Magnesium Sulfate
Handling/Processing

Identification of Petitioned Substance

Chemical Names:
Magnesium sulfate

Other Name:
Epsom salts
Bitter salts
Magnesium sulfate anhydrous
Sulfuric acid, magnesium salt

Trade Names:
None

CAS Numbers:
7487-88-9 (magnesium sulfate anhydrous)
18939-43-0 (sulfuric acid magnesium salt)
14168-73-1 (monohydrate)
10034-99-8 (heptahydrate)

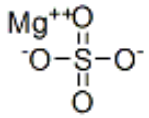
Other Codes:
050503 (USEPA PC Code [U.S. EPA 2010])
231-298-2 (EINECS)

Characterization of Petitioned Substance

Composition of the Substance:

The compound magnesium sulfate (anhydrous) contains magnesium, sulfur, and oxygen, $MgSO_4$. Magnesium sulfate also occurs in hydrated forms ($MgSO_4xH_2O$), including monohydrate and heptahydrate. The monohydrate and heptahydrate forms contain one and seven H_2O molecules, respectively (ChemIDplus Lite, 2011; Kawamura and Rao, 2007). Magnesium sulfate is considered ionic because a metal (magnesium) and a non-metal (sulfate) are bonded. Within the sulfate molecule, there is a covalent bond between the sulfur and oxygen atoms. The molecular structure of anhydrous magnesium sulfate is shown in Figure 1.

Figure 1. Molecular Structure of Magnesium Sulfate (Anhydrous)



Properties of the Substance:

Magnesium sulfate is an odorless solid that is generally found as needle-like colorless crystals or as a white crystalline powder (Kawamura and Rao, 2007). The substance is considered very soluble in boiling water. Different forms of magnesium sulfate have different molecular weights and differ in their solubility in water. The physical and chemical properties of magnesium sulfate are presented in Table 1. The properties presented in Table 1 apply to all three forms of magnesium sulfate (ie. monohydrate, heptahydrate, and anhydrous) unless specifically noted.

Specific Uses of the Substance:

Magnesium sulfate has a wide variety of uses in agriculture, food processing, personal care products, and medicine. In agriculture, magnesium sulfate is added to soil to correct for magnesium deficiency (Kawamura and Rao, 2007) or to improve the uptake of nitrogen and phosphorous by crops (Epsom Salt Council, 2009). Crops that heavily depend on magnesium-rich soil include potatoes, peppers, tomatoes, and roses. Magnesium sulfate also is commonly added to potted plants. The high solubility of magnesium sulfate makes it an ideal compound for adding magnesium to the soil.

Table 1. Physicochemical Properties of Magnesium Sulfate

Physical or Chemical Property	Value
Physical State	Solid
Appearance	White crystalline powder or needle-like colorless crystals
Odor	Odorless
Taste	Bitter, salty, cooling
Molecular Weight	120.36 (anhydrous); 138.38 (monohydrate); 246.47 (heptahydrate)
Boiling Point	NA
Melting Point	2,055 °F or 1124 °C
Solubility in Water	anhydrous: 269 g/L (0 °C), 255 g/L (20 °C) heptahydrate: 710 g/L (20 °C)
Vapor Pressure	< .01 mm Hg at 20 °C
Density	2.66 g/cm^3 (anhydrous); 2.445 g/cm3 (monohydrate); 1.68 g/cm^3 (heptahydrate)

Source: Chemical Book, 2010

In food processing, magnesium sulfate is used as a flavor enhancer in bottled water and as a firming agent in soybean curd. Magnesium sulfate also is used as a nutrient, primarily in salt-replacer products, dietary supplements, carbonated diet soft drink beverages, sports drinks, and enhanced (fortified) water beverages. It is used as a fermentation and malting aid in beer, ale, and other malt beverages (Kawamura and Rao, 2007).

Magnesium sulfate has many human medicinal uses. Injections of magnesium sulfate can be used as an anticonvulsant to control and prevent seizures in children suffering from acute nephritis. Magnesium sulfate injections can help lower the blood pressure of pregnant females suffering from preeclampsia and prevent pre-term labor. Asthma attacks can be treated with magnesium sulfate. When taken intravenously, it reduces the resistance within the airways and facilitates normal airflow. Magnesium sulfate can act as a laxative when taken orally and is used to relieve constipation (Adnani, 2010).

Epsom salt, a common form of magnesium sulfate, is easily dissolved in water and is used to relieve muscle aches and pains as well as to reduce itching and inflammation. It is commonly added to bath water and used by individuals suffering from joint pain (Epsom Salt Council, 2009).

Magnesium sulfate also has a number of veterinary uses. It acts as an anticonvulsant, laxative, bronchodilator, electrolyte replacement aid with hypomagnesaemia, and may be used to treat cardiac arrhythmias. Specifically in swine, magnesium sulfate is administered to treat malignant hypothermia (Dodman, 2010).

Magnesium sulfate can be added to livestock feed to treat conditions stemming from a magnesium deficiency.[1] Lactation tetany or grass tetany occurs when ruminants graze on grasses low in magnesium or suffer from a low level of magnesium in their diet. The condition is often realized after cases of sudden death in cattle. Clinical signs include convulsions and muscular spasms, and death may occur due to respiratory failure (Organic Livestock Research Group, 2000). If livestock are feeding on pastures with high potassium levels, which interfere with the uptake of magnesium by grasses, supplemental magnesium sulfate may be needed (Epsom Salt Council, 2009).

[1]There are two types of veterinary hypomagnesaemia (i.e., magnesium deficiency) recognized clinically—hypomagnesaemic tetany in calves, which appears to be due to a straightforward deficiency of magnesium in the diet, and lactation tetany (or grass tetany), where there may be a partial dietary deficiency but in which nutritional and metabolic factors reduce the availability or increase the body loss of magnesium (Organic Livestock Research Group, 2000).

Magnesium capsules can be inserted into the rumen of livestock and after a one-week stabilization period, the capsule begins to release magnesium for up to 80 days. This capsule is recommended for use in high-risk or valuable animals. It is advised that, in addition to the capsule, the livestock be fed hay in order to increase absorption of the magnesium (Champness, 2007). If immediate treatment for magnesium deficiency is needed, magnesium sulfate can be administered intravenously (Papich, 2007).

A magnesium lick can also be provided for livestock to increase the amount of magnesium in the diet. Because magnesium sulfate is not palatable, molasses is added to the magnesium lick to encourage cattle's use. Licks are generally 80 percent molasses and 20 percent magnesium sulfate and are considered to be less reliable than supplementing feed with magnesium (Harris, 2005).

Magnesium sulfate, as Epsom salts, can be used to treat inflammation and abscesses in livestock. Soaking the affected area in a mixture containing Epsom salt and water can reduce signs of inflammation (Epsom Salt Council, 2009).

Approved Legal Uses of the Substance:

Magnesium sulfate is currently included on the National List as a synthetic substance allowed for use in organic crop production as a soil amendment if a magnesium deficiency is documented (7 CFR 205.601). Magnesium sulfate is also included on the National List as a synthetic substance allowed for use in livestock production when used as a disinfectant, sanitizer, or in medical treatments as applicable (7 CFR 205.603). In addition, the National List states that magnesium sulfate is allowed for use as a nonsynthetic ingredient "in or on processed products labeled as 'organic' or 'made with organic (specified ingredients or food group[s])' (7 CFR 205.605).

Magnesium sulfate is considered by the Food and Drug Administration (FDA) as generally recognized as safe (GRAS) when used as a nutrient or dietary supplement (21 CFR 184.1443). The Food and Nutrition Board, an organization established by the Institute of Medicine that provides guidance to the public and policy makers on nutrition and food sciences, has recommended that cereal grain products be fortified with magnesium in response to the potential risk of deficiency among significant segments of the population (FAQS, 2010).

Multiple products containing magnesium sulfate are approved by the FDA for medicinal use in humans. Magnesium sulfate can be administered via injection or can be orally ingested (U.S. FDA, 2010). In 2010, the FDA approved a product containing magnesium sulfate, which acts a colon cleanser in preparation for a colonoscopy (Braintree Laboratories, 2010).

The FDA allows magnesium sulfate to be prescribed legally by veterinarians as an extra-label drug. An extra-label drug is defined as the veterinary use of a drug in a manner for which it was not approved.[2] No specific veterinary formulations of magnesium sulfate are available. The National Lists allows the addition of magnesium sulfate to animal feed according to 7 CFR 205.603. Intravenous injection is used when treatment is required immediately; however, adding magnesium sulfate to animal feed offers an alternative in less urgent situations.

Under the authority of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), the EPA exempts residues of magnesium sulfate—used as a solid diluent, carrier, or safener—from the requirement of a tolerance when used in accordance with good agricultural practices as inert (or occasionally active) ingredients in pesticide formulations applied to pre- and post-harvest agricultural crops (40 CFR 180.1001[c]). No pesticide products containing magnesium sulfate as an active ingredient are currently registered with the EPA.

[2]Veterinarians may use drugs in an extra-label manner under authority of the Animal Medicinal Drug Use Clarification Act, which became effective in December 1996.

Action of the Substance:

Magnesium, found naturally in some foods, is an essential nutrient for health. Magnesium is essential for muscle and nerve function, heart rhythm and blood pressure, immune system health, bone strength, blood sugar level regulation, and energy metabolism and protein synthesis. Half of all magnesium in the body is found in the bone and only 1% is circulated in the blood. The remainder is contained in the cells and tissues. Magnesium sulfate is often added to food or produced in supplement form to provide additional magnesium to the majority of adults in the US that do not obtain the recommended amount from their diet (NIH, 2009).

Magnesium sulfate acts in a variety of ways in its various non-nutritive applications. It works as an enzyme stabilizer, coagulator, fermenting aid, water hardener, and flavor enhancer. These processes are described further in the Evaluation Questions section (Evaluation Questions 5, 6, and 7). For example, in tofu production, magnesium sulfate is added to soybean curd to ferment and firm the tofu (described in more detail in Evaluation Question 11).

Combinations of the Substance:

Magnesium sulfate is sometimes combined with other coagulators in the production of tofu. Natural nigari (derived from seawater) is a popular coagulant in Japan that contains magnesium sulfate and a number of other minerals. Nigari is predominantly magnesium chloride, with much smaller amount of magnesium sulfate, sodium chloride, potassium chloride, and other minerals. However, natural nigari is not approved by the FDA for use in the US and is not generally recognized as safe (GRAS). Dry mixtures of coagulants are sometimes found on the market as well (e.g., mixtures of lactone and magnesium sulfate) to combine the desirable effects of a number of coagulants (Shurtleff and Aoyagi, 2000).

Status

Historic Use:

Historically, magnesium sulfate has had a wide variety of uses in construction, manufacturing/processing, personal care products, food processing, medicine, and agriculture, and many of these uses are summarized by Giles Chemical (2008). As a building material, magnesium sulfate has been used as a setting agent and an extender in various adhesive products, as a component of cement for roofing panels and wallboard, and as an ingredient in flame retardant coatings and brick.

In pulp and paper manufacturing, magnesium sulfate acts as a stabilizing agent for oxygen and peroxide bleaching as well as for dyes. Magnesium sulfate precipitates heavy metals out of water during plating processes and acts as a coagulating agent in latex and rubber processing and a weighting agent in leather processing. In water treatment, magnesium sulfate removes heavy metals and acts as a water hardener (Giles Chemical, 2008).

In cosmetic hair products, magnesium sulfate acts as a hair wave neutralizer and as a product to increase hair density. In laundry detergents, magnesium sulfate is used as an anti-caking agent, foam stabilizer, viscosity control agent, and as a source for synthetic magnesium water hardness (Giles Chemical, 2008).

Fermentation processes are aided by magnesium sulfate, which is a source of magnesium ion in yeast and antibiotic production. Magnesium sulfate is an enzyme stabilizer in breweries and in cheese and high-fructose corn production (Giles Chemical, 2008).

Magnesium sulfate has many human medicinal uses (also discussed in Specific Uses of the Substance). Injections of magnesium sulfate can be used as an anticonvulsant to control and prevent seizures in children suffering from acute nephritis. Magnesium sulfate injections can also lower the blood pressure of pregnant females suffering from preeclampsia and prevent pre-term labor. Asthma attacks can be treated

with magnesium sulfate. When taken intravenously, magnesium sulfate reduces the resistance within the airways and facilitates normal airflow. Magnesium sulfate can act as a laxative when taken orally and is used to relieve constipation (Adnani, 2010).

Epsom salt, a common form of magnesium sulfate, is an analgesic soaking agent (Giles Chemical, 2008). It is easily dissolved in water and is used to relieve muscle aches and pains as well as reduce itching and inflammation. It is commonly added to bath water and used by individuals suffering from joint pain (Epsom Salt Council, 2009).

In veterinary medicine, magnesium sulfate acts as an anticonvulsant, laxative, bronchodilator, electrolyte replacement aid with hypomagnesaemia, and has been used for the treatment of cardiac arrhythmias. Specifically in swine, magnesium sulfate is administered to treat malignant hypothermia (Dodman, 2010).

In accordance with 7 CFR 205.601, magnesium sulfate may be used in combination with synthetic or non-synthetic crop fertilizers to act as a plant or soil amendment. Epsom salt, a synthetic form of magnesium sulfate, is also used in this way (OMRI, 2010). For plants, magnesium sulfate improves nitrogen and phosphorous uptake, helps seeds to germinate, increases chlorophyll production, and aids in the production of flowering (Epsom Salt Council, 2009). In scenarios where immediate treatment is needed, livestock may be injected intravenously with a solution of magnesium sulfate.

Magnesium sulfate is added as a source of magnesium to livestock feed, particularly for cattle and sheep. Supplemental magnesium is necessary when livestock are feeding on pastures with high potassium levels; high potassium interferes with the uptake of magnesium by grasses (Epsom Salt Council, 2009). It also may be added to livestock feed for its laxative properties.

OFPA, USDA National Organic Program Final Rule:

Magnesium sulfate is currently included on the National List of Allowed and Prohibited Substances (hereafter referred to as the National List) as a synthetic substance allowed for use in organic crop production (25 CFR 205.601). Specifically, magnesium sulfate is approved for use as a plant or soil amendment when soil deficiency has been documented. The National List also includes magnesium sulfate as a synthetic substance allowed for use in organic livestock production as a disinfectant, sanitizer, or in medical treatments as applicable (25 CFR 205.603). Non-synthetic sources of magnesium sulfate are allowed as ingredients labeled as "organic" or "made with organic (specified ingredients or food group[s])" (25 CFR 205.605).

International:

The Canada Food Inspection Agency, Food and Drug Regulations (last modified in 2009), permit the use of magnesium sulfate as a soil amendment and crop nutrient when a soil deficiency has been documented. Acceptable forms of magnesium sulfate include mined kieserite and natural or synthetic Epsom salt. Mined sources of magnesium sulfate are permitted for use in healthcare products and production aids. Non-synthetic sources of magnesium sulfate are classified as a food additive. Sulfates produced using sulfuric acid are prohibited (Canadian General Standards Board, 2009).

The European Economic Community (EEC) Council Regulation permits the use of non-synthetic magnesium sulfate (kieserite) as a fertilizer and soil conditioner (Annex I, EC No. 889/2008). Non-synthetic magnesium sulfate is also permitted as a feed material of mineral origin (Annex V, EC No. 889/2008). Magnesium sulfate is not listed as an approved organic processing agent.

International Federation of Organic Agriculture Movements (IFOAM) lists magnesium sulfate as a permissible mineral for use as a fertilizer and soil amendment agent (KRAV, 2001). Approved mineral fertilizers can only be applied in their natural form (i.e., without any further processing to increase solubility, with the exception of grinding).

Evaluation Questions for Substances to be used in Organic Handling

Evaluation Question #1: Describe the most prevalent processes used to manufacture or formulate the petitioned substance. Further, describe any chemical change that may occur during manufacture or formulation of the petitioned substance when this substance is extracted from naturally occurring plant, animal, or mineral sources (7 U.S.C. § 6502 (21)).

Magnesium sulfate can be produced by recovery of the mineral kieserite (magnesium sulfate monohydrate) or epsomite (magnesium sulfate heptahydrate) from natural sources. Open-pit mines are used to recover mineral forms of magnesium sulfate. These products then undergo a process of dehydration to form anhydrous $MgSO_4$ and subsequent purification (HSDB, 2003). The substance is characterized as synthetic.

The synthetic form of magnesium sulfate is produced by a chemical reaction in which magnesite ore (consisting of $MgCO_3$) or magnesium hydroxide (obtained from seawater) is ignited to produce magnesium oxide. Magnesium oxide is then reacted with sulfuric acid, producing magnesium sulfate. To produce a high grade of purity, the magnesium sulfate is re-crystallized and separated from the parent solution (Kawamura and Rao, 2007).

Evaluation Question #2: Is the substance synthetic? Discuss whether the petitioned substance is formulated or manufactured by a chemical process, or created by naturally occurring biological processes (7 U.S.C. § 6502 (21)).

Magnesium sulfate can be obtained from naturally-occurring sources or manufactured by a chemical process. OMRI-listed products are sold as either solid (crystal) or liquid forms of synthetic magnesium sulfate (OMRI, 2010).

Several mineral forms of magnesium sulfate are recovered from the ground. The magnesium sulfate generally found in nature is in the hydrated form (i.e., contains water). Specifically, magnesium sulfate monohydrate and magnesium sulfate heptahydrate occur in nature as the minerals kieserite and epsomite, respectively (Kawamura and Rao, 2007).

As discussed in the response to Evaluation Question #1, the synthetic form of magnesium sulfate is produced by a chemical reaction in which magnesite ore (containing $MgCO_3$) or magnesium hydroxide ($Mg(OH)_2$) is ignited to produce magnesium oxide. Magnesium oxide is then reacted with sulfuric acid, producing magnesium sulfate. To produce a high grade of purity, the magnesium sulfate is re-crystallized and separated from the parent solution (Kawamura and Rao, 2007).

Evluation Question #3: Provide a list of non-synthetic or natural source(s) of the petitioned substance (7 CFR § 205.600 (b) (1)).

Magnesium sulfate can occurs naturally as the minerals epsomite ($MgSO_4 \cdot 7H_2O$) and kieserite ($MgSO_4 \cdot H_2O$).

Evaluation Question #4: Specify whether the petitioned substance is categorized as generally recognized as safe (GRAS) when used according to FDA's good manufacturing practices (7 CFR § 205.600 (b)(5)). If not categorized as GRAS, describe the regulatory status. What is the technical function of the substance?

Magnesium sulfate is categorized as generally recognized as safe (GRAS) when used as a nutrient or dietary supplement (21 CFR 184.1443).

Evaluation Question #5: Describe whether the primary function/purpose of the petitioned substance is a preservative. If so, provide a detailed description of its mechanism as a preservative (7 CFR § 205.600 (b)(4)).

This substance is not used as a preservative. It is used in food as a nutrient, coagulator, flavor enhancer, fermentation and malting aid, and an enzyme stabilizer.

Evaluation Question #6: Describe whether the petitioned substance will be used primarily to recreate or improve flavors, colors, textures, or nutritive values lost in processing (except when required by law) and how the substance recreates or improves any of these food/feed characteristics (7 CFR § 205.600 (b)(4)).

The addition of magnesium sulfate to food enhances flavors and textures and is also used for its nutritive value. Magnesium sulfate is added to foods or produced as a nutritional supplement as a source of magnesium. Magnesium, found naturally in some foods, is an essential nutrient for health; it helps with muscle and nerve function, heart rhythm and blood pressure, immune system health, bone strength, blood sugar level regulation, and energy metabolism and protein synthesis. Many adults in the US do not get the recommended amount of magnesium through their diets (NIH, 2009). Magnesium sulfate is approved for use as a flavor enhancer as defined in 170.3(o)(11); a nutrient supplement as defined in 170.3(o)(20); and a processing aid as defined in 170.3(o)(24) of the Code of Federal Regulations for Food and Drugs (21 CFR 184.1443).

Evaluation Question #7: Describe any effect or potential effect on the nutritional quality of the food or feed when the petitioned substance is used (7 CFR § 205.600 (b)(3)).

Magnesium sulfate supplements contain about 10% magnesium, as opposed to other magnesium supplements (e.g., magnesium oxide), which can contain up to 60% magnesium. According to Morris et al. (1987), magnesium sulfate administered orally has limited bioavailability that varies in individual people. Magnesium sulfate has reduced bioavailability when it is covered in an enteric coating. Bioavailability of magnesium from food sources also varies; absorption from almonds was considered equal to a soluble magnesium acetate supplement (Fine et al., 1991). Based on this information, it appears the addition of magnesium sulfate to food products provides a potential source of magnesium and inorganic sulfate to the body, although the relative absorbed doses will vary based on the route of administration and inter-individual variability.

The available literature identified only one reaction magnesium sulfate may have with food products. In particular, magnesium compounds may bind with fiber and some fiber-associated compounds with chelating ability (e.g., phytate, polyphenols and organic acids) (Kawamura and Rao, 2007).

Evaluation Question #8: List any reported residues of heavy metals or other contaminants in excess of FDA tolerances that are present or have been reported in the petitioned substance (7 CFR § 205.600 (b)(5)).

Impurities in magnesium sulfate are reportedly limited to those in the raw material. Potential contaminants include zinc, selenium, arsenic, iron, lead, and chloride; and small concentrations of other acidic and alkaline materials including sulphites and oxides (Kawamura and Rao, 2007). Information on the specific levels of these contaminants in the final product could not be obtained. However, the fact that that magnesium sulfate meets the specifications of the Food Chemicals Codex suggests that levels do not exceed the accepted reference standards for metals and other contaminants in food ingredients.

Evaluation Question #9: Discuss and summarize findings on whether the manufacture and use of the petitioned substance may be harmful to the environment or biodiversity (7 U.S.C. § 6517 (c) (1) (A) (i) and 7 U.S.C. § 6517 (c) (2) (A) (i)).

According to the U.S. Geological Survey (USGS), while there are sources of magnesium sulfate in the United States, it is not mined in this country. Therefore, it does not appear that mining-related environmental impacts are applicable in the United States (Kramer, 2001).

In industrial plants obtaining magnesium from seawater, the water is returned to the ocean after the element is removed. According to the USGS, the effluent causes minimal changes to the ocean environment and none of the discharges from either natural or synthetic magnesia plants has a noxious quality (Kramer, 2001).

In the presence of water molecules, magnesium sulfate does not undergo hydrolysis, a process in which water molecules split apart existing molecules into two parts (Bodek et al., 1988). This means that magnesium sulfate will remain in the water in its original form.

Evaluation Question #10: 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)).

While dietary doses of magnesium generally do not pose health risks, pharmacologic doses may cause adverse effects. Symptoms of hypermagnesia from high doses of magnesium in supplements or medicines are similar to magnesium deficiency and include mental changes, nausea, abdominal cramping, diarrhea, appetite loss, muscle weakness, difficulty breathing, low blood pressure, and irregular heartbeat (NIH, 2009).

Magnesium sulfate has many human medicinal uses (see Specific Uses of the Substance). It is has exhibited laxative properties when ingested orally and is an effective anticonvulsant when administered via injection. Before using magnesium sulfate, it is important to check that renal function is adequate as an accumulation of magnesium ions in body fluids can cause toxic effects, including heart changes, cyanosis, and flaccid paralysis (Gilman et al., 1980).

Toxic effects have been observed in the neonates of women that have been administered an incorrect dose of magnesium sulfate for conditions such as preeclampsia. Effects include depression of cardiac function and of reflexes, flushing, sweating, hypotension, flaccid paralysis, hypothermia, and circulatory collapse. These symptoms can proceed to fatal respiratory paralysis (McEvoy, 2002). There is also an increased risk in blood loss in mothers administered magnesium sulfate injections (Kynczl-Leisure et al., 1996). Magnesium is known to cause vasodilation, which causes the symptoms of flushing and sweating in low doses and circulatory collapse in higher toxic doses (Micromedex, 2010).

Evaluation Information #11: Provide a list of organic agricultural products that could be alternatives for the petitioned substance (7 CFR § 205.600 (b)(1)).

No organic agricultural products are available as alternatives for the organic handling/processing uses of magnesium sulfate allowed by the National List. The information provided below describes non-agricultural (nonorganic) products that are potential alternative for these uses.

A number of alternative coagulants can be used in tofu production. Calcium citrate, calcium chloride (from seawater), calcium sulfate (the mined form; also known as gypsum powder), and glucono-delta-lactone (GDL; production with bromine water prohibited) all appear on the National List.

Research indicates that coagulants of different types will affect the texture, chewiness, color, and other properties of the final tofu product. Although the property preferences may dictate the coagulant chosen, some advocate that calcium chloride is the best option in American tofu because it has high calcium content, the fastest reactant coagulation time, an excellent flavor, and it is generally recognized as safe

(GRAS). Calcium sulfate, another well-performing coagulant, is a popular tofu coagulant in Japan. It is one of the least expensive coagulants in the U.S., producing the cheapest tofu. It is obtained from mining and is not chemically processed or refined. Furthermore, it contains less than 10 ppm of heavy metal contaminants and is generally recognized as safe (Shurtleff and Aoyagi, 2000). GDL is an acid coagulant rather than a salt, and thus is best suited for soft, silken tofu. It is widely used for other applications in the food industry. However, GDL is not on the GRAS list (Shurtleff and Aoyagi, 2000).

Two magnesium supplements appear on the National List: magnesium chloride and magnesium carbonate. Magnesium hydroxide, magnesium oxide, and magnesium lactate also are used as magnesium supplements, but these substances are not on the National List.

It is unclear if any of the dietary supplements of magnesium are more effective than magnesium sulfate. The only information obtained regarding the comparison of magnesium supplements (NIH, 2009) did not include magnesium sulfate supplements. However, research (National Heart, Lung, and Blood Institute, as cited in NIH, 2009) has indicated that magnesium chloride performs superiorly (higher absorption and bioavailability) to magnesium oxide and magnesium lactate (NIH, 2009).

Calcium sulfate can be used in beer processing as an alternative to magnesium sulfate to increase water hardness (Hardwick, 1995). According to one source (Goldammer, 2008), calcium sulfate is more effective at reducing pH than magnesium sulfate. Calcium sulfate (mined) is on the National List.

While many other flavor enhancers are on the National List, it is unclear if there any of these substances are suitable alternatives to magnesium sulfate.

References:

Adnani, S. 2010. Health Benefits of Magnesium. Retrieved Dec. 10, 2010, from http://www.organicfacts.net/health-benefits/minerals/health-benefits-of-magnesium.html

Bodek, I., et al. 1988. Environmental Inorganic Chemistry. Elmsford, NY: Pergamon Press pp. 6.5-1 to 6.5-10.

Braintree Laboratories. 2010. Highlights of Prescribing Information. Retrieved December 10, 2010, from http://www.accessdata.fda.gov/drugsatfda_docs/label/2010/022372s000lbl.pdf

Dodman, N. 2010. Magnesium Sulfate. Retrieved Dec. 9, 2010 from http://www.petplace.com/drug-library/magnesium-sulfate/page1.aspx.

Epsom Salt Council. 2009. Garden Benefits. Retrieved December 8, 2010, from http://www.epsomsaltcouncil.org/garden_benefits.htm

FAQS. 2010. Minerals. Retrieved December 8, 2010, from http://www.faqs.org/nutrition/Met-Obe/Minerals.html

Fine, K.D., Santa Ana, C.A., Porter, J.L., and Fordtran, J.S. 1991. Intestinal absorption of magnesium from food and supplements. J Clin Invest 1991;88:296-402.

Giles Chemical. 2008. Typical Uses of Magnesium Sulfate, dated October 27, 2008. Retrieved December 9, 2010, from http://www.gileschemical.com/pdfs/MGSO4TYP.pdf

Gilman, A. G. and L. S. Goodman. 1980. The Pharmacological Basis of Therapeutics. 6th ed. New York: Macmillan Publishing Co., p. 880.

Goldammer, T. 2008. Chapter 5: Brewing Water. In: The Brewer's Handbook. Clifton, VA: Apex Publishers; 496 pp. Retrieved December 9, 2010, from http://www.beer-brewing.com/beer-brewing/brewing_water/mineral_salt_adjustment.htm

Hardwick, W. 1995. Handbook of brewing. Boca Raton: CRC press; 714 pp.

Hazardous Substances Data Bank (HSDB). 2003. Magnesium Sulfate, CASRN: 7487-88-9. Last revised 9-12-2003. Retrieved February 1, 2001, from at http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB

Kawamura, Y. and Rao, M. 2007. Magnesium Sulfate: Chemical and Technical Assessment. Retrieved December 9, 2010, from http://www.fao.org/ag/agn/agns/files/jecfa68/CTA%20Magnesium%20Sulfate%20-%20Final%202007.pdf

Kramer, D., 2002. USGS: Magnesium, its Alloys and Compounds. Retrieved February 2, 2011, from http://pubs.usgs.gov/of/2001/of01-341/of01-341.pdf

KRAV. 2001. Standards. Retrieved December 9, 2010, from http://www.krav.se/System/Spraklankar/In-English/KRAV-standards/

Kynczl-Leisure, M. and L.A. Cibils. 1996. Increased bleeding time after magnesium sulfate infusion. *Am J Obstet Gynecol* 175(5):1293–1294.

National Institutes of Health (NIH). 2009. Dietary Supplement fact sheet: magnesium. Retrieved Dec. 9, 2010 from, http://ods.od.nih.gov/factsheets/magnesium/. Updated 7/13/2009.

Magnesium Sulfate. Code of Federal Regulations: Food and Drugs. 50 FR 13560, Apr. 5, 1985. Retrieved Dec. 9, 2010 from, http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&sid=7e5a52ecadd5330ebb577733a67107b7&rgn=div8&view=text&node=21:3.0.1.1.14.2.1.120&idno=21

McEvoy, G.K. 2002. American Hospital Formulary Service- Drug Information, Bethesda, MD: American Society of Health-System Pharmacists, Inc., p. 2163.

Micromedex. 2010. Drugs.com: Magnesium sulfate. Retrieved December 10, 2010, from http://www.drugs.com/pro/magnesium-sulfate.html

Morris, M.E., Leroy, S., and Sutton, S.C. 1987. Absorption of magnesium from orally administered magnesium sulfate in man. Clinical Toxicology 25(5):371-382.

OMRI. 2010. Products List: magnesium sulfate. Retrieved December 9, 2010, from http://www.omri.org/simple-opl-search/results/magnesium%20sulfate

Shurtleff, W. and A. Aoyagi. 2000. Tofu & soymilk production: A craft and technical manual. Lafayette, CA: Soyfoods Center; 336 pp.

U.S. EPA. 2010. Index of chemical names and pesticide chemical codes report; updated 9/30/10. Retrieved on January 25, 2011, from http://www.epa.gov/pesticides/DataSubmittersList/

U.S. FDA. 2010. FDA Approved Drug Products. Retrieved December 10, 2010, from http://www.accessdata.fda.gov/scripts/cder/drugsatfda/index.cfm?fuseaction=Search.SearchAction&SearchTerm=magnesium%20sulfate&SearchType=BasicSearch&