,746,871, 1956.
482. Griffith, C. L., and Sair, L. (Griffith Laboratories, Inc.), Canadian Patent 531,497, 1956.
483. Kuhrt, N. H. (Eastman Kodak Co.), U.S. Patent 2,665,991, 1954; Canadian Patent 540,553, 1957; German Patent 1,042,363, 1958.

of food applications. The polyphosphates can aid in the following applications:

1. improving dispersion and solubility of proteins,
2. increasing the water binding and gel formation of the proteins,
3. improving whipping properties (which appear to be related to increasing the protein insolubility),
4. improving the coagulation, precipitation, and insolubilization of the proteins for better separation,
5. improving their nutritional properties, and
6. purifying the proteins to remove heavy metals and unwanted flavor and odor components.

These will be discussed in subsequent paragraphs.

Applications in Protein Dispersion

The dispersion of proteins, such as those from milk (casein) or peanuts used to prepare a powdered protein food, was accomplished by treating the protein with alkali or alkaline salts; these included sodium and potassium di- or triphosphate (assumed to be TSPP, TKPP, STP, and KTP). The protein dispersion was dried and mixed with various minerals, vitamins, and flavoring agents to obtain a dried protein food.[867] The treatment of the protein with the alkali was reported to produce a dispersible aqueous solution without breakdown of the protein molecule. A number of examples of phosphate applications to maintain proteins in solution[29] have been reviewed previously in this chapter. These include their applications in pasteurized processed cheese, in meat products in which they solubilize proteins and allow them to form protective films about fat globules in order to improve emulsification, and in stabilizing milk proteins to prevent their gelling during storage.

Increasing Protein Water-holding and Gelling Properties

The ability of polyphosphates to improve the water-holding capacities and, often, to cause the formation of protein gels has been utilized in a number of applications. Hall[868] reported that the addition of a buffering agent, which would maintain the pH between 6.5–7.0 in a mixture of gelatin, water, and propylene glycol, would produce a gelling film that was resistant to attack by microorganisms. The film would protect any food product that it coated against spoilage. Among the buffering agents that could be used in this application was DSP.

Ferrel and his co-workers[865,869,871] and Mohammad and co-workers[870] reported several methods of preparing a gluten-phosphate complex with excellent gelling properties. The most satisfactory method involved treating the wet gluten with urea and 85% phosphoric acid, drying it, heating the dried material for 30 minutes at 140°C, and then neutralizing it with sodium hydroxide, washing, and drying it. The gluten phosphate prepared in this manner could absorb 200 times its weight of water, and it could form colorless, tasteless gels that could be used in the preparation of food products. Gel Soy, a soy protein prepared from specially processed, defatted, dehulled soybean flakes,[872,873] was reported by Glabe *et al.*[874] to have improved water- and fat-binding capacities when it was treated with SHMP.

Controlling the pH of protein solutions has long been recognized as important in increasing their water absorption. Norris and Johnson[875]

393. *Ibid.*, 1937, *20*:231.
394. Templeton, H. L., Sommer, H. H., and Stewart, J. K., 1937, *Wis. Agr. Exp. Sta. Bull. 439*:66 (Annual Report, 1937, Part 1).
395. Templeton, H. L., 1937, *J. Dairy Sci. 20*:470.
396. Templeton, H. L., Sommer, H. H., and Stewart, J. K., 1938, *Natl. Butter Cheese J. 29(2)*:16; 1938, *Chem. Abstr. 32*:17967.
397. Palmer, H. J., and Sly, W. H., 1944, *J. Soc. Chem. Ind. 63*:363.
398. Holtstorff, A. F., Mularz, V., and Traisman, E., 1951, *J. Dairy Sci. 34*:486.
399. Kiermeier, F., and Mohler, K., 1960, *Z. Lebensm.-Unters. Forsch. 112*:175.
400. Kiermeier, F., 1962, *Z. Lebensm.-Unters. Forsch. 118*:128.
401. Roesler, H., 1966, *Milchwissenschaft 21(2)*:104.
402. Scharpf, L. G., Jr., and Kichline, T. P., 1967, *J. Agr. Food Chem. 15*:787.
403. Rank, B., and Siepenlist, E., 1941, *Dtsch. Molkerei-Ztg. 62*:1036; 1943, *Chem. Abstr. 37*:6045.
404. Blanchard, J. F., 1949, *Food Ind. 21*:51; 1949, *Chem. Abstr. 43*:3534c.
405. Ovchinnikov, A., and Alyamovskii, 1952, *Molochn. Prom-st.' 13(10)*:21; 1953, *Chem. Abstr. 47*:1860h.
406. Morris, H. A., Manning, P. B., and Jenness, R., 1969, *J. Dairy Sci. 52*:900.
407. Sommer, H. H., and Templeton, H. L., 1941, *Dairy Ind. 6*:14.
408. Kozin, N. I., and Starodubtsev, N. V., 1959, *Sb. Nauchn. Rab. Moskov. Inst. Narod. Khoz. 1959(16)*:202.
409. Hayter, T. C., Olson, N. F., and Price, W. V., 1969, *J. Dairy Sci. 52*:900.
410. Pikarr, H. R. (Purex Corporation, Ltd.), U.S. Patent 3,211,659, 1965.
411. Chin, R. G. L., and Redfern, S. (Standard Brands, Inc.), Canadian Patent 723,609, 1965; U.S. Patent 3,383,221, 1968.
412. Anon., March 19, 1966, *Fed. Reg. 31*:4677; *ibid.*, 1968, *33*:8225.
413. Hall, G. O. (Hall Laboratories, Inc.), U.S. Patent 2,445,879, 1948.
414. Bellamy, A. J. (Egg Patents, Ltd.), British Patent 570,268, 1945.
415. Tongur, V. S., 1947, *J. Appl. Chem. 20*:1191.
416. Sourby, J. C., Kohl, W. F., and Ellinger, R. H. (Stauffer Chemical Company), U.S. Patent 3,561,980, 1971; Belgian Patent 726, 348, 1969; Netherlands Patent 69,00026, 1969; New Zealand Patent 155,019, 1969; British Patent 1,219,519, 1971; French Patent 1,600,264, 1970.
417. Kohl, W. F., and Ellinger, R. H. (Stauffer Chemical Company), U.S. Patent 3,549,388, 1970; Belgian Patent 734,812, 1969; South African Patent 69/3784, 1969; Argentine Patent, 176,511, 1970.
418. Kothe, H. J. (Standard Brands, Inc.), Canadian Patent 503,484, 1954.
419. Finucane, T. P., and Mitchell, W. A. (General Foods Corp.), U.S. Patent 2,671,730, 1954.
420. Finucane, T. P. (General Foods Corp.), U.S. Patent 2,916,379, 1959.
421. Chang, P. K., Ph.D. Thesis, University of Wisconsin, 1969.
422. Chang, P. K., Powrie, W. D., and Fennema, O., 1970, *Food Technol. 24*:63.
423. Kohl, W. F., Ellinger, R. H., and Sourby, J. C., A New Process for Pasteurizing Egg Whites, paper presented before the 30th Annual Meeting of the Institute of Food Technologists, San Francisco, California, May 26, 1970.
424. Kohl, W. F., Sourby, J. C., and Ellinger, R. H. (Stauffer Chemical Company), U.S. Patent 3,520,700, 1970; Netherlands Patent 69,00027, 1969; Belgian Patent 726,347, 1969; New Zealand Patent 154,947, 1968.
425. Rousseau, P. M., 1955, *Oleagineux 10*:183.
426. Lever Bros. Co., British Patent 661,703, 1951.
427. Sullivan, F. E. (De Laval Separator Co.), U.S. Patent 2,702,813, 1955; British Patent 736,885, 1952.
428. Hayes, L. P., and Wolff, H. (A. E. Staley Mfg. Co.), U.S. Patent 2,881,195, 1959.
429. Rini, S. J. (Lever Bros. Co.), U.S. Patent 2,507,184, 1950.
430. Appleton, L. F. (Sherwin-Williams Company), Canadian Patent 330,967, 1933.
431. Eckey, E. W. (The Procter & Gamble Company), U.S. Patent 1,993,152, 1935.
432. Johnson, J. Y., British Patent 337,336, 1932.
433. Colomb, P., 1951, *Lack. Farben. Chem. 5(9/12)*:14.
434. Taussky, L., U.S. Patent 2,654,766, 1953.
435. Braae, B., and Nyman, M., 1957, *Nordisk Symposium om Harskning Af Fedstoffer 2*:231.
436. Bergman, L. O. (Aktiebolaget Pellerins Margarinfabrik), German Patent 1,135,600, 1962; Belgian Patent 595,217, 1961.

reported that the water absorption of soybean protein could be increased if the pH was maintained within the alkaline range of 7.0–9.0. A number of alkaline salts could be used for this purpose, among which was TSP. Pintauro and coworkers[876] reported that the water-binding capacity of a gelatin food product could be highly improved by maintaining a pH of 3.2–3.6 with a mixture of MSP, DSP, and citric acid to buffer the gelatin composition within this pH range. A cold-water-soluble gelatin composition was prepared by Wingerd,[316] who combined gelatin with lactalbumin phosphate, a compound prepared by precipitating lactalbumin proteins from whey with long-chain polyphosphates.

Improving Protein Whipping Properties

The effects of polyphosphates on improving the whipping properties of egg white have been mentioned previously. The addition of polyphosphates to a number of other protein compounds has also improved their whipping properties. Burnett and Gunther[877] prepared a whipping composition from soybean protein isolated from soybean flakes by modifying the protein in the flakes with the enzyme pepsin in the presence of a peptizing salt, such as sodium chloride or sodium phosphate. The salt was added to aid in dissolving any of the unhydrolyzed protein remaining in the preparation. Sevall and Schaeffer[878] prepared protein whipping compositions from soy protein by combining the protein with SHMP, sodium tetrapolyphosphate, TSPP, or sodium orthophosphates; the phosphates stabilized the degraded proteins during whipping in an aqueous system. Patterson[879] formulated whipping compositions similar and equivalent to egg white by combining an alkali-metal caseinate, lactose, or starch and a polyphosphate. This composition successfully replaced 20–35% by weight of the egg whites and still maintained stable whipped foams in which the egg white was the principal whipping agent.

Gunther[880] produced an entirely new whipping composition by combining gelatin, an enzyme-modified soy protein similar to Gel Soy, and a polyphosphate. The specific polyphosphates mentioned were STP, sodium tetrapolyphosphate, and SHMP. According to Gunther the mechanism by which the polyphosphate stabilized the whipping properties of the soy protein and gelatin combination were not known; he speculated, however, that it could be a combination of protein precipitation and the protein ability to sequester heavy metal ions that might interfere. After treatment with the polyphosphate, the protein could form thin walls between the air cells that had sufficient stiffness and storage stability to produce excellent whipped compositions.

Sutton[881] reported that a protein material, such as nonfat milk solids, soybean flour, dried egg-white solids, dried whole eggs, gelatin, caseinate, and similar proteinaceous substances, combined with the alkyl ester of an aliphatic polycarboxylic acid and a polyphosphate salt would provide highly improved whipping compositions with high-foam volume and high-foam stability. Among the alkyl esters of aliphatic polycarboxylic acids specified were those of malonic, succinic, glutaric, tartaric, malic, and citric acids. The polyphosphates that could be used for this purpose were SAPP, TSPP, STP, and the longer-chain polyphosphates with average chain lengths from 4 to several thousand, including SHMP, Graham's salt, TKPP, KTP, and the very-long-chain potassium Kurrol's salts. The ammonium salts of the various polyphosphates also could be used for this purpose.

345. Guidelines to the Formulation of Whipped Toppings, April 1968, Atlas Chemical Industries, Inc.
346. Chip-Dip Base, Data Sheet, issued by Crest Foods Co., Inc.
347. Little, L. L. (Battelle Development Corp.), U.S. Patent 3,391,002, 1968.
348. Frozen Dessert Base, Non-Dairy, Data Sheet, issued by Crest Foods Co., Inc.
349. Frozen Dessert (Containing No Milk Products), LDS-288-D, Durkee Famous Foods.
350. Ryberg, J. R., 1968, *Food Prod. Devel. 2(5)*:60.
351. Webster, D. P., U.S. Patent 3,310,406, 1967.
352. Terada, K., and Yoshida, K. (Asahi Electro-Chemical Co., Ltd.), Japanese Patent 9261, 1962; 1963, *Chem. Abstr. 58*:11900d.
353. Paragraph 19.530(b)(5), 1971, *Code of Federal Regulations, Title 21*, revised as of January 1, 1971, U.S. Government Printing Office.
354. Bristol, D. C., and Martin, J. H., 1970, *J. Dairy Sci. 53*:1381.
355. Continuous Cottage Cheese Process, Form 744-8046, CP Division, St. Regis.
356. Kielsmeier, E. W. (Swift & Company), U.S. Patent 2,851,363, 1958.
357. Vorob'ev, A. I., 1962, *Proc. 16th Int. Dairy Congr., Copenhagen, Sect. B*:576; 1962, *Dairy Sci. Abstr. 24*:2778.
358. Anon., May 1968, *Food Eng. 40*:15.
359. Olson, N. F., 1968, *Food Prod. Devel. 2(5)*:90, 92, 94, 96, 99.
360. Batra, S. C., and deMan, J. M., 1964, *J. Dairy Sci. 47*:673.
361. deMan, J. M., and Batra, S. C., 1964, *J. Dairy Sci. 47*:954.
362. Odagiri, S., and Nickerson, T. A., 1964, *J. Dairy Sci. 47*:673.
363. deMan, J. M., 1966, *Proc. 17th Int. Dairy Congr. 2*:365; 1967, *Chem. Abstr. 67*:2210a.
364. Samuelsson, E. G., 1969, *Nord. Mejeri-Tidskr. 35(1)*:9; 1969, *Food Sci. Technol. Abstr. 1*:5P497.
365. Shew, D. I., 1949, *Nature 164*:492.
366. Potter, N. N., and Nelson, F. E., 1952, *J. Bacteriol. 64*:113.
367. Babel, F. J., 1958, *J. Dairy Sci. 41*:697.
368. Hargrove, R. E., 1959, *J. Dairy Sci. 42*:906.
369. Olson, H. C., 1960, *J. Dairy Sci. 43*:439.
370. Hargrove, R. E., McDonough, F. E., and Tittsler, R. P., 1961, *J. Dairy Sci. 44*:1799.
371. Galesloot, T. E., and Hassing, F., 1962, *Versl. Ned. Inst. Zuivelonerzoek 1962(70)*:117.
372. Kadis, V. W., and Babel, F. J., 1962, *J. Dairy Sci. 45*:486.
373. Hargrove, R. E. (U.S.A.), U.S. Patent 3,041,248, 1962.
374. Waters, H. L. H., U.S. Patent 1,910,195, 1933.
375. Schulz, M. E. (Johann A. Benckiser G.m.b.H.), British Patent 692,055, 1953.
376. Conochie, J., and Sutherland, B. J., 1961, *Aust. J. Dairy Technol. 16*:227.
377. Kraft, J. L., U.S. Patent 1,186,524, 1916.
378. Sommer, H. H., and Templeton, H. L., 1940, *Dairy Ind. 5*:185, 218.
379. Van Slyke, L. L., and Price, W. V., 1952, *Cheese*, Orange Judd Publishing Company, p. 355.
380. Irvine, D. M., and Price, W. V., April 1955, *Process Cheese Abstr.*, Department of Dairy and Food Industries, University of Wisconsin.
381. Garstin, G. H. (Phoenix Cheese Company), U.S. Patent 1,368,624, 1921.
382. Ney, K. H., and Garg, O. P., 1970, *Fette Seifen Anstrichm. 72*:279; 1970, *Food Sci. Technol. Abstr. 2*:11P1489.
383. Rohlfs, H. A. *et al.* (Benckiser-Knapsack G.m.b.H.), British Patent 1,180,716, 1970; 1970, *Food Sci. Technol. Abstr. 2*:7P864.
384. Stauffer Chemical Company, British Patent 1,189,003, 1970.
385. Lauck, R. M., Vanstrom, R. E., and Tucker, J. W. (Stauffer Chemical Company), U.S. Patent 3,097,949, 1963.
386. Kichline, T. P., Stahlheber, N. E., and Vetter, J. L. (Monsanto Company), U.S. Patent 3,337,347, 1967.
387. Paragraph 19.750(c), 1971, *Code of Federal Regulations, Title 21*, revised as of January 1, 1971, U.S. Government Printing Office.
388. Bolanowski, J. P., and Ziemba, J. V., 1966, *Food Eng. 38(11)*:86.
389. Templeton, H. L., and Sommer, H. H., 1930, *J. Dairy Sci. 13*:203.
390. *Ibid.*, 1932, *15*:29.
391. Templeton, H. L., and Sommer, H. H., 1934, *Wis. Agr. Exp. Sta. Bull. 428*:43 (Annual Report, 1932-33).
392. Templeton, H. L., and Sommer, H. H., 1936, *J. Dairy Sci. 19*:561.

A series of patents was obtained by investigators from the research laboratories of the General Foods Corporation for whipping compositions containing proteins that could be precipitated and/or denatured by polyphosphate compounds in acid medium. These whipping compositions were reported to produce superior whipped dessert products, such as chiffons and chiffon-type pie fillings.[882-885] Clausi *et al.*[882] combined gelatin, partially hydrolyzed soy protein, pregelatinized starch, and polyphosphates, including those with an average chain length of 2 through the very-long-chain polyphosphates but preferably SHMP, to produce superior whipping compositions with highly stable foams for use in chiffon desserts and pie fillings. From 1-20% phosphate, based on the level of the partially hydrolyzed soy protein, was used; 20% SHMP was preferred, since it produced the highest foam volume, the shortest whipping time, and the greatest foam stability.

Mancuso and Common[883] prepared foaming compositions for use in chiffon food products or pie fillings, using partially degraded soy protein, a vegetable gum, gelatin, and a polyphosphate, especially SHMP and the sodium polymetaphosphates of longer chain lengths. Mitchell and Seidel[884] produced a phosphated gelatin, prepared by reacting untreated gelatin with a polyphosphoric acid or one of its salts at a pH of less than 4. Whereas the addition of chocolate to normal chiffon mixes suppressed the foam properties, the use of the phosphated gelatin produced superior chocolate chiffon products. Block[885] eliminated the necessity of preparing the phosphated gelatin for chocolate-chiffon desserts by combining cocoa powder, gelatin, partially hydrolyzed soy protein, sugar, and a pregelatinized starch with the phosphate compound. SHMP and Graham's salts were preferred because of the superior properties imparted to the foaming composition.

Downey[886] prepared a dry mix for use in marshmallows. Downey's mix did not require the close attention and special processing conditions of conventional marshmallow manufacture, and it also could be used to prepare uniform batches of marshmallows in the home kitchen. The composition contained a major quantity of dextrose and small quantities of starch, gelatin, phosphates, and vegetable gums. SHMP was the preferred polyphosphate in the patent. Grettie and Tiemstra[887] patented another gelatin-containing marshmallow composition with highly improved properties; it also required the addition of polyphosphates.

Applications as Protein Precipitants

The polyphosphates could also be used as protein precipitants to coagulate proteins, separate and purify them. Schwartz[888] produced artificial fibers or filaments of casein by first dissolving the casein in an alkaline solution and passing the dissolved casein through a spinnerette. A thin filament of the protein solution was discharged into polyphosphoric acid maintained at a pH of approximately 2.5. The polyphosphoric acid solution coagulated the filaments, which then contained a casein-polyphosphate complex of great stability.

Horvath[889] devised a method for the isolation of vegetable proteins as vegetable protein-polyphosphate complexes for numerous food applications. The process involved the preparation of a weak solution of the polyphosphate, which could be any one of the phosphates having a ratio of alkali-metal oxide

299. Parsons, C. H., and Scott, E. C. (Industrial Patents Corp.), U.S. Patent 2,279,205, 1942.
300. Frazeur, D. R., 1959, *Ice Cream Field 73(3)*:25.
301. Weinstein, B. (Crest Foods, Inc.), U.S. Patent 2,856,289, 1958.
302. Keeney, P. G., 1962, *J. Dairy Sci. 45*:430.
303. Anon., September 6, 1967, *Fed. Reg. 32*:12750.
304. Wallander, J. F., 1969, *Diss. Abstr. Int. B. Sci. Eng. 29*(12, Part 1):4523; 1969, *Food Sci. Technol. Abstr. 2*:1P68.
305. Amundson, C. H., 1967, *Amer. Dairy Rev. 29(7)*:22, 96.
306. Zboralski, U. (Johann A. Benckiser G.m.b.H.), German Patent 1,008,220, 1957.
307. Stein, W. (Molkerei Everswinkel Inh. Josef Roberg), German Patent 1,097,380, 1962.
308. Ward, P. J., Johnson, J. D., and Robertson, R. G. (National Dairy Products Corporation), U.S. Patent 3,061,442, 1962.
309. Arena, J. M., 1970, *Nutr. Today 5(4)*:2.
310. Gordon, W. G. (Smith Kline & French Laboratories), U.S. Patent 2,377,624, 1945.
311. McKee, J. I., and Tucker, J. W. (Stauffer Chemical Company), U.S. Patent 3,269,843, 1966; British Patent 1,045,860, 1967.
312. Wingerd, W. H. (The Borden Co.), Canadian Patent 790,580, 1968.
313. Hartman, G. H., Jr., Ph.D. Thesis, University of Wisconsin, 1966.
314. Hartman, G. H., Jr., and Swanson, A. M., 1966, *J. Dairy Sci. 49*:697.
315. Protolac®-Sodium, Technical Data Sheet 402, and Protolac®-Calcium, Technical Data Sheet, The Borden Co.
316. Wingerd, W. H. (The Borden Co.), U.S. Patent 3,332,782, 1967.
317. Wingerd, W. H. (The Borden Co.), U.S. Patent 3,356,507, 1967.
318. Ellinger, R. H. (Stauffer Chemical Company), U.S. Patent 3,563,761, 1971; British Patent 1,145,638, 1969; French Patent 1,549,831, 1968; Netherlands Patent 67,16873, 1968; Belgian Patent 708,289, 1968; Mexican Patent 99,510, 1969.
319. Broadhead, S. A. (Stauffer Chemical Company), British Patent 1,162,735, 1969; Belgian Patent 708,279, 1968; Netherlands Patent 67,17398, 1968; French Patent 1,549,751, 1968; Mexican Patent 99,256, 1967.
320. Endo, N., Japanese Patent 8531 ('62), 1962; Japanese Patent 9271 ('62), 1962; 1963, *Chem. Abstr. 58*:10666c.
321. Ellinger, R. H., and Schwartz, M. G. (Stauffer Chemical Company), French Patents 2,012,982 and 2,012,983, 1970; Belgian Patents, 736,123 and 736,124, 1970.
322. Holland, R. F., and Bandler, D. K., 1967, *Cornell Food Plant Tech. Serv. Lett. 1(4)*:2.
323. McCormick, R. D., and Beck, K. M., 1968, *Food Prod. Devel. 2(1)*:26.
324. Moede, H. H., May 1968, *Dairy Situation*, DS-320, Economic Research Service, U.S. Department of Agriculture, p. 30.
325. Kozin, N. I., and Rodionova, I. F., 1964, *Izv. Vyssh. Uchebn. Zaved. Pishch. Teknol. 1964(5)*:51; 1965, *Chem. Abstr. 62*:9691d.
326. Sabharwal, K., and Vakaleris, D. G., 1969, *J. Dairy Sci. 52*:891.
327. Nutritionally Balanced Non-Dairy Bases, 1968, *Food Prod. Devel. 2(5)*:99.
328. Kempf, C. A., and Blanchard, E. L. (Golden State Company, Ltd.), U.S. Patent 2,645,579, 1953.
329. Brochner, H. S., U.S. Patent 3,241,975, 1966.
330. The Use of Carrageenan in Liquid Coffee Whiteners, June 1966, Technical Bulletin No. 255, Marine Colloids, Inc.
331. Miller, D. E., 1968, *J. Dairy Sci. 51*:1330.
332. Knightly, W. H., 1969, *Food Technol. 23*:171.
333. Anon., February 1966, *Food Eng. 38*:135.
334. Paramount C in Imitation Coffee Cream, February 8, 1963, Durkee Famous Foods.
335. Coffee Whitener, DS-214-C, Durkee Famous Foods.
336. Coffee Whitener, DS-237-C, Durkee Famous Foods.
337. Test Formulas for Coffee Whiteners, 1968, Stauffer Chemical Company.
338. Powdered Coffee Whitener, August 18, 1964, Stauffer Chemical Company.
339. Miller, D. E., and Ziemba, J. V., August 1966, *Food Eng. 38*:97, 105.
340. Mason, R. D., and Justesen, A. C., U.S. Patent 2,407,027, 1946.
341. Noznick, P. P., and Tatter, C. W. (Beatrice Foods Co.), U.S. Patent 3,098,748, 1963.
342. Nash, N. H., and Cheselka, G., June 1966, *Baker's Dig. 40*:58.
343. Thalheimer, W. G., 1968, *Food Eng. 40(5)*:112.
344. Knightly, W. H., 1968, *Food Technol. 22*:731.

to P_2O_5 of 0.9:1 to 1.7:1. The polyphosphate solution was used to extract the protein from the finely pulverized, protein-containing vegetable material and to precipitate the protein-polyphosphate complex by acidification. A British patent described a similar process for isolating vegetable protein-polyphosphate complexes that then could be precipitated around any food material to form an edible food coating.[890] The process for extraction of the protein from the vegetable material was quite similar to that described by Horvath, and the precipitation of the protein-polyphosphate complex as a coating around the food material was performed by acidifying a solution of the complex. Solutions of the complex were readily prepared by dissolving the complex in urea, neutral salts, or alkali.

Rane and Newhouser[891] precipitated proteins without forming a protein-polyphosphate complex by use of the cyclic polyphosphate sodium tetrametaphosphate. This procedure was advantageous in that the protein could be obtained without the associated phosphate. Although the procedure was especially applicable for the precipitation of proteins from blood serum, the authors claimed that it could be used for recovery of proteins from animal or vegetable fluids, such as milk, liver extract, corn extract, or industrial, protein-bearing wastes. The process involved (1) adding the tetrametaphosphate, (2) acidifying to precipitate the protein, (3) separating the protein from the supernatant, and (4) subsequently drying the precipitate or using it directly for the intended purpose. Rane and Newhouser also used this process to fraction some of the components of blood, such as fibrinogen, globulins, and albumins. They first lowered the pH to 5 to precipitate fibrinogen and the globulins, then lowered the pH to approximately 4.2 to precipitate albumins, and later lowered the pH to approximately 3.5 to obtain the balance of the blood proteins. Lowering the pH below 3.5 would result in denaturing the protein. This process was especially beneficial in that it did not denature the proteins in any way.

Nitschmann *et al.*[892] implemented a similar fractionation procedure for blood-plasma proteins involving the use of polyphosphoric acid. The proteins again were reported to be undenatured, and a fractionation of proteins was described. In the fractionation procedure increasing amounts of the polyphosphoric acid were added to precipitate the various blood-protein fractions.

Keil and co-workers[893] obtained two patents for a fungus-resistant food coating prepared from gelatin, SHMP, and water acidified to pH values of 2.15–3.5. The coating could be applied by dipping the food product into the solution. The gelatin-polyphosphate composition dried as a transparent film, which prevented crystallization of salt and mold growth on the surface of the food products.

Fukamachi and Watanabe[894] added sodium citrate and sodium polyphosphates to soybean milk in the presence of calcium salts to improve formation of curd.

Waugh[895] isolated casein from skim milk by first increasing the calcium ion concentration to 0.05–0.1 mol, with 0.06–0.08 mol calcium ion preferred; the precipitated casein was separated from the whey, the calcium ion was removed by precipitating it with oxylate, orthophosphate, or carbonate to reduce the calcium ion concentration to less than 0.2% in the final casein compound. The addition of the calcium ion was necessary to increase the size of the calcium-

258. Muller, L. L., 1963, *Aust. J. Dairy Technol. Suppl.*, Technical Publication No. 12, p. 25; 1964, *Chem. Abstr. 60*:13791e.
259. Seehafer, M. E., The Development and Manufacture of Sterilized Milk Concentrate, 1967, *FAO Agricultural Series*, No. 72.
260. Leviton, A., and Pallansch, M. J., 1962, *J. Dairy Sci. 45*:1045.
261. Leviton, A., Anderson, H. A., Vettel, H. E., and Vestal, J. H., 1963, *J. Dairy Sci. 46*:310.
262. Wilson, H. K., Vetter, J. L., Sasago, K., and Herreid, E. O., 1963, *J. Dairy Sci. 46*:1038.
263. Leviton, A., and Pallansch, M. J. (U.S.A., per U.S.D.A.), U.S. Patent 3,119,702, 1964.
264. Herreid, E. O., and Wilson, H. K., 1963, *Manuf. Milk Prod. J. 54(1)*:14, 31.
265. Swanson, A. M., and Calbert, H. E., 1963, *Food Technol. 17*:721, 727.
266. Magnino, P. J., Jr., Ph.D. Thesis, University of Wisconsin, January 1968; University Microfilms, Inc., No. 68-5, 332, Ann Arbor, MI.
267. Bixby, H. H., and Swanson, A. M., 1969, *J. Dairy Sci. 52*:892.
268. Kadan, R. S., and Leeder, J. G., 1966, *J. Dairy Sci. 49*:709.
269. Stewart, A. P. (Nodaway Valley Foods, Inc.), U.S. Patent 3,348,955, 1967.
270. Bolt, M. G., and Kastelic, J., 1968, *J. Dairy Sci. 51*:693.
271. Calbert, H. E., and Jackson, H. C., 1960, *J. Dairy Sci. 43*:846.
272. A New Marketing Opportunity—2.5 Billion Quarts of Beverage Quality Canned Milk—As a Minimum, 1965, United States Steel Corporation.
273. Continental Can Company and United States Steel Corporation, 1965, Summary Report: One Week Family Test of Commercially Produced, Aseptically Canned, Sterilized Milk Concentrate, United States Steel Corporation.
274. Alwes, M. L., and Swanson, A. M., 1969, *J. Dairy Sci. 52*:891.
275. Nakanishi, T., and Itoh, T., 1969, *Agr. Biol. Chem. 33*:1270; Nakanishi, T., and Itoh, T., 1969, *J. Agr. Chem. Soc. Japan 43*:725; 1970, *Food Sci. Technol. Abstr. 2*:2P215, 3P385.
276. Tamate, R., and Ohtaka, F., 1969, *Jap. J. Dairy Sci. 18(2)*:A37; 1970, *Food Sci. Technol. Abstr. 2*:6P773.
277. Hoff, J. E., Sunyach, J., Procter, B. E., and Goldblith, S. A., 1960, *Food Technol. 14*:24, 27.
278. Leviton, A., Vestal, J. H., Vettel, H. E., and Webb, B. H., 1966, *Proc. 17th Int. Dairy Congr., Munich, E*:133.
279. Johnson, C. E., and Winder, W. C., May 1969, *Quick Frozen Foods 31(10)*:43, 127.
280. Kennedy, M. H., and Castagna, M. P. (Standard Brands, Inc.), U.S. Patent 2,607,692, 1952; Canadian Patent 501,696, 1954; British Patent 709,931, 1954.
281. Breivik, O. N., Slupatchuk, W., Carbonell, R. J., and Weiss, G. (Standard Brands, Inc.), U.S. Patent 3,231,391, 1966.
282. Clausi, A. S. (General Foods Corp.), U.S. Patent 2,801,924, 1957; British Patent 741,076, 1955; Canadian Patent 565,651, 1958.
283. Charie, H. J., and Savage, J. P. (Thomas J. Lipton, Inc.), U.S. Patent 2,927,861, 1960.
284. Moirano, A. L. (Marine Colloids, Inc.), U.S. Patent 3,443,968, 1969; Canadian Patent 847,287, 1970.
285. Pfrengle, O., and Zboralski, U. (Chemische Fabrik Budenheim Rudolf A. Oetker K.-G), German Patent 1,129,813, 1962.
286. Partridge, E. P. (Hall Laboratories, Inc.), U.S. Patent 2,582,353, 1952.
287. McGowan, J., 1970, *Food Prod. Devel. 4(5)*:16, 18.
288. Roland, C. T. (Calgon, Inc.), U.S. Patent 2,665,212, 1954.
289. Freund, E. H., and Danes, E. N., Jr. (National Dairy Products Corp.), U.S. Patent 2,957,770, 1960.
290. Salzberg, H. K. (The Borden Co.), U.S. Patent 2,181,003, 1939; British Patent 503,841, 1939.
291. Wouters, O. J. (Alien Property Custodian), U.S. Patent 2,319,362, 1943.
292. Curry, C. C. (Research and Development Corporation), U.S. Patent 2,341,425, 1944.
293. Lindewald, T. W., and Kimstad, S. G. (Swenska Mjölk-Produkter Aktiebolag), U.S. Patent 2,468,677, 1949.
294. Lewis, M. A., Marcelli, V., and Watts, B. M., 1953, *Food Technol. 7*:261.
295. Kempf, C. A., and Blanchard, E. L. (Golden State Company, Ltd.), U.S. Patent 2,645,579, 1953.
296. Kumetat, K. (Commonwealth Scientific and Industrial Research Organization), U.S. Patent 2,739,898, 1956.
297. Hayes, J. F., Dunkerley, J., and Muller, L. L., 1969, *Aust. J. Dairy Technol. 24(2)*:69; 1969, *Food Sci. Technol. Abstr. 1*:12P1299.
298. Prodanski, P., 1970, *Molochn. Prom-st.' 31(3)*:43; 1970, *Food Sci. Technol. Abstr. 2*:7P916.

caseinate micelles and to cause greater precipitation and easier separation of the calcium-caseinate curd. After separation by filtrating or centrifuging, the calcium curd was washed to remove additional whey and resuspended in water. The calcium ion then was precipitated with orthophosphate or other calcium-precipitating salts, or it could be removed in the form of a soluble complex by adding one of the polyphosphates, such as STP or SHMP. However, when a soluble calcium-phosphate complex has been formed, such as when using SHMP, the soluble complex must be removed by dialysis and might complicate the procedure. The resulting casein was reported to be highly soluble and was also compatible with milk. It could be used to increase the protein content of the milk or to improve the protein and nutritional contents of other food products.

The polyphosphates and orthophosphates also have been reported to aid in the purification of gelatin from impure solutions through their ability to precipitate heavy-metal contaminants from the gelatin composition.[896] The impure gelatin was dissolved in water, phosphoric acid was added, and magnesium chloride was then added to the solution at an alkaline pH, such as 9.15. The precipitate of magnesium ammonium phosphate that was formed brought down with it the impurities in the gelatin; the filtrate contained highly purified gelatin.

Phosphate Applications in Starch Processing

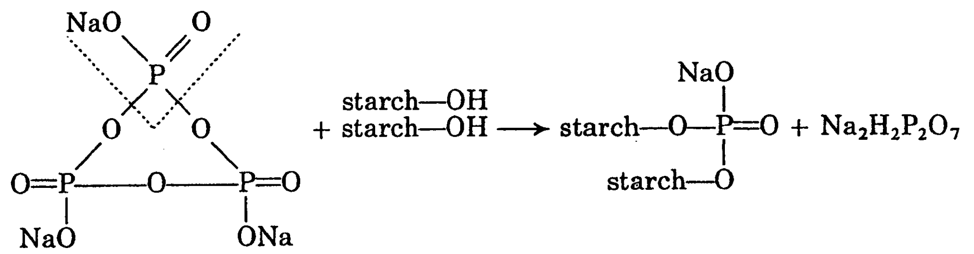
It is well known that acids react with the hydroxyl groups in starch. The esters thus formed have been useful in a number of industrial applications and also in some food applications. Phosphoric acid will form esters with starches. There are phosphoric acid ester groups in natural starches, particularly in potato starch.[897-900] Investigations have demonstrated that the paste viscosity of the potato starch increases as its phosphoric acid ester content increases. The potato starch also can form primary and secondary phosphate complexes with metal ions, depending on the amount of phosphate in the starch.

Effects of Phosphates on Starch Properties

Phosphates have significant effects on starch viscosities, as demonstrated by Nara *et al.*[901] They showed that sodium pyrophosphate had a greater effect in decreasing the swelling of starch granules and depressing viscosity of the starch pastes than various types of monoglycerides and other surface-active agents. Similar effects were obtained with flour, where the addition of phosphates decreased the degree of swelling of two hard-wheat varieties of 70% extraction.[902]

Kuhl[903] reported that the salts of H_3PO_4 reacted differently in gelatinizing starch than the acid; the salts also reacted differently with variations in the quantity of the salt and with the degree of saturation of the acidic radical with alkali. Nutting[904] demonstrated that treatment of potato-starch pastes with SHMP decreased the viscosity of the potato-starch paste to a greater degree at pH 8.5 than any other treatment. Conditions that increased ionization also increased the hydration of the starch, the particle volume, and the viscosity of the paste. All factors that depressed ionization decreased the viscosity of the paste.

209. Sommer, H. M., and Hart, E. B., 1926, *Wisc. Agr. Exp. Sta. Res. Bull. 67*:1.
210. Vujicic, I., Batra, S. C., and deMan, J. M., 1967, *J. Agr. Food Chem. 15*:403.
211. Vujicic, I., deMan, J. M., and Woodrow, I. L., 1968, *Can. Inst. Food Technol. J. 1*:17.
212. Puri, B. R., Kalra, K. C., and Toteja, K. K., 1965, *Ind. J. Dairy Sci. 18(4)*:126; 1967, *Chem. Abstr. 66*:1652r.
213. Tessier, H., and Rose, D., 1958, *J. Dairy Sci. 41*:351.
214. Kiermeier, F., 1952, *Z. Lebensm.-Unters. Forsch. 95*:85.
215. Pyne, G. T., and McGann, T. C. A., 1960, *J. Dairy Res. 27*:9.
216. Zittle, C. A., Della Monica, E. S., Rudd, R. K., and Custer, J. H., 1958, *Arch. Biochem. Biophys. 76*:342.
217. Zittle, C. A., 1966, *J. Dairy Sci. 49*:361.
218. Morr, C. V., and Kenkare, D. B., 1964, *J. Dairy Sci. 47*:673.
219. Odagiri, S., and Nickerson, T. A., 1964, *J. Dairy Sci. 47*:1306; Odagiri, S., and Nickerson, T. A., 1965, *J. Dairy Sci. 48*:19.
220. Ellinger, R. H., *et al.*, 1969-1971, various studies.
221. Feagen, J. T., Griffin, A. T., and Lloyd, G. T., 1966, *J. Dairy Sci. 49*:1010.
222. Zittle, C. A., and Pepper, L., 1958, *J. Dairy Sci. 41*:1671.
223. Rose, D., 1961, *J. Dairy Sci. 44*:430.
224. Rose, D., 1963, *Dairy Sci. Abstr. 25*:45.
225. Rose, D., 1962, *J. Dairy Sci. 45*:1305.
226. Kenkare, D. B., Morr, C. V., and Gould, I. A., 1964, *J. Dairy Sci. 47*:947.
227. Edmondson, L. F., Landgrebe, A. R., Sadler, A. M., and Walter, H. E., 1965, *J. Dairy Sci. 48*:1597.
228. Tessier, H., and Rose, D., 1961, *J. Dairy Sci. 44*:1238.
229. Puri, B. R., Arora, K., and Toteja, K. K., 1969, *Ind. J. Dairy Sci. 22*:85; *ibid., 22*:155; 1970, *Food Sci. Technol. Abstr. 2*:11P1459.
230. Dusek, B., Semjan, S., and Kazimir, L., 1970, *18th Intern. Dairy Congr. (Sydney) 1E*:92; 1970, *Food Sci. Technol. Abstr. 2*:11P1539.
231. Fox, K. K., Harper, M. K., Holsinger, V. H., and Pallansch, M. J., 1964, *J. Dairy Sci. 47*:179.
232. Vujicic, I., and deMan, J. M., 1968, *J. Inst. Can. Technol. Aliment. 1*:171.
233. Lauck, R. M., and Tucker, J. W., 1962, *Cereal Sci. Today 7(9)*:314, 322.
234. Briggs, D. R., 1940, *J. Biol. Chem. 134*:261.
235. Katchman, B. J., and Van Wazer, J. R., 1954, *Biochim. Biophys. Acta 14*:445.
236. Perlmann, G. E., 1941, *J. Biol. Chem. 137*:707.
237. Horvath, A. A., 1946, *Ind. Eng. Chem., Anal. Ed. 18*:229.
238. Lyons, J. W., and Siebenthal, C. D., 1966, *Biochim. Biophys. Acta 26*:174.
239. Leach, A. A., *GGRA Literature Review*, Series D-8, published by the Gelatin and Glue Research Association, Birmingham, England.
240. Leviton, A., 1964, *J. Dairy Sci. 47*:670.
241. Herreid, E. O., and Wilson, H. K., 1963, *Manuf. Milk Prod. J. 54*:14.
242. Morr, C. V., 1967, *J. Dairy Sci. 50*:1038.
243. Hall, R. E. (Hall Laboratories, Inc.), U.S. Patent 2,064,110, 1936. Schwartz, C., U.S. Patent 2,135,054, 1938.
244. Kawanishi, G., 1963, *Nippon Shokuhin Kogyo Gakkaishi 10(4)*:123; 1965, *Chem. Abstr. 63*:1147g.
245. Wouters, O. J. (A.P.C.), U.S. Patent 2,319,362, 1943.
246. Jackson, J. M. (American Can Co.), U.S. Patent 2,396,265, 1946.
247. Roland, C. T. (Calgon, Inc.), U.S. Patent 2,665,212, 1954.
248. Malkov, A. M., Trippel, A. I., and Kirichkova, G. A., 1964, *Sb. Tr. Leningr. Inst. Sov. Torgovli. 1964(23)*:112.
249. North, C. E., U.S. Patent 2,550,288, 1951.
250. Meyer, A., and Weck, G. (Hagen Chemicals & Controls, Inc.), U.S. Patent 2,977,232, 1961.
251. Corbin, E. A., and Long, J. E. (Nopco Chemical Co.), U.S. Patent 3,340,066, 1967.
252. Rothwell, J., 1968, *J. Soc. Dairy Tech. 21*:136.
253. Wilson, H. K., and Herreid, E. O., 1969, *J. Dairy Sci. 52*:1229.
254. Paragraph 18.520(a)(1)(i), 1971, *Code of Federal Regulations, Title 21*, revised as of January 1, 1971, U.S. Government Printing Office.
255. Edmondson, L. F., 1959, *J. Dairy Sci. 42*:910.
256. Martynova, K., 1962, *Molochn. Prom-st.' 23(11)*:17.
257. Shtal'berg, S., and Radaeva, I., 1966, *Proc. 17th Int. Dairy Congr., Munich 5*:153.



It was thought that small amounts of the mono- and trisubstituted esters occurred along with a major proportion of the starch-phosphate diesters.[911] The resulting cross-bonded starches produced exceptionally clear sauces and viscous pastes, which made them especially desirable for pie fillings. They have excellent freeze-thaw stability, resisting the bleeding of water after as many as 10 freeze-thaw cycles. In contrast to untreated and starch-phosphate monoesters, these starches maintain their viscosities, even if they are cooked for long periods of time or added to high-acidity products, such as fruits.[910,911] They are unaffected by long cooking, high temperatures, and low pH values.

Gramera *et al.*[927] analyzed the glucose-phosphate compounds, which they isolated upon hydrolysis of this type of starch phosphate. The isolated compounds indicated that there was 28% phosphate substitution of the C-2 position, 9% of the C-3 position, and 63% of the C-6 position in the glucose units of the starch phosphates.

A cold-water-swelling starch was also reportedly prepared by first treating cereal or potato starch for a short time in an acidic solution with a pH of 3.0-4.0, then adding TSPP, drying, and gelatinizing the preparation.[928] Vermicelli compositions of improved stability, gloss, and smoother texture were also prepared by treating the vermicelli with hydrogen peroxide and polyphosphates.[929]

Among the numerous applications for the starch phosphates that have been reported in the literature are their uses as stabilizers for fountain syrups and ice-cream toppings, ice cream, beer foam, and various types of fat and water emulsions; suspending agents for insoluble solids, which could also include fruits in pie fillings, and for Chinese-type foods in which great thickening and suspending characteristics, as well as maximum clarity, are desirable; as pan greases in combination with fats; in bakery mixes, instant puddings, and various types of cheese sauces; and numerous other nonedible applications.[910,911] The various starch phosphates have been approved for use in foods, providing they contain no more than 0.4% residual phosphate calculated as phosphorus.[930]

Phosphate Applications in Sugar Processing

The term *sugar* is most commonly applied to the disaccharide sucrose, the major food sweetener in human nutrition. Sucrose is a common constituent of all plant cells. Sugar cane and sugar beets are the most common sources of the sucrose in use as a food.

164. Muhler, J. C. (Indiana University Foundation), U.S. Patent 3,467,529, 1969; Canadian Patent 823,140, 1969.
165. Schohl, A. T., 1939, *Mineral. Metabolism*, American Chemical Society Monograph Series No. 82, Reinhold Publishing Corporation.
166. The Importance of Calcium and Phosphorus Supplements in Foods, Technical Service Bulletin, Stauffer Chemical Company. (Out of print.)
167. Anon., 1944, *Bull. Natl. Res. Counc. 40*:38.
168. Anon., September 15, 1969, *Food Chem. News*, 24.
169. Nizel, A. E., Keating, N., Sundstrom, C., and Harris, R. S., 1958, *J. Dent. Res. 37*:35.
170. Buttner, W., and Muhler, J. C., 1958, *J. Dent. Res. 37*:860.
171. McClure, F. J., and Muller, A., Jr., 1959, *J. Amer. Dent. Assoc. 58*:36.
172. Stralfors, A., 1964, *J. Dent. Res. 43*(suppl.):1137.
173. McClure, F. J., and Muller, A., Jr., 1959, *J. Dent. Res. 38*:776.
174. McClure, F. J., 1960, *J. Nutr. 72*:131.
175. Stookey, G. K., and Muhler, J. C., 1966, *J. Dent. Res. 45*:856.
176. Stookey, G. K., Carroll, R. A., and Muhler, J. C., 1967, *J. Amer. Dent. Assoc. 74*:752.
177. Carroll, R. A., Stookey, G. K., and Muhler, J. C., 1968, *J. Amer. Dent. Assoc. 76*:564.
178. Luoma, H., Niska, K., and Tustola, L., 1968, *Arch. Oral Biol. 13(11)*:1343; 1969, *Oral Res. Abstr. 4*:779.
179. Averill, H. M., and Bibby, B. G., 1964, *J. Dent. Res. 43*(suppl. 6):1150.
180. Nizel, A. E., and Harris, R. S., 1964, *J. Dent. Res. 43*(suppl. 6):1123.
181. Council on Foods and Nutrition, 1968, *J. Amer. Med. Assoc. 203*:407.
182. Crosby, W. H., 1969, *J. Amer. Med. Assoc. 208*:347.
183. Jacobs, A., and Greenman, D. A., 1969, *Brit. Med. J. 1*:673.
184. Finch, C. A., 1965, *Nutr. Rev. 23*:129.
185. Proposals to Increase the Levels of Iron in Enriched Flour and Bread, submitted to FDA by the Millers' National Federation and the American Bakers' Association, November 5, 1969; Lampman, H. H., Memorandum of November 17, 1969, Millers' National Federation.
186. Nakamura, F. I., and Mitchell, H. H., 1943, *J. Nutr. 25*:39.
187. Street, H. R., 1943, *J. Nutr. 26*:187.
188. Freeman, S., and Burrill, N. W., 1945, *J. Nutr. 30*:293.
189. Steinkamp, R., Dubach, R., and Moore, C. V., 1955, *Arch. Intern. Med. 95*:181.
190. Fritz, J. C., *Proceedings of Medicine and Nutrition Conference*, March 20–21, 1969, p. 1.
191. Fritz, J. C., 1969, *Fed. Proc. 28*:692.
192. Iron in Flour, 1968, *Reports on Public Health and Medical Subjects*, No. 117, Ministry of Health, London, Her Majesty's Stationery Office.
193. Hinton, J. J. C., Carter, J. E., and Moran, T., 1967, *J. Food Technol. 2*:129.
194. Hinton, J. J. C., and Moran, T., 1967, *J. Food Technol. 2*:135.
195. White, H. S., and White, P. L., 1968, *Food Nutr. News 39(7)*:1, 4.
196. White, H. S., Should Food Iron Be Increased?, paper presented at Symposium on Nutrition and Food Technology, Chicago, February 12, 1969.
197. Anon., 1970, *Cereal Sci. Today 15*:121.
198. Anon., April 1, 1970, *Fed. Reg.*; 1970, *Food Eng. 42(5)*:22.
199. Anon., 1971, *Chem. Eng. News 49(6)*:52.
200. Billings, H. J. (Arthur D. Little, Inc.), U.S. Patent 2,131,881, 1938.
201. Rao, P. V. S., Ananthachar, T. K., and Desikachar, H. S. R., 1964, *Ind. J. Technol. 2*:417; 1965, *Chem. Abstr. 62*:13768d.
202. Tanaka, M., and Yukami, S. (Lion Dentifrice Co., Ltd.), U.S. Patent 3,484,249, 1969; 1970, *Food Sci. Technol. Abstr. 2*:4M268.
203. Malkov, A. M., Deeva, V. E., and Drizina, T. S., 1955, *Tr. Leningr. Tekhnol. Inst. Pishch. Prom-st. 12*:100; 1957, *Zhur. Khim., Biol. Khim.*, No. 11509.
204. Stauffer Chemical Company, Belgian Patent 634,380, 1963; Stauffer Chemical Company, British Patent 1,019,508, 1966.
205. Payumo, E. M., Briones, P. R., Banzon, E. A., and Torres, M. L., 1969, *Philipp. J. Nutr. 22*:216; 1970, *Food Sci. Technol. Abstr. 2*:11M1096.
206. Thames Rice Milling Co., Ltd., British Patent 650,192, 1951.
207. Keller, H. M. (General Mills, Inc.), U.S. Patent 2,909,431, 1959.
208. Madrazo, M. G., and Cortina, G. A. (Process Millers, Inc.), U.S. Patent 3,117,868, 1964.

Sugar refining is the process by which the sugar-bearing juices are extracted from the plant cells of sugar cane or sugar beets, purified, and crystallized. The process involves many complicated steps, the purposes of which are rupturing the plant cells containing the sugar, concentrating the sugar while removing impurities that also are extracted from the cells, and then crystallizing it. The modern sugar processes result in one of the most highly purified compounds known to man.

Clarification of the Sugar-bearing Juices

The juices obtained through the rupture of plant cells (by pressing the stalks of sugar cane and by water extraction of the sliced root of sugar beets) contain numerous, soluble, nonsugar compounds. These must be removed, and the usual practice is to treat the juices with lime and then to precipitate the calcium by formation of insoluble calcium phosphates or carbonates; these in turn aid in the precipitation of the colloidal, nonsugar materials in the solution. Filter aids or Fuller's earth are added if the precipitates are to be removed by filtration. Some processes remove the precipitates by centrifuging the juices. Phosphates are often used to precipitate the calcium in this step; a number of literature references advocate the use of orthophosphoric acid.[931-944] Some find the addition of phosphoric acid and/or acid phosphates useful.[932,940,941] Bennett, who studied the effects of calcium and phosphate levels in the sugar-clarification step, reported that the optimum phosphate concentration is 4 mmol, and the optimum calcium ion concentration is about 15 mmol.[945]

Phosphates other than phosphoric acid can also be used. Various sodium, ammonium, potassium, and calcium orthophosphates have been proposed as additives to the sugar solution along with lime.[937,946-962] The polyphosphates, such as SHMP,[963] superphosphate,[964-966] and pyrophosphate,[967] have also been proposed. Barrett and his co-workers[968,969] have proposed a synthetic hydroxyapatite for the clarification step. Most of the phosphates, particularly the alkaline sodium and potassium phosphates, are used to maintain an optimum pH for the precipitation of the lime, as proposed by Kubala.[970] The control of pH is critical if all of the lime is to be removed from the juice. According to Kortschak[971] the calcium phosphate precipitate is not a definite compound; after it precipitates, the calcium phosphate absorbs additional calcium hydroxide from the juice. Jung[972] patented the use of polyphosphoric acid in combination with a dicarboxylic acid for the clarification of sugar juices. Cummings[973] reported that the filtration of sugar liquors is easier when the calcium phosphate is combined with a diatomaceous-earth filter aid.

Bleaching the Juices

Another important step in the refining of sugar is the bleaching of the sugar syrup prior to crystallization. This is often accomplished by treating the solution with calcium hypochlorite in the presence of a calcium phosphate to act as a stabilizer and to aid in final precipitation of the calcium from the bleached solution.[932,974] Several soluble phosphates have been proposed for precipitating the calcium contributed by the calcium hypochlorite bleach—MCP,[975] orthophosphoric acid,[976] and a combination of calcium hydroxide and MCP.[977] Andresen[978] advocated the replacement of mineral constituents of raw sugar by adding various calcium compounds, including calcium phosphates.

125. Hunt, F. E., and Green, M. E., 1955, *Food Technol. 9*:241.
126. Bradley, W. B., and Tucker, J. W., Bakery Processes and Leavening Agents, pp. 41-59, 1964, *The Encyclopedia of Chemical Technology*, R. E. Kirk, and D. F. Othmer, Eds., Vol. 3, The Interscience Encyclopedia, Inc.
127. Butterworth, S. W., and Colbeck, W. J., 1938, *Cereal Chem. 15*:475.
128. Burhans, M. E., and Clapp, J., 1942, *Cereal Chem. 19*:196.
129. Carlin, G. T., 1947, *Baker's Dig. 21(8)*:22, 35.
130. Jongh, G., 1961, *Cereal Chem. 38*:140.
131. Ellinger, R. H., The Use of Microscopy and Histology in Development of Cereal Products, paper presented at the Fifth Annual Symposium, St. Louis, Missouri, 1964, sponsored by the Central States Section, American Association of Cereal Chemists.
132. Ellinger, R. H., The Sodium Aluminum Phosphates: Their Properties and Uses as Leavening Acids, paper presented at the Sixth Annual Symposium, St. Louis, Missouri, 1965, sponsored by the Central States Section, American Association of Cereal Chemists.
133. Barackman, R. A., 1931, *Cereal Chem. 8(5)*:423.
134. Van Wazer, J. R., and Arvan, P. G., February 1954, *Northwest. Miller 251*:3a; *ibid.*, March 1954, 5, 17.
135. Conn, J. F., Chemical Leavening, paper presented at the First Annual Symposium, St. Louis, Missouri, 1960, sponsored by the Central States Section, American Association of Cereal Chemists.
136. Parks, J. R., Handleman, A. R., Barnett, J. C., and Wright, F. H., 1960, *Cereal Chem. 37*:503.
137. Modern Leavening with Sodium Aluminum Phosphates, 1966, Food Industry Release No. 4, Stauffer Chemical Company.
138. What Leavening Does for Food—What Phosphates Do in Leavening, 1965, Food Industry Release No. 3, Stauffer Chemical Company.
139. Reiman, H. M., 1965, Properties and Uses of Leavening Agents, Technical Service Leaflet, Stauffer Chemical Company.
140. Tucker, J. W., 1959, *Cereal Sci. Today 4(4)*:91.
141. Joslin, R. P., 1960, *Baker's Dig. 34(10)*:58.
142. Joslin, R. P., and Ziemba, J. V., 1955, *Food Eng. 27(9)*:59, 184.
143. Leaven Right with Levn-Lite and Pan-O-Lite, Sodium Aluminum Phosphate Sales Brochure, The Monsanto Company.
144. Upgrade Your Self-rising Flours with Stabil-9, Sales Brochure, The Monsanto Company.
145. Huff, A. E. (Monsanto Chemical Company), U.S. Patent 2,314,090, 1943; Russihyvili, R. (Bird and Sons, Ltd.), British Patent 608,708, 1948.
146. Hurka, R. J. (Monsanto Chemical Company), U.S. Patent 2,366,857, 1945.
147. McDonald, G. A. (Victor Chemical Works), U.S. Patents 2,550,490 and 2,550,491, 1951.
148. Dyer, J. N. (Stauffer Chemical Company), U.S. Patent 2,995,421, 1961.
149. Lauck, R. M., and Tucker, J. W. (Stauffer Chemical Company), U.S. Patent 3,041,177, 1962.
150. Vanstrom, R. E. (Stauffer Chemical Company), U.S. Patents 3,223,479 and 3,223,480, 1965; Belgian Patents 627,509 and 627,511, 1963.
151. Chemische Fabrik Budenheim Aktiengesellschaft, British Patent 390,743, 1933.
152. Griffith, E. J. (Monsanto Chemical Company), U.S. Patent 2,774,672, 1956.
153. Conn, J. F., 1965, *Baker's Dig. 39(4)*:66, 70.
154. Handleman, A. R., Conn, J. F., and Lyons, J. W., 1961, *Cereal Chem. 38*:294.
155. Leavening Indicator Chart, Stauffer Chemical Company.
156. Tucker, J. W. (Stauffer Chemical Company), U.S. Patent 3,109,738, 1963.
157. Armstrong, L., and Willoughby, L. B. (Ballard and Ballard Co.), U.S. Patent 2,478,618, 1949.
158. Baker, J. S., and Lindeman, C. G. (Procter and Gamble Co.), U.S. Patent 3,297,449, 1967.
159. Erekson, A. B., and Duncan, R. E. (The Borden Co.), U.S. Patent 2,942,988, 1960; Matz, S. A. (The Borden Co.), U.S. Patent 3,397,064, 1968.
160. Barackman, R. A., and Bailey, C. H., 1927, *Cereal Chem. 4*:400.
161. Lannuier, G. L., M.S. Thesis, August 1961, Florida State University; Lannuier, G. L., and Bayfield, E. G., 1961, *Baker's Dig. 35(6)*:34, 40, 42, 88; Bayfield, E. G., and Lannuier, G. L., 1962, *Baker's Dig. 36(1)*:34, 77; Bayfield, E. G., and Lannuier, G. L., 1962, *Baker's Dig. 36(6)*:57, 92.
162. Takebayashi, Y., 1963, *Nippon Shokuhin Kogyo Gakkaishi 10(9)*:382.
163. Carter, J. E., and Hutchinson, J. B., 1965, *Chem. Ind. (Lond.) 1965(42)*:1765.

Other Applications

The sweetness of beet sugar, reported to be not as sweet as cane sugar,[979] can be increased by the addition of calcium sulfate and DCP to the wet beet sugar with subsequent drying. Schongart[980] reported that orthophosphoric acid produced a lower ratio of inversion of sucrose than an equivalent level of hydrogen ion produced by hydrochloric acid. The addition of DSP to clarified sugar cane juice at levels of 0.01-0.05% reduced the hydrolysis of the sugars and, thus, reduced caramelization, which leads to dark-colored raw sugar.[981]

The addition of TCP to sugar reduced caking,[982] provided free-flowing properties,[983] and reduced its hygroscopicity.[984] Mead[985] reported that the addition of pyrophosphoric acid or SAPP to molasses produced a greater amount of clarification and resulted in a clearer, more brilliant molasses.

Food Applications for Organic Phosphates

Numerous organic phosphate compounds are known in nature. These include the phosphate esters, those in which phosphate groups are chemically linked through the hydroxyls of organic compounds, such as sugars, and the numerous energy-giving compounds containing phosphate esters, such as ATP, the various sugar phosphates, and similar substances. Any biochemical textbook can provide numerous examples of the energy-rich phosphate esters of organic compounds. There is considerable evidence that phosphate compounds of organic materials also occur, in which case there would be a carbon-to-phosphorus bond.[3]

The methods for preparing compounds that include the esterification of hydroxyl groups of organic substances, such as carbohydrates, polyhydroxylic alcohols, and hydroxy acids, are well known. One of the first patents for the preparation of such compounds for food use was granted as early as 1910.[986] Few food applications for organic phosphates have been developed, and fewer have been approved by FDA for commercial use. It is necessary to demonstrate that these compounds are not toxic, which is a time-consuming and costly process. The development costs for these compounds as food additives are very high, and the manufacturers often cannot foresee sufficient profit during the life of the product to return his investment.

Applications as Antioxidants

Epstein and Harris[987] reported that a phosphorylated mono- or diglyceride of a fatty acid could be used as an antioxidant in food applications. Martin[989] patented the preparation of the orthophosphoric esters of phenolic compounds, which he claimed were excellent, neutral phosphate-ester antioxidants for treatment of animal, vegetable, and marine oils and prevented or inhibited development of rancidity.

Nyrop[989] obtained a patent for the preparation and application of phosphate esters of fermentable sugar compounds, such as hexoses, pentoses, and trioses. He reported that these organic phosphate-sugar compounds, when added to organic food materials subject to oxidative deterioration, would stabilize the organic food compounds against rancidity and oxidative deterioration.

83. Lehman, A. J., 1960, *Assoc. Food Drug Officials U.S. Quart. Bull. 24*:45.
84. Gosselin, R. E., Tibdall, C. S., Megirian, R., Maynard, E. A., Downs, W. L., and Hodge, H. C., 1953, *J. Pharmacol. Exp. Ther. 108*:117.
85. Paragraph 121.101(d), revised as of January 1, 1971, *Code of Federal Regulations, Title 21*, U.S. Government Printing Office.
86. Paragraph 318.7(4), revised as of January 1, 1971, *Code of Federal Regulations, Title 9*, U.S. Government Printing Office.
87. Navet, P., 1947, *Tech. Eau (Belg.) 1947(6)*:11; 1947, *Chem. Abstr. 41*:6003g.
88. Hofer, P., 1958, *Kondensierte Phosphate in Lebensmitteln* (Symposium, 1957, Mainz), Springer-Verlag, p. 122.
89. Adler, H. (Victor Chemical Works), U.S. Patent 2,262,745, 1942.
90. Corrie, L. M. (Harry Chin), U.S. Patent 3,231,394, 1966.
91. Roland, C. T., 1942, *Milk Plant Mon. 31(6)*:38, 45.
92. Visser, S. A., 1962, *J. Dairy Sci. 45*:710.
93. Hamm, R., 1956, *Z. Lebensm.-Unters. Forsch. 104*:245.
94. Rose, D., 1969, *Dairy Sci. Abstr. 31*:171.
95. Warning, W. G., and Schille, T. W. (Swann Research), U.S. Patent 1,865,733, 1932; reissue 18,907, 1933.
96. Lubeck, W. D. (Daitz Patents Foundation), U.S. Patent 1,978,040, 1934.
97. Kemmerer, K. S. (Mead Johnson and Co.), U.S. Patent 2,829,056, 1958.
98. Sorgenti, H. A., Nack, H., and Sachsel, G. F. (The Battelle Development Corp.), U.S. Patent 3,035,918, 1962.
99. Heyer, W., U.S. Patent 2,816,032, 1957.
100. Bah, S., and MacKeen, W. E., 1965, *Can. J. Microbiol. 11*:309.
101. Malkov, A. M., and Kormushkina, A. M., U.S.S.R. Patent 135,064, 1961.
102. Kohl, W. F., and Ellinger, R. H. (Stauffer Chemical Company), Netherlands Patent 68,00059, 1968; South African Patent 67,7804, 1968; Belgian Patent 708,863, 1968; French Patent 1,568,002, 1969; British Patent 1,154,079, 1969.
103. Kohl, W. F., and Ellinger, R. H. (Stauffer Chemical Company), Netherlands Patent 68,00060, 1968; Belgian Patent 708,864, 1968; South African Patent 67,7805, 1968; French Patent 1,568,003, 1969.
104. Libbey, A. G., U.S. Patent 2,075,653, 1937.
105. Peynaud, E., 1953, *Inds. Agr. Aliment. (Paris) 70*:559.
106. Freed, E., U.S. Patent 2,995,446, 1961.
107. Skrivanek, M., 1948, *Chemie (Prague) 4*:227.
108. Ohara, I., Nonomura, H., Kushida, T., and Maruyama, C., 1956, *J. Ferment. Technol. 34*:431.
109. Karlson, W. N., U.S. Patent 2,943,939, 1960.
110. 120 Q's and A's about How Phosphates Are Used in Foods, 1966, Food Industry Release No. 2, Stauffer Chemical Company.
111. Ingredients for Food Processors, 1965, Monsanto Company.
112. Diller, I. M. (H. Brout), U.S. Patents 2,851,360 and 2,851,361, 1958.
113. Diller, I. M. (H. Brout), U.S. Patent 2,953,459, 1960.
114. Common, J. L. (General Foods Corp.), U.S. Patent 3,023,106, 1962.
115. DiNardo, A., U.S. Patent 3,224,879, 1965.
116. Stayton, F. J., U.S. Patent 2,341,826, 1944.
117. Hashimoto, K., Miyazaki, S., Japanese Patent 15,550, 1961.
118. Feldheim, W., and Seidemann, J., 1959, *Pharmazie 14*:12.
119. Niwa, S., Katayama, N., and Matsubara, S., 1959, *Vitamins (Kyoto) 18(2)*:492; Niwa, S., Katayama, N., Matsubara, S., and Tanaka, H., 1960, *Vitamins (Kyoto) 20(3)*:497; Niwa, S., and Katayama, N., 1961, *Vitamins (Kyoto) 24(2)*:73; and 1965, *Chem. Abstr. 62*:1002f, 4531g.
120. Stahl, J. E., and Ellinger, R. H., Use of Phosphates in the Cereal and Baking Industry, paper presented at the Phosphates in Food Processing Symposium, 1970, University of Guelph, Guelph, Ontario, Canada; to be published.
121. Kichline, T. P., and Conn, T. F., 1970, *Baker's Dig. 44(8)*:36.
122. Carlin, G. T., 1944, *Cereal Chem. 21*:189.
123. Hanssen, E., and Dodt, E., 1952, *Mikroskopie 7*:2.
124. Jooste, M. E., and Mackay, A. O., 1952, *Food Res. 17*:185.

Applications as Emulsifying Agents

Harris[990] reported that organic phosphate esters of mono- and diglycerides were able to modify interfaces between aqueous fat systems. These compounds were excellent emulsifiers when added to shortenings to be used in most of the applications of shortenings, such as in baked products, and the preparation of icings. Katzman[991] patented the preparation and application of metaphosphoric acid esters of many types of high-molecular-weight alcohols as emulsifying, foaming, and improving agents for baked products, particularly for non-shortening foam cakes, such as angel food cakes.

Thurman[992,993] obtained patents for the preparation of sodium phosphate esters of phosphatides, which made excellent surface-active agents for use as emulsifiers and similar applications in foods. Examples claimed emulsifying properties for mayonnaise, margarine, and shortening compositions.

Pader and Gershon[994,995] obtained patents for the application of phosphoric acid esters of mono- and diglycerides as emulsifiers and aerating agents for aerosol toppings. They could be dispensed as light foams from pressurized cans and had the texture and appearance of whipping cream. The aerosol preparation was reported to be stable to temperatures of −10° to 70°F.

Applications as Whipping Agents

Katzman[996] prepared tetrapolyphosphoric acid esters of long-chain alkyl alcohols, such as stearyl tetrapolyphosphate, to be used as excellent foaming agents when added to egg white in small quantities. The author listed 35 examples of organic phosphate esters, ranging from the alkyl alcohols through mono- and diglyceride fatty compounds. All were reported to provide a strongly hydrophilic group through the tetrapolyphosphoric acid and a strongly lipophilic group through the alkyl compound.

Thompson[997] reported the methods for preparation and the food applications of an alkyl phosphoryl halide, e.g., octadecyl phosphoryl dichloride, as improvers of air incorporation and foam stability in foamed food products. These compounds were reported to be especially useful when incorporated into baked products requiring a great deal of aeration, such as cakes and breads.

Cunningham and co-workers[998] obtained a patent for the application of triethyl phosphate as a foaming agent for egg whites. The incorporation of 0.001–0.1% of the compound, based on the weight of the egg white, would improve the whipping properties of egg whites, which normally had lowered whipping properties due to pasteurization procedures now required of all such products. Concern over the toxicity of triethyl phosphate was the reason for research by Gumbmann *et al.*,[999] who studied the toxicity of the compound in quantities up to 10% of the diet of rats. Feeding and reproductive studies indicated that the compound had no effect at levels that would be encountered if it were used as a food additive in the manner proposed by Cunningham and his co-workers.

Other Applications

Curtin and Gagolski[1000] and Toy[1001] patented the preparation of sucrose-calcium phosphate compounds of a very complex nature; they formed soluble compositions, even though a considerable quantity of dicalcium phosphate was detectable in the product. The ability of the sucrose-phosphate complex to form

38. Food Protection Committee, 1966, *Food Chemicals Codex*, No. 1406. National Academy of Sciences-National Research Council.
39. Brout, H., British Patent 883,169, 1961; Diller, I. M. (Henry Brout), U.S. Patent 2,851,359, 1958.
40. Van Wazer, J. R., 1950, *J. Amer. Chem. Soc. 72*:647.
41. Westman, A. E. R., and Crowther, J., 1954, *J. Amer. Ceram. Soc. 37*:420.
42. Westman, A. E. R., and Gartaganis, P. A., 1957, *J. Amer. Ceram. Soc. 40*:293.
43. Bernhart, D. N., and Chess, W. B., 1959, *Anal. Chem. 31*:1026.
44. Corbridge, D. E. C., 1967, *Top. Phosphorus Chem. 3*:57-394.
45. Batra, S. C., 1965, *J. Food Sci. 30*:441.
46. Van Wazer, J. R., and Campanella, D. A., 1950, *J. Amer. Chem. Soc. 72*:655.
47. Van Wazer, J. R., and Callis, C. F., 1958, *Chem. Rev. 58*:1011.
48. Thilo, E., 1955, *Angew. Chem. Int. Ed. Engl. 67*:141.
49. Irani, R. R., and Callis, C. F., 1962, *J. Amer. Chem. Soc. 39*:156.
50. Irani, R. R., and Morgenthaler, W. W., 1963, *J. Amer. Chem. Soc. 40*:283.
51. Kutscher, W., 1961, *Dtsch. Lebensm.-Rundsch. 57(6)*:140.
52. Karl-Kroupa, E., Callis, C. F., and Seifter, E., 1957, *Ind. Eng. Chem. 49*:2061.
53. Bell, R. N., 1947, *Ind. Eng. Chem. 39*:136.
54. Hermann, S., 1947, *Exp. Med. Surg. 5*:160.
55. Behrens, B., and Seelkopf, K., 1932, *Naunyn-Schmiedebergs Arch. Pharmakol. Exp. Pathol. 169*:238.
56. Eichler, O., 1950, *Handbuch der experimentellen Pharmakologie, Ergänzungswerk, Bd 10*, p. 363; quoted in World Health Organization Technical Report, Series No. 281, ref. 37.
57. McFarlane, D., 1941, *J. Pathol. Bacteriol. 52*:17.
58. van Esch, G. J., Vink, H. H., Wit, S. J., and van Genderen, H., 1957, *Arneimittel-Forschung. 7*:172.
59. Datta, P. K., Frazer, A. C., Sharratt, M., and Sammons, H. G., 1962, *J. Sci. Food Agr. 13*:556.
60. Zipf, K., 1957, *Arneimittel-Forschung. 7*:445.
61. Gosselin, R. E., and Megirian, R., 1955, *J. Pharm. Exp. Ther. 115*:402.
62. Bonting, S. L., 1952, The Effect of a Prolonged Intake of Phosphoric Acid and Citric Acid in Rats, Ph.D. Thesis, The University of Amsterdam.
63. MacKay, E. M., and Oliver, J., 1935, *J. Exp. Med. 61*:319.
64. Hahn, F., Jacobi, H., and Seifen, E., 1958, *Arneimittel-Forschung. 8*:286.
65. Dymsza, H. A., Reussner, G., and Thiessen, R., 1959, *J. Nutr. 69*:419.
66. Hogan, A. G., Regan, W. O., and House, W. B., 1950, *J. Nutr. 41*:203.
67. House, W. B., and Hogan, A. G., 1955, *J. Nutr. 55*:507.
68. Hahn, F., and Seifen, E., 1959, *Arneimittel-Forschung. 9*:501.
69. Hahn, F., 1961, *Z. Ernährungsw., Suppl. 1*, 55.
70. Hodge, H. C., 1956, Short-term Oral Toxicity Tests of Condensed Phosphates in Rats and Dogs (unpublished mimeographed report), University of Rochester, Rochester, New York.
71. Hodge, H. C., 1959, Chronic Oral Toxicity Studies in Rats of Sodium Tripolyphosphate (unpublished mimeographed report), University of Rochester.
72. Hodge, H. C., 1960, Chronic Oral Toxicity Studies in Rats of Sodium Hexametaphosphate (unpublished mimeographed report), University of Rochester.
73. Hodge, H. C., 1960, Chronic Oral Toxicity Studies in Rats of Sodium Trimetaphosphate (unpublished mimeographed report), University of Rochester.
74. Gassner, K., Kiekebusch, W., and Lang, K., 1957, *Biochem. Z. 328*:485.
75. van Genderen, H., 1961, *Z. Ernährungsw., Suppl. 1*, 32.
76. Lang, K., 1958, *Kondensierte Phosphate in Lebensmitteln* (Symposium, 1957, Mainz), Springer-Verlag, p. 135.
77. Borenstein, M. K., and Schwartz, C., 1948, *J. Nutr. 36*:681.
78. Schreier, K., and Noeller, H. G., 1955, *Arch. Exp. Path. Pharmakol. 227*:199.
79. Mitchell, L. C., 1958, *J. Assoc. Official Agr. Chem. 41*:185.
80. Gosselin, R. E., Rothstein, A., Miller, G. J., and Berke, H. L., 1952, *J. Pharmacol. Exp. Ther. 106*:180.
81. Gotte, H., 1953, *Z. Naturforsch. 8b*:173.
82. Lang, K., Schachinger, L., Karges, O., Blumenberg, F. K., Rossmuller, G., and Schmutte, I., 1955, *Biochem. Z. 327*:118.

soluble dicalcium phosphate compounds was not understood but was adequately demonstrated. These compounds were shown to increase crispness of the sugar coatings on breakfast cereals[1002, 1003] and to inhibit the development of dental caries in the teeth of children who ate food compositions containing the compound.[1004]

A Japanese patent[1005] reported that organic phosphates, such as the sugar phosphates and glycerol phosphates, improved the flavor of alcoholic beverages.

Future Trends

As demonstrated in the preceding sections, the food-science literature contains much evidence of the usefulness of the phosphates in food processing. Many of the applications described, however, are not being exploited by the food industry. The ability of the phosphates, and especially the polyphosphates, to control firmness or tenderness of the tissues of fruits and vegetables is not applied to the extent that the published research indicates. The use of the polyphosphates in increasing the acceptability of meat products, including fresh and frozen meats, poultry, and seafood, is well documented, but it is mostly used only in cured meats. A major reason that these applications are not exploited is that the regulatory agencies, the USDA and FDA, have been very cautious in approving phosphate applications in processed foods. These agencies most frequently cite three reasons, as follows:

One reason for not accepting phosphates in more food applications is fear that the polyphosphates will allow the processor to upgrade lower-grade food products. This use has repeatedly been disproved. The phosphates are unable to improve the quality of low-grade foods. They are, however, capable of preventing further lowering of the quality and in many cases, of improving some of the characteristics that make these foods less acceptable to the consumer.

The second reason often given by the FDA and USDA is that phosphate treatment allows the processor to increase the water content of foods. This is most often mentioned in regard to meat, poultry, and seafood products. Yet, careful research, especially as reviewed in the sections on poultry and seafoods, has clearly demonstrated that treating these foods with phosphate dips often *reduces* the amount of water absorbed during ice chilling of the products. In fact, the evidence presented indicates that phosphate treatment seals the surfaces of the food; therefore, it prevents internal juices from escaping and water or saline solutions from entering.

The third argument given against food applications of phosphates is that their increased use will reach a level that will be toxic to humans. Evidence presented in the section on the toxicology of the food phosphates has demonstrated that they are little, if any, more toxic than common table salt, which is now used in most foods. The effective levels of the phosphates are usually 0.5% or less. When this level of phosphate was consumed in the diets of many animals, it was shown to be nontoxic. Since the phosphates have adverse effects in many foods, it is inconceivable that their use could never result in a level of 0.5% of phosphate in the total human diet.

As the need to conserve every available amount of food increases over the next few years due to the population explosion, the use of phosphates to aid in making more foods acceptable and in increasing their nutritional value by retaining internal juices should be given further serious consideration. The pressure of the increased need for expansion of the world food supply is certain to result in the increased application of phosphates in food processing.

References

1. Nazario, G., 1952, *Rev. Inst. Adolpho. Lutz 11*:141.
2. Sanchelli, V., 1965, *Phosphates in Agriculture*, Reinhold Publishing Company, p. 90.
3. Quin, L. D., 1967, *Top. Phosphorus Chem. 4*:23.
4. Fox, S. W., Ed., 1965, *The Origins of Prebiological Systems*, Academic Press.
5. Miller, S. L., and Parris, M., 1964, *Nature 204*:1248.
6. Ponnamperuma, C., Sagan, C., and Mariner, R., 1963, *Nature 199*:222.
7. Lohmann, K., 1958, *Kondensierte Phosphate in Lebensmitteln* (Symposium, 1957, Mainz), Springer-Verlag, p. 29.
8. Harold, F. M., 1966, *Bacteriol. Rev. 30*:772.
9. Wiame, J. M., 1949, *J. Biol. Chem. 178*:919.
10. Stich, H., 1953, *Z. Naturforsch. 8b*:36.
11. Kornberg, S. R., 1957, *Biochim. Biophys. Acta 26*:294.
12. Ipata, P. L., and Felicioli, R. A., 1963, *Boll. Soc. Ital. Biol. Sper. 39(2)*:85; 1963, *Chem. Abstr. 59*:874g.
13. Van Steveninck, J., and Booij, H. L., 1964, *J. Gen. Physiol. 48*:43.
14. Shiokawa, K., and Yamana, K., 1965, *Exp. Cell Res. 38(1)*:180; 1965, *Chem. Abstr. 63*:4722A.
15. Miyachi, S., 1961, *J. Biochem. (Tokyo) 50*:367; 1962, *Chem. Abstr. 56*:9121a.
16. Tewari, K. K., and Singh, M., 1964, *Phytochemistry 3(2)*:341; 1964, *Chem. Abstr. 61*:963c.
17. Grossmann, D., and Lang, K., 1962, *Biochem. Z. 336*:351.
18. Griffin, J. B., Davidian, N. M., and Penniall, R., 1965, *J. Biol. Chem. 240*:4427.
19. Mattenheimer, H., 1958, *Kondensierte Phosphate in Lebensmitteln* (Symposium, 1957, Mainz), Springer-Verlag, p. 45.
20. Sober, H. A., Ed., 1970, *Handbook of Biochemistry*, 2nd ed., The Chemical Rubber Co.
21. Sherman, H. C., 1947, *Calcium and Phosphorus in Foods and Nutrition*, Columbia University Press, p. 91.
22. Kiermeier, F., and Mohler, K., 1957, *Z. Lebensm.-Unders. Forsch. 106*:33.
23. Ruf, F., 1957, *Mitt. Geb. Lebensmittelunters. Hyg. 48*:451.
24. Shettino, O., 1965, *Farmaco (Pavia) 20(2)*:65.
25. 1958, *Kondensierte Phosphate in Lebensmitteln* (Symposium, 1957, Mainz), Springer-Verlag.
26. Barackman, R. A., and Bell, R. N., 1953, *Food Eng. 25(6)*:68, 108.
27. The Functions of Phosphates in Food Products, 1966, Food Industry Release No. 1, Stauffer Chemical Company.
28. Ellinger, R. H., 1972, *Phosphates as Food Ingredients*, The Chemical Rubber Co.
29. deMan, J. M., and Melnychyn, P., Eds., 1971, *Symposium: Phosphates in Food Processing*, Avi Publishing Co.
30. Van Wazer, J. R., 1958, *Phosphorus and Its Compounds*, 2 volumes, Interscience Publishers, Inc.
31. Nomenclature and Classification of Inorganic Phosphates, 1965, Technical Service Release Number One, Stauffer Chemical Company.
32. Van Wazer, J. R., Phosphoric Acids and Phosphates, 1968, in *The Encyclopedia of Chemical Technology*, R. E. Kirk, and D. F. Othmer, Eds., Vol. 15, Interscience Encyclopedia, Inc.
33. Bell, R. N., 1948, *Ind. Eng. Chem. 40*:1464.
34. Huhti, A. L., and Gartaganis, P. A., 1956, *Can. J. Chem. 34*:785.
35. Partridge, E. P., 1949, *Chem. Eng. News 27(4)*:214.
36. Thilo, E., 1958, *Kondensierte Phosphate in Lebensmitteln* (Symposium, 1957, Mainz), Springer-Verlag, p. 7.
37. Specifications for the Identity and Purity of Food Additives and Their Toxicological Evaluation: Emulsifiers, Stabilizers, Bleaching, and Maturing Agents, 1964, World Health Organization Technical Report, Series No. 281, World Health Organization. (May be obtained from National Agency for International Publications, Inc., 317 East 34th Street, New York, NY 10016.)