United States Department of Agriculture
Agricultural Marketing Service | National Organic Program
Document Cover Sheet
https://www.ams.usda.gov/rules-regulations/organic/petitioned-substances

Document Type:

☐ **National List Petition or Petition Update**

A petition is a request to amend the USDA National Organic Program's National List of Allowed and Prohibited Substances (National List).

Any person may submit a petition to have a substance evaluated by the National Organic Standards Board (7 CFR 205.607(a)).

Guidelines for submitting a petition are available in the NOP Handbook as NOP 3011, National List Petition Guidelines.

Petitions are posted for the public on the NOP website for Petitioned Substances.

☒ **Technical Report**

A technical report is developed in response to a petition to amend the National List. Reports are also developed to assist in the review of substances that are already on the National List.

Technical reports are completed by third-party contractors and are available to the public on the NOP website for Petitioned Substances.

Contractor names and dates completed are available in the report.

Sodium Silicate

Crops

Identification of Petitioned Substance

Chemical Names:
Disodium metasilicate; Disodium monosilicate; Silicic acid disodium salt; Silicic acid nonahydrate silicic acid; Sodium betasilicate; Sodium metasilicate; Sodium metasilicate anhydrous; Sodium orthosilicate; Sodium pyrosilicate; Sodium salt; Sodium silicate; Sodium silicate glass; Sodium trisilicate; Tetrasodium orthosilicate.

Other Names:
Sodium silicate glass; Sodium water glass; Water glass.

Trade Names:
Agrosil (S, LR); Britesil; N® sodium silicate; Metso Beads® 2048; Portil A; Silica E; Silica K; Silica R; Silican; Soluble glass.

CAS Numbers:
1344-09-8
6834-92-0
106985-35-7
10213-79-3
15859-24-2

Other Codes:
EC / List no. 239-981-7
EC number: 215-687-4

Summary of Petitioned Use

This limited scope technical report provides information to the National Organic Standards Board (NOSB) to support the sunset review of sodium silicate, listed at 7 CFR 205.601(l). This report focuses on the uses of sodium silicate in organic crops, as a floating agent in postharvest handling for tree fruit and fiber processing (per the substance's annotation). A full scope technical report on sodium silicate was written for the NOSB in 2011.

Sodium silicate was included on the National List of Allowed and Prohibited Substances (hereafter referred to as the "National List") with the first publication of the National Organic Program (NOP) Final Rule (65 FR 80548, December 21, 2000). The NOSB has continued to recommend its renewal in 2006, 2011, 2015, and 2020 (NOSB, 2006, 2011, 2015, 2020).

As sodium silicate is listed at § 205.601, synthetic forms are allowed. The annotation for sodium silicate specifies that it is "a floating agent in postharvest handling for tree fruit and fiber processing." Sodium silicate increases the density of water, allowing fruits like pears to float.

Background

Description of the substance

Sodium silicate, also known as water glass, is a generic name for chemical compounds with the formula (EPA, 2022):

$$Na_2O \cdot (SiO_2)_x$$

Examples of sodium silicates are:

- sodium metasilicate, Na_2SiO_3
- sodium orthosilicate, Na_4SiO_4
- sodium pyrosilicate, $Na_6Si_2O_7$

These compounds are generally colorless, transparent solids or white powders (Liu & Ott, 2020), and their solubility varies in water depending on their specific composition and pH (Alexander et al., 1954).

Sodium silicate is the most commonly used of the soluble silicates and has many industrial uses (Ebnesajjad, 2011). Despite being known for millennia, scientists are still investigating the chemistry of sodium silicate solutions (Matinfar & Nychka, 2023). These solutions are complex, variable mixtures of water, anionic silicate species, and sodium cations, in dynamic equilibrium (Matinfar & Nychka, 2023). Grades of sodium silicate used in different industrial applications are usually characterized by their silica:alkali (SiO_2:Na_2O) weight ratio (Schweiker, 1978). The molecular weight of silicon dioxide (SiO_2) is 60, while that of sodium oxide (Na_2O) is 62. A ratio of 1.032:1 will have equal amounts of silica and alkali (Lagaly et al., 2003). The SiO_2:Na_2O weight ratio can vary between 0.5:1 (or 1:2) and 3.75:1.[1] Commercial silicate products that have a ratio larger than 1:1 (more silica than alkali) are termed amorphous materials.[2] Crystalline orthosilicates, sesquisilicates, and metasilicates have ratios of 0.5:1, 0.67:1, and 1:1, respectively. Given their high sodium content, these materials with low ratios are known as alkaline silicates. The higher ratio materials are known as siliceous due to their higher silicate composition (Schweiker, 1978).

Sodium silicates can form inorganic polymers in solution (Yang et al., 2008). The solubility of silica is determined by its pH, while the degree of polymerization is determined by pH and concentration (Alexander et al., 1954; Dietzel & Usdowski, 1995; O'Connor, 1961). Silica solubility in water increases dramatically above a pH of 9 (Alexander et al., 1954). When the ratio of SiO_2 to Na_2O exceeds 2:1, and the pH is low, sodium silicate reacts to produce colloidal silica, a type of polymeric silicate (Kupka & Rudolph, 2018).

Use as a floating agent for fruit and fiber in organic production

Sodium silicate is used as a floating agent for tree fruit, especially pears, and fiber. The flotation agent is a salt typically added to the dump tank to raise the solution specific gravity, with the required gravity normally ranging from 1.02 to 1.05, depending on pear cultivar, growing season and the design of the fruit handling system (Sugar & Basile, 2005). In post-harvest processing and handling, producers commonly immerse fruit in water to reduce damage and bruising when it is unloaded from field bins (Bertrand et al., 1979). Pears have a higher density than pure water (Kajiura et al., 1976; Wang, 2004; Wrolstad et al., 1991), which makes them sink in the processing basin. Therefore, producers add floating agents that increase the water density and help pears float. Sodium silicate is used at a starting concentration of 30 g L^{-1} (Barik, 2016).

Currently, sodium silicate is the only synthetic substance specifically allowed for use as a floating agent in organic agriculture [7 CFR 205.601(l)]. Lignin sulfonate was allowed as a floating agent until it was removed from the National List for this purpose in October 2015 (NOSB, 2015).[3]

Use as a bleach stabilizer for fiber processing in conventional production

While not allowed in organic production for this purpose, sodium silicate is the most readily available and widely used bleach stabilizer for use in conventional fiber processing (Abdul & Narendra, 2013). Stabilization is the process of regulation or control of the per hydroxyl ion to prevent rapid decomposition of bleach and to minimize fiber degradation (Abdul & Narendra, 2013). Peroxides used for bleaching degrade under the catalytic influence of metals such as copper, iron, and manganese (Hage & Lienke, 2006). Adding sodium silicate to the bleach solution inactivates these metals and prevents the reactive oxygen species from degrading prematurely (Wuorimaa et al., 2006). Sodium silicate forms a complex with per hydroxyl ions, which are liberated slowly at higher temperatures during the bleaching process (Abdul & Narendra, 2013).

Evaluation Questions for Substances to be used in Organic Crop Production

Classification of the substance

Evaluation Question #1(A): Describe if the substance is extracted from naturally occurring plant, animal, or mineral sources.

Sodium silicate is not extracted from naturally occurring plants, animals, or minerals. It is produced by reacting the minerals silicon dioxide with sodium carbonate or sodium sulfate [see *Evaluation Question #1(B)*, below]. Alternatively, sodium silicate is produced by reacting silicon dioxide and the synthetic chemical sodium hydroxide.

Evaluation Question #1(B): Describe the most prevalent processes used to manufacture or formulate the petitioned substance. Include any chemical changes that may occur during manufacture or formulation of the substance.

Commercial manufacturers use two main processes to produce sodium silicate (Fan et al., 2021; Hossain et al., 2021; Matinfar & Nychka, 2023; Schweiker, 1978):

- the furnace process
- the autoclave process, also known as pressure reaction and hydrothermal process

[1] Often, these ratios will simply be written as a single number (*e.g.,* "0.5" rather than 1:2).
[2] Amorphous materials have a non-periodic, random molecular arrangement, as opposed to crystalline (Keramydas et al., 2020).
[3] Lignin sulfonate remains allowed as a chelating agent or dust suppressant [§ 205.601(j)(4)].

The EPA (2022) states that most sodium silicates in the United States are produced with the furnace method, using silicon dioxide and sodium carbonate as precursors. Authors of an older source state that when sodium carbonate is not available, sodium sulfate can be used as a precursor (Schweiker, 1978).

The pressure reaction, or hydrothermal process, utilizes sodium hydroxide and silicon dioxide as feedstocks and requires high pressure within an autoclave in order to produce sodium silicates (Fan et al., 2021; Schweiker, 1978). We describe these two manufacturing processes in further detail below.

Furnace process

1. In the furnace process, sodium silicate is produced by fusing sand (silicon dioxide) and sodium carbonate (soda ash) inside a furnace at temperatures between 1100°C and 1400°C (see *Equation 1*, below) (Mohamed Ismail et al., 2020; Schweiker, 1978).

$$Na_2CO_3 + x\,SiO_2 \xrightarrow{\Delta} (Na_2O)\cdot(SiO_2)_x + CO_2$$

$$\text{(sodium carbonate)} + \text{(silicon dioxide)} \xrightarrow{\textbf{high heat}} \text{(sodium silicate)} + \text{(carbon dioxide)}$$

Equation 1

When sodium carbonate is not available, it can be replaced by sodium sulfate (Schweiker, 1978). In this case, a reducing agent, primarily carbon in the form of finely divided coal, is also used as a raw material (see *Equation 2*, below) (Schweiker, 1978).

$$Na_2SO_4 + x\,SiO_2 + \frac{1}{2}C \xrightarrow{\Delta} (Na_2O)\cdot(SiO_2)_x + SO_2 + CO_2$$

$$\text{(sodium sulfate)} + \text{(silicon dioxide)} + \text{(carbon)} \xrightarrow{\textbf{high heat}} \text{(sodium silicate)} + \text{(sulfur dioxide)} + \text{(carbon dioxide)}$$

Equation 2

2. The furnace process produces sodium silicate particles that are then dissolved in water at elevated temperature and pressure to produce a silicate solution of the desired density (EPA, 2022; Mohamed Ismail et al., 2020).
3. The solution is then filtered, and sodium hydroxide may be added to obtain the proper silicon dioxide to sodium oxide ratio (EPA, 2022; Schweiker, 1978). As noted in *Description of the substance* (above), this ratio is important because it determines the physical and chemical properties of the product (EPA, 2022).
4. The final solution can then be sold as a solution, sprayed, or drum-dried to produce hydrous powders and granules with various particle sizes, densities, and physical forms (Schweiker, 1978).

Autoclave process, pressure reaction, or hydrothermal method

1. This process utilizes silica flour (or powder), obtained through sand grinding (Schweiker, 1978), and sodium hydroxide as precursors.
2. The materials are heated to about 130 °C to 200 °C in an autoclave under pressure of 12-20 bar (see *Equation 3*, below) (Fan et al., 2021; Schweiker, 1978).

$$2\,NaOH + SiO_2 \xrightarrow{\text{pressure and moderate }\Delta} (Na_2O)\cdot(SiO_2)_x + H_2O$$

$$\text{(sodium hydroxide)} + \text{(silicon dioxide)} \rightarrow \text{(sodium silicate)} + \text{(water)}$$

Equation 3

3. The product is filtered and dried in drum or spray dried yielding hydrous powders (about 20% water) which can readily be redissolved on application (Fawer et al., 1999).

The autoclave method requires 30% of the energy need by the furnace method (Schweiker, 1978).

Other manufacturing processes

The furnace and autoclave methods consume a lot of energy to break the very strong Si-O bond (Laine et al., 2016) and require expensive equipment, resulting in excessive production costs (Qu et al., 2024). Manufacturers have attempted to find ways of reducing the cost and environmental impact of sodium silicate manufacturing, and have mainly focused on using by-products such as condensed silica fume (Rodríguez et al., 2013) and rice husk ash

(Andreola et al., 2020; Kamseu et al., 2017; Tong et al., 2018). The positive effect of the condensed silica fume activator is attributed to the intensification of the production of calcium silicate hydrates and the densifying of the forming pore structure of the activated binder (Živica, 2006). However, these methods are still in the experimental stage and are not yet utilized for large-scale production of sodium silicates. Commercial tire manufacturers use sodium silicates produced from rice husk ash that is generated by biomass power plants (Chan, 2022) or other crop residues (*e.g.,* sugarcane) (Pérez-Casas et al., 2023). The products manufactured with this process are comparable to those produced with conventional silica (Chundawat et al., 2022).

Evaluation Question #1(C): Based on the manufacturing process description, discuss if the substance is classified as synthetic or a nonsynthetic. [7 U.S.C. 6502(21); NOP 5033-1]

Evaluation of sodium silicate against Guidance NOP 5033-1 *Decision Tree for Classification of Materials as Synthetic or Nonsynthetic* (NOP, 2016) is discussed below.

1. *Is the substance manufactured, produced, or extracted from a natural source?*

Commercially produced sodium silicate is not extracted from a natural source. The material is produced from both natural and synthetic precursors, which are then reacted together to form a new substance (sodium silicate).

2. *Has the substance undergone a chemical change so that it is chemically or structurally different than how it naturally occurs in the source material?*

Yes. Under both commonly known manufacturing processes, the material is synthesized by chemically reacting two substances under high temperature or high pressure. The resulting material is chemically different from the source materials.

3. *Is the chemical change created by a naturally occurring biological process, such as composting, fermentation, or enzymatic digestion; or by heating or burning biological matter?*

No. The material is synthesized using chemical reactions driven by high temperatures and pressure not involving biological processes or organic matter.

Thus, sodium silicate, produced by these two methods (furnace process; or autoclave process, pressure reaction, or hydrothermal method) is classified as synthetic according to the decision tree.

Evaluation Question #1(D): Does the substance in its raw or formulated forms contain nanoparticles?

According to NOP Policy Memo 15-2, nanotechnology is conducted at the nanoscale, which is about 1 to 100 nanometers (nm) (USDA, 2015). NOP uses the term "incidental nanomaterials" to refer to substances that are byproducts of other manufacturing (*e.g.,* homogenization, milling) or that occur naturally (USDA, 2015).

Sodium silicate, in its raw form, does not contain engineered nanoparticles. However, it can be a suitable precursor for silicon nanoparticle synthesis (Hwang et al., 2021; Weichold et al., 2008; Zulfiqar et al., 2016). Böschel et al. (2003) used dynamic light scattering and viscosity measurements to characterize three types of aqueous sodium silicate solutions with molar SiO_2:Na_2O ratios of 2.2, 3.3, and 3.9. The solutions were prepared by diluting concentrated commercial products to SiO_2 content between 0.5 and 15 wt%. They noticed the presence of at least three size classes of colloidal particles with radii of 0.4-0.6 nm, 2.5-13 nm, and 75-85 nm, in these solutions, respectively.

Hydrolysis and condensation reactions of sodium metasilicate can produce silica nanoparticles (Navarro & Salas, 2022). This process involves vigorous stirring followed by reflux at 95 °C for one hour to improve suspension stability and avoid precipitation and calcination steps (Navarro & Salas, 2022).[4] Similarly, Chapa-González et al. (2018) obtained silica nanoparticles from Na_2SiO_3 solution by:

1. agitating the solution magnetically
2. heating to 80 °C
3. lowering the pH to 6.0
4. removing the formed sodium salts using ethanol and water
5. centrifuging the solution to separate the materials

Evaluation Question #1(E): Is the substance created using Excluded Methods?

No. The substance is not manufactured using Excluded Methods. Sodium silicate is produced from the reaction of minerals and synthetic substances produced from minerals, without the use of biological organisms.

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[4]Reflux refers to a process where liquid is boiled, and the resulting vapor liquefies and returns to the boiling vessel. Condensers are used to help cool the vapors, typically made from wound tubes.

Harm to human health

Evaluation Question #8: Describe and summarize any reported effects upon human health from use of the petitioned substance [7 U.S.C. 6517(c)(1)(A)(i), 7 U.S.C.6517(c)(2)(A)(i) and 7 U.S.C. 6518(m)(4)].
The last technical report evaluating this substance described health effects associated with exposure to sodium silicate (NOSB, 2011). Our report builds on that information and adds the results from a packhouse study describing the exposure of workers to this material, among other chemicals.

Sodium silicate is an inorganic salt classified by the FDA as 'Generally Recognized as Safe' (GRAS) when it is used as a component of packaging and migrates into food (21 CFR 182.70; §182.90). The FDA also considers sodium silicate to be safe to use:

- in the preparation of steam that will contact food (§ 173.310)
- as a component of cellophane (§ 177.1200)
- as a component of zinc-silicon dioxide matrix coatings for food contact items (§ 175.390)
- as a component of paper and paperboard in contact with aqueous and fatty foods (§ 176.170)

Silica (silicon dioxide) exists in crystalline and non-crystalline (amorphous) forms (Steenland & Ward, 2014). Sodium silicate melts and glasses are not homogenous at the microscopic scale and contain non-crystalline microgroups (Davidenko et al., 2014). According to OSHA, workers who inhale crystalline silica dust particles are at increased risk of developing serious silica-related diseases (Occupational Safety and Health Administration, 2024). On the other hand, amorphous silica is less toxic and presents less exposure hazards than crystalline forms of silica (such as quartz) (Steenland & Ward, 2014). Sodium silicate does not cause pulmonary silicosis (Mallinckrodt Baker Inc., 2007).

Material safety data sheets indicate that the sodium silicate can be absorbed into the body by inhalation and by ingestion (ILO & WHO, 2021). The aerosol, which is not applicable to the petitioned use, is irritating to the eyes, skin and respiratory tract. While evaporation of the material at 20°C is negligible, a harmful concentration of airborne particles can be reached quickly on spraying (ILO & WHO, 2021). PubChem website mentions the following human health hazards (PubChem, 2024):

- harmful if swallowed
- causes severe skin burns and eye damage
- causes skin irritation
- causes serious eye damage
- causes serious eye irritation
- may cause respiratory irritation

Health Canada compiled health effects of sodium silicates to conclude acute toxicity levels (Workplace Hazardous Materials Bureau, 2023). The classifications of silicic acid, sodium salt, depend on the concentration and molar ratio (MR) of SiO_2:Na_2O, which may vary from 1.5-4.0. The reported LD_{50} (for rabbits) was > 4,640 mg kg^{-1} (MR 2.0 and 2.4). The available data do not meet the classification criteria for dermal acute toxicity. The available data meet the classification criteria for "Skin Corrosion – Category 1" for silicic acid, sodium salt, at MR 0.5 (≥90%), MR 1.6 (≥52%), and MR 2.4 (≥44%); and "Skin Irritation". As with skin corrosion and irritation, the classification of eye irritation and serious eye damage depends on the MR and concentration of the substance (Workplace Hazardous Materials Bureau, 2023).

Effects on human health in fruit packing facilities
Little information exists on the effects on human health from exposure to sodium silicate in fruit packhouses. Packhouse workers might be exposed to sodium silicate on their skin or eyes. The National Institute for Occupational Safety and Health, published the results of a health study involving 369 workers in nine apple and pear packhouses in northwestern Oregon (Apol & Lybarger, 1979). They observed that 18% of the workers had a history of skin rash associated with work, and 10% had an observable rash on exposed skin surfaces. The same researchers found 19 potential sensitizing and/or irritating chemicals used in the fruit preparation process, including sodium silicate, which they classified as a skin irritant without specifically identifying it as a reason for the rash.

Diluted solutions of sodium silicate are strong alkaline irritants because of their high pH (Mallinckrodt Baker Inc., 2007). Tanaka et al. (1982) observed an immediate wheal (a swollen mark) formation 15 minutes after a scratch test was performed with 20% sodium silicate. Since this reaction was not observed on other control subjects, the authors hypothesized that the coexistence of an urticarial reaction with primary irritant contact dermatitis might be of critical importance in some way in the development of ulcerative dermatitis evoked by sodium silicate in this case (Tanaka et al., 1982).

The irritation severity of sodium silicate depends on its concentration (Elmore & Cosmetic Ingredient Review Expert Panel, 2005). Sodium metasilicate in a detergent (at 37% concentration) mixed with water caused severe skin irritation when tested on intact and abraded human skin, but 6%, 7%, and 13% sodium silicate were negligible skin irritants to intact and abraded human skin (Elmore & Cosmetic Ingredient Review Expert Panel, 2005). Sodium silicate (10% of a 40% aqueous solution) was negative in a repeat-insult predictive patch test in humans. The same aqueous solution of sodium silicate was considered a mild irritant under normal use conditions in a study of cumulative irritant properties (Elmore & Cosmetic Ingredient Review Expert Panel, 2005). As these ingredients have limited dermal absorption and sodium metasilicate is a GRAS direct food substance, a panel of experts deemed the ingredients safe for use in cosmetic products in the practices of use and concentration described in this safety assessment, when formulated to avoid irritation.

According to one manufacturer of sodium silicate (Carolina Biological Supply Company, 2014), workers exposed to this material should:

- Avoid skin contact by wearing chemically resistant nitrile gloves, an apron and other protective equipment depending upon conditions of use.
- Workers should inspect gloves for chemical break-through and replace them at regular intervals.
- Protective equipment should be cleaned regularly.
- Workers should wash their hands and other exposed areas with mild soap and water before eating, drinking, and when leaving work.

Absorption of sodium silicate in the human body

We were not able to find information related to residues of sodium silicate solutions on fruits as a result of petitioned use.

Silicon is the third most abundant trace element in the human body, after iron and zinc (Farooq & Dietz, 2015; Jugdaohsingh, 2007; McLean, 2021). How the body absorbs silicon is not well understood. In human and animal studies, researchers reported increases in serum silicate concentration or excretion of silicon in urine after ingesting silicates, which suggests silicates are partially absorbed in the gastrointestinal tract (Jugdaohsingh, 2007). In contrast, according to a 2018 re-evaluation of silicon dioxide (E 551) by the European Food Safety Authority panel, this material is considered safe as a food additive (EFSA Panel on Food Additives and Nutrient Sources added to Food (ANS) et al., 2018). They concluded that the available data indicates that this compound is poorly absorbed by the body, thus posing no major health concern at typical consumption levels (EFSA Panel on Food Additives and Nutrient Sources added to Food (ANS) et al., 2018).

Jugdaohsingh (2007) notes that accumulating evidence over the last 30 years strongly suggests that dietary silicon is important for the health of connective tissues, bones, cartilage, tendons, and joints. Silicon also plays a vital role in the production and elasticity of collagen, a major component of connective tissue (McLean, 2021). It is also necessary for the formation of glycosaminoglycans, such as hyaluronic acid and chondroitin sulfate, which, together with collagen, form the extracellular matrix of connective tissue (McLean, 2021). Based on research performed on rabbits, Loeper et al. (1984) and Abraham (2005), estimated that the amount of silicon required for a 70-kg person is 35 mg of silicon per day, in the form of bioavailable and bioactive mineral silicates. Rondanelli (2021) studied extrapolations from animal and human research models and suggests that a daily silicon intake of around 25 mg is necessary to promote bone health.

Alternatives

Evaluation Question #9: Describe all natural (non-synthetic) substances or products which may be used in place of a petitioned substance [7 U.S.C. 6517(c)(1)(A)(ii)]. Provide a list of allowed substances that may be used in place of the petitioned substance [7 U.S.C. 6518(m)(6)].

The last technical report evaluating this substance described alternative allowed substances such as lignin sulfonate, potassium phosphate and potassium pyrophosphate (NOSB, 2011). However, lignin sulfonate was removed as an organic floating agent by the NOP as of 2017 (NOSB, 2015).

In order for pears and other similar fruit to float in water, the density of the liquid must be adjusted to a specific gravity of 1.05 or larger (Sugar & Basile, 2005). Other potential floating agents that can increase the density of processing water are (Barik, 2016; Sugar & Basile, 2005):

- sodium carbonate
- sodium sulfate
- potassium carbonate
- calcium chloride
- potassium phosphate

We found no information on how common these alternative floating agent salts are.

In NOP 5023: *Guidance, Substances Used in Post-Harvest Handling of Organic Products* (USDA, 2016), the NOP describes how to consider input materials used for post-harvest processing steps, such as washing, cleaning, sorting, packing, cooling and storing raw agricultural products. We used criteria in this guidance document to identify what alternatives could be allowed.

Calcium chloride [§ 205.605(a)(7)] and sodium carbonate [7 CFR 205.605(a)(27)] are nonsynthetic, and also included on the National List, as 'nonagricultural (nonorganic) substances allowed as ingredients in or on processed products labeled as "organic" or "made with organic (specified ingredients or food group(s))."' Therefore, these materials would be allowed for use as floating agents.

Sodium sulfate can be either synthetic or nonsynthetic (Garrett, 2001). Nonsynthetic sodium sulfate is produced from natural minerals deposited in lake beds or dissolved in lake water, such as Great Salt Lake in Utah (Kostick, 2004). Sodium sulfate is a specific gravity enhancer for pears and is used at a starting concentration of 30 g L^{-1} (Barik, 2016). It is practically non-toxic, with an LC_{50} (48hr) of 1190 mg L^{-1} for *Daphnia magna* (a small planktonic crustacean). The FDA has classified this chemical as an indirect food additive due to being poorly absorbed into the gastrointestinal tract (Barik, 2016). Nonsynthetic sodium sulfate is also allowed for use as a floating agent in post-harvest processing per the instructions in NOP 5023: *Guidance, Substances Used in Post-Harvest Handling of Organic Products* (USDA, 2016).

While potassium carbonate is a synthetic, it is also present on 205.605(b) without annotation. Therefore, it would also be allowed for use in post-harvest handling as a floating agent. It is usually used at a starting concentration of 27 g L^{-1} (Barik, 2016). It is slightly toxic to rats with an oral LD_{50} of 1870 mg kg^{-1}. It is also slightly toxic to aquatic organisms, with an LC_{50} (96hr) of 68 mg L^{-1} for rainbow trout and an EC_{50} (48 hr) of 430 mg L^{-1} for *Daphnia magna*) (Barik, 2016).

When used as floating agents, the starting concentrations of potassium carbonate and sodium sulfate are 27,000 ppm and 30,000 ppm, respectively (Barik, 2016). The maximum use concentration for calcium chloride is 2200 mg L^{-1} (Barik, 2016). We were not able to find the specific concentration needed when sodium carbonate is used as a flotation aid.

We found limited research evaluating the performance of the aforementioned alternatives. Sugar and Basile (2005) conducted pear floatation experiments using different compounds and durations, lasting from 15 to 60 minutes, at two different temperature ranges of 2-5°C and 15-20°C. They found that fruit treatment with calcium chloride, potassium carbonate, sodium carbonate, or sodium sulfate resulted in no damage to the fruits when the process was done at either temperature range. They also reported that injury was moderate to severe when using potassium phosphate or calcium chloride for 45- or 60-minute durations.

Evaluation Question #10: Describe any alternative practices that would make the use of the petitioned substance unnecessary [7 U.S.C. 6518(m)(6)].

The last Technical Report evaluating this material suggested decreasing fruit injury through reducing the speed of the unpacking and dumping process (NOSB, 2011). Since that report, engineering developments to reduce fruit injury during fruit unloading have occurred, as detailed below.

While there were some studies comparing different flotation salts (*e.g.,* Sugar & Basile (2005)), we were not able to find any studies that compare the alternative practices below with sodium silicate solution.

The recent advances in pear genetics and processing techniques have reduced the need for floating agents (Organic Trade Association, 2014), leading to the removal of lignin sulfonate as an approved organic floating agent in 2017 (82 FR 31241, July 06, 2017) (NOSB, 2015).

Since sodium silicate and similar compounds are used to help fruits float in immersion water dumps, fruit unloading systems that do not rely on this method would make using sodium silicate unnecessary. Switching to a soft-landing, dry-drop system could be an alternative. Celik (2017) tested the dry drop method using different impact platforms at different drop heights and orientations to evaluate the bruises of the 'Ankara' variety of pears. The results revealed that dropping the fruit on a rubber-based platform with a 45-degree orientation at one-meter height minimized bruising.

A European processing company designed apple and pear processing lines that use a photocell to precisely dispense fruit into the sorter. The line also has a foam-coated belt that envelops the fruit to prevent spillage during rotation and to reduce bruising (Green Sort, 2024).

Besides improvements to the unloading system, padded picking containers are another alternative that could minimize bruises during harvest (Ait-Oubahou et al., 2019). Packaging pears in individual polyethylene film bags can also reduce bruising during transit between packhouse and markets (Slaughter et al., 1998).

Report Authorship

The following individuals were involved in research, data collection, writing, editing, and/or final approval of this report:

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All individuals are in compliance with Federal Acquisition Regulations (FAR) Subpart 3.11—Preventing Personal Conflicts of Interest for Contractor Employees Performing Acquisition Functions.

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