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

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.

Tamarind Seed Gum

Handling/Processing

Identification of Petitioned Substance

Chemical Names:
Tamarind Seed Polysaccharide (TSP); Tamarind Seed Gum

Other Names:
Tamarind Seed Xyloglucan; Tamarind Seed Galactoxyloglucan; Tamarind Gum; Tamarind Extract; Tamarind Xyloglucan

Trade Names:
GLYLOID®; GLYATE; Tamarind Gum

CAS Numbers:
39386-78-2

Other Codes:
EC/List no. 254-442-6

Summary of Petitioned Use

Tamarind seed gum has been petitioned for addition to the National List at § 205.606 as a non-organic agricultural ingredient permitted in processed products labeled as "organic" when organic forms are not commercially available. This full technical report also addresses additional focus areas requested by the National Organic Standards Board (NOSB) Handling Subcommittee:

- The petitioner states that there are very small amounts of residuals from the processing chemicals utilized to separate the gum from the seed. Are there any health issues from these residuals, including, but not limited to methyl alcohol? *See* *Evaluation Question #10*.
- How do the properties of this gum vary from other gums on the National List (e.g., gellan gum, xanthan gum, Arabic gum, guar gum, locust bean gum, carob bean gum, tragacanth gum, etc.)? *See* *Evaluation Question #12*.

Characterization of Petitioned Substance

Composition of the Substance:

Tamarind seed gum is a high molecular weight plant storage polysaccharide (Nishinari, Takemasa, et al. 2007). More specifically, it is a galactoxyloglucan, meaning it is principally comprised of three sugars: glucose, xylose and galactose (Manchanda, 2014; Health Canada, 2017). The linear backbone is a β (1→4)-D-glucan chain, with α-D-xylose units attached to approximately 75 percent of the glucan units. All xyloglucans share this common structure, but additional molecular side chains differentiate tamarind seed gum from other xyloglucan sources (Nishinari et al., 2007). In tamarind seed gum, the xylose units may also have a galactose unit attached by a β 1,2 linkage. The side chains in the structure can alternatively be described as partial substitution at position 6 of the glucopyranosyl unit mainly by a single α-D-xylopyranosyl residue as well as by disaccharide side chains composed of β- D-galactopyran-osyl-(1→2)-α-D-xylopyranosyl residues (Patel et al., 2008) (Gidley et al., 1991). The ratio of glucose, xylose, and galactose is 2.8:2.25:1 (or 43–45% glucose, 35–38% xylose, and 15–17% galactose) (Gidley et al., 1991; Patel, et al., 2008; Khounvilay and Sittikijyothin, 2012; Nishinari et al., 2007). Another minor polysaccharide in tamarind seed gum (2–3 percent) contains unbranched 1,4-β-D-galactopyranan and branched 1,5-α-L-arabinofuranan features (Gidley et al., 1991). The gel form arises when the xyloglucan is in the aqueous phase under certain conditions, and is considered to be a two-phase substance with a three-dimensional macromolecular structure that retains liquid (Salazar-Montoya, Ramos-Ramirez, and Delgado-Reyes 2002). The structure of tamarind seed gum's xyloglucan polysaccharide is shown in Figure 1.

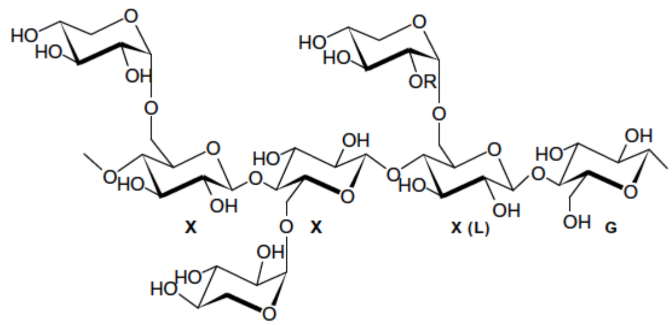

Figure 1. Tamarind seed gum's xyloglucan polysaccharide structure (Patel, et al. 2008). X indicates xylosylated glucopyranose units; G indicates an unsubstituted glucopyranose unit; and L indicates a galactopyranose unit attached to the xylose unit.

The petition for tamarind seed gum submitted to the National Organic Program (NOP) specifically references a brand name, GLYLOID. The composition information above describes GLYLOID. However, although GLYLOID is the only brand name product identified in the petition, an alternative, partially acid-hydrolyzed tamarind seed gum is made by the same manufacturer and marketed under the brand name GLYATE (JHeimbach LLC, 2014). The GRAS notification for tamarind seed polysaccharide (TSP) identifies both GLYLOID and GLYATE as brand/trade names of the substance (JHeimbach LLC, 2014).

Acid hydrolysis is used to separate monosaccharides from polysaccharides (Gidley et al., 1991; Hoebler et al., 1989) and is a processing step used in the production of GLYATE. Information regarding the specific chemical composition of GLYATE was not found in the literature, however it is expected that acid hydrolysis affects its chemical composition and function since it removes certain monosaccharides. The GRAS notification for TSP states that in the production of GLYATE, acid hydrolysis of tamarind kernel powder (TKP) is carried out until the desired viscosity is obtained (JHeimbach LLC, 2014). As will be described under <u>*Action of the Substance*</u>, viscosity is largely determined by a substance's chemical composition.

<u>Source or Origin of the Substance:</u>
Tamarind seed gum comes from the kernel, or endosperm, of seeds of the tamarind tree (*Tamarindus indica L).* Its native range includes the tropical dry savannah of Africa to India and Southeast Asia (CAMEO, 2016), with India being the predominant producer, followed by Thailand, Bangladesh, Sri Lanka, and Indonesia. Thirty-six other countries including Costa Rica, Mexico, and Brazil cultivate the tamarind tree (Bagul, Sonawane, and Arya, 2015). Tamarind trees are leguminous (in the Family Leguminosae, or Fabacae) and produce long pods that contain fruit in the form of a tart, fleshy pulp surrounding glossy, flat seeds. Tamarind pulp is high in tartaric acid and sugars, and is a widely-used food product. The seeds, which are composed of 65–75 percent carbohydrates, are considered a by-product of the pulp industry. Once dehulled and crushed, the seeds make tamarind kernel powder (TKP), a crude preparation of non-starch polysaccharide that functions as an energy reserve for the seed. The purified, soluble polysaccharide fraction of TKP is what is referred to as tamarind seed gum, tamarind seed polysaccharide (TSP), or tamarind seed xyloglucan. For more details on the manufacturing process, see <u>*Evaluation Question #1*</u>.

<u>Properties of the Substance:</u>
Tamarind seed gum is a free-flowing, tasteless powder that is white or light beige in color, and may be odorless or have a slight grease odor. It is insoluble but dispersible in cold water and insoluble in most organic solvents including ethanol, methanol, acetone, and ether (Manchanda, 2014) (Sidley Chemical Co., Ltd. 2013) (Joseph et al., 2012). Tamarind seed gum is soluble in hot water and at least one manufacturer, DSP Gokyo, markets a tamarind seed gum product, GLYLOID 3S, as being cold-water soluble (DSP GOKYO, 2017). A cold, aqueous solution of tamarind seed gum heated to 85˚C results in its dissolution and the formation of a uniform solution (Whistler and Barkalow, 1993). The following subsections detail the viscosity and gelling properties of the substance, which can also be found in Table 1.

Table 1. Properties of tamarind seed gum (Mohamed, Mohamed and Ahmed 2015) (Khounvilay and Sittikijyothin, 2012) (Joseph, et al., 2012) (Nishinari, Takemasa, et al., 2007) (Salazar-Montoya, Ramos-Ramirez and Delgado-Reyes 2002).

Property	Value
Molecular weight*	Reported variously from 650,000–2,100,000 g/mol; most commonly 880,000 g/mol
Viscosity average molecular mass	980,000 g/mol
Linear viscoelasticity	0.637–6.37 Pa of oscillary sheer stress
Viscosity	400-800 mPa·s
Bulk density	0.24–0.651 g/mL
Compressibility index	15.33–16.64%
pH (1% w/v TSP)	6–6.81
Swelling index (in water)	12–17%
Surface tension	61.3–83.26 dynes/cm
Water retention	20.00 ± 1.34%
Moisture content	3.8–8.1%
Melting point	240–260°C

**While molecular weight plays an important role in determining the viscosity of tamarind seed gum, there is wide variation for this property reported in the literature. Several sources suggest that this is due to the self-association of the polysaccharide chains and the related difficulty in isolating molecular solutions that have been fully solubilized (Picout et al., 2003) (Nishinari et al., 2007). There are also differences based on the method of measurement, for example by gel permeation chromatography or light scattering.*

Viscosity

Similar to other gums, tamarind seed gum is a hydrocolloid. Hydrocolloids are a heterogeneous group of long chain polymers (polysaccharides and proteins) characterized by their property of forming viscous dispersions and/or gels when dispersed in water. Thus, gums are substances that disperse in water and provide a thickening and/or gelling effect by increasing the viscosity of a solution. This effect is common to all hydrocolloids, serving as gums' primary function (Saha and Battacharya, 2010; Edwards, 2003). The viscosity of gum solutions/hydrocolloids depends on how the hydrocolloid behaves in various concentrations or environments, such as temperature, pH, amount of physical agitation, or addition of sugars or other gums. Viscosity at low concentrations only depends on temperature, but at higher concentrations gum viscosity depends on shear rate thinning or thickening. *Shear rate* is a term used to describe the flow characteristics of materials that exhibit a combination of fluid, elastic, viscous, and plastic properties and behaviors (Saha and Battacharya, 2010; Chenlo, 2010). *Shear stress* is the force acting in the plane of the fluid (CP Kelco, 2007).

As with other gums, the viscosity of tamarind seed gum depends largely on its concentration in solution. At low concentrations, the viscosity of a tamarind seed gum solution is dependent only on temperature (Sidley Chemical Co. Ltd., 2013). At higher concentrations of tamarind seed gum, however, the viscosity of a solution decreases as shear rate increases (Khounvilay and Sittikijyothin, 2012; Whistler and Barkalow, 1993), a phenomenon known as shear thinning. *Shear thinning* is the behavior of a fluid becoming runnier and less viscous as it flows in response to an applied force (TACC, 2004). This phenomenon occurs due to the structural reorganization of the polysaccharide molecules in high-concentration TSP solutions during flow (Nishinari and Takahashi, 2003). A similar decrease in viscosity is not observed at lower shear rates, where the solution maintains its viscosity (Khounvilay and Sittikijyothin, 2012).

Temperature also affects the viscosity of tamarind seed gum solutions, over a range of concentrations. Tamarind seed polysaccharide in solution at 25°C is in a substantially disaggregated state of single chains (Gidley et al., 1991). However, when boiled for 20 to 30 minutes, the viscosity peaks (Whistler and Barkalow, 1993) and then decreases, but is still somewhat stable, only decreasing to half of what it was at the peak after 5 hours of boiling (Sidley Chemical Co. Ltd., 2013). Tamarind seed gum has been cited as being relatively heat resistant, though research does indicate that as temperature increases, viscosity decreases (JHeimbach, 2014; Buckley, 2017a).

Tamarind seed gum is also salt resistant, stable at neutral pH, and only minimally affected by the presence of organic acids in the pH range from 2 to 7. In fact, maximum gel strength for a solution with 1 percent tamarind seed gum and 50 percent sugar has been reported to be at pH 2 (Wüstenberg, 2015). Acidification with strong inorganic acids, on the other hand, does cause dramatic decrease in tamarind seed gum's viscosity (Sidley Chemical Co. Ltd., 2013). The acid-hydrolyzed tamarind seed gum product, GLYATE, has a much lower viscosity, ranging from 1 to10 mPa·s, compared to over 400 mPa·s for non-hydrolyzed tamarind seed gum.

Gelling Properties

While all hydrocolloids thicken aqueous dispersions, comparatively few gums form gels. Tamarind seed gum does not form a gel in isolation, but does gel in the presence of alcohol and sugars, and exhibits sol to gel transition at certain temperatures (Chemical Book, 2017). In the aqueous phase, tamarind seed gum combined with 40-70 percent sugar gels over a wide range of pH levels (Nishinari and Takahashi, 2003) (Wüstenberg, 2015). These gels show low syneresis, meaning they do not tend to separate or weep liquid (Wüstenberg, 2015). Tamarind seed gum also forms a gel in the presence of alcohol (Gidley et al., 1991) (Nitta and Nishinari, 2005) (Salazar-Montoya, Ramos-Ramirez, and Delgado-Reyes, 2002) or by removing some of its galactopyranosyl side chains (Nitta, Kim, et al., 2003). One study evaluated gels made from tamarind seed gum and saccharose and found that gel stability and shear resistance was dependent on both the saccharose and polysaccharide concentrations (Salazar-Montoya, Ramos-Ramirez, and Delgado-Reyes, 2002).

Tamarind seed gum has also been reported to have more pronounced shear thinning than xyloglucans from other plants such as apple pomace and *Nicotiana plumbaginifolia* (Sims, et al. 1998).

Specific Uses of the Substance:

Tamarind seed gum is used in numerous applications as a food additive. Because it has rheological functions that affect foods in the liquid phase, tamarind seed gum can be used as a thickening and gelling agent to improve the viscosity of certain foods. It can also modify the texture of foods (Khounvilay and Sittikijyothin, 2012). As an emulsifier, tamarind seed gum stabilizes foods such as ice cream, mayonnaise and cheese (Bagul, Sonawane, and Arya, 2015). Tamarind seed gum forms gel at low water activity, such as in solutions with sugar content greater than 60 percent, and is thus used in jams, jellies, and fruit preserves in place of pectin. It can also function as a starch modifier (Nishinari, Takemasa, et al., 2007). Added to starch, tamarind seed gum produces high viscosity paste with increased pseudo-plasticity. It can improve the gelatinization and retrogradation of tapioca starch pastes during storage at 5˚C (Pongsawatmanit et al., 2006). It can also be used to replace gluten as a dough-binding agent in gluten-free food products (Bagul, Sonawane and Arya, 2015). Added to foods, tamarind seed gum can enhance characteristics such as maintenance of viscosity over a wide range of shear rates, water-holding, and a food's resistance to heat, salt, and pH treatments used during processing (Nishinari, Takemasa, et al., 2007).

Tamarind seed gum is used in textile and jute industries as a textile thickener and for textile sizing during dyeing. It is also used in industries such as printing, paper, plywood, cosmetics, and oil drilling; as a soil stabilizer in mining operations, in the manufacturing of paints (Nagajothi et al., 2017), art preservation (CAMEO, 2016) and other industries. A recent area of interest is its use as an excipient for pharmaceuticals due to its high drug-holding capacity, high swelling index, thermal stability, and non-toxicity (Joseph et al., 2012; Manchanda 2014). Other medicinal uses of tamarind seed gum include eyebaths and for the treatment of ulcers (Mishra and Malhotra, 2009). It has also been suggested as an immunity booster (Bagul, Sonawane, and Arya, 2015).

Approved Legal Uses of the Substance:

Tamarind seed gum, under the chemical name Tamarind Seed Polysaccharide, is Generally Recognized as Safe (GRAS) under GRAS Notice No. 503 (JHeimbach LLC, 2014). The GRAS notice covers the use of tamarind seed polysaccharide as a thickener, stabilizer, emulsifier and gelling agent in 12 food categories: ice cream, sauces and condiments, dressings and mayonnaise, fruit preserves, desserts, beverages, pickles, tsukudani, spreads and fillings, flour products, soup and all other food categories at levels ranging from

0.2–1.5 percent of product composition. Use levels are identified for each food category. The stated intended effect of the addition of tamarind seed gum to food is as a stabilizer and thickener as defined in 21 CFR § 170.3(o)(28). The FDA had no questions in its Agency Response Letter of August 12, 2014 to the industry's determination of GRAS status for tamarind seed gum (FDA 2014).

The GRAS Notice No. 503 for Tamarind Seed Polysaccharide covers three brand name products manufactured by DSP Gokyo: GLYLOID 2A (hot-water soluble), GLYLOID 3S (cold-water soluble), and GLYATE (acid-hydrolyzed, low viscosity).

Tamarind seed gum is on the EPA's 2016 Chemical Data Reporting (CDR) Full Exempt List, which lists chemicals that are fully exempt from reporting requirements under the Toxic Substances Control Act.

Action of the Substance:

The actions of thickening and stabilizing of tamarind seed gum are due to its self-association in solution. Hydrocolloids thicken solutions through the nonspecific entanglement of their long molecular chains. When hydrocolloids are present in a suspension in very dilute concentrations, their individual molecules can move freely and may not cause thickening. As the concentration increases, molecule movement is restricted as they begin to come into contact with one another. The disordered molecule chains become entangled and thickening takes place (Saha and Battachyra, 2010). Gidley et al. (1991) also described "hyperentaglements" which resist shear more than non-specific entanglements, and may occur when stiff chains in a non-ionized environment align with neutral segments in solution.

The specific physiochemical properties of a xyloglucan are a function of the number and position of the side chains attached to its molecular backbone (Nishinari, Takemasa, et al., 2007). In tamarind seed gum, the molecular chain is very stiff and has restricted movement due to the extensive glycosylation (approx. 80 percent) of its cellulose-like backbone (Gidley et al., 1991) (Nishinari and Takahashi, 2003). The polymers show both hydrophobic and hydrophilic properties, leading the individual macromolecules to not fully hydrate and thus to aggregate even in dilute solutions (Picout et al., 2003). Tamarind seed gum xyloglucans also tend to self-associates to a higher degree than do xyloglucans from other sources, even though the solution properties for isolated chains of all xyloglucans are very similar. This has been attributed to the ratio of repeating units that make up tamarind seed xyloglucan enabling more interaction with other molecules including other xyloglucans (Nishinari, Takemasa, et al., 2007). Tamarind seed gum contains a high ratio of heptasaccharides (XXXG; See Figure 1), which self-associate to a larger degree than do other oligosaccharides (Nishinari, Takemasa, et al., 2007). It has also been suggested that the extensive substitution on the molecular backbone helps to shield the polysaccharide from hydrolyzing agents, thus imparting tamarind seed gum's resistance to heat, mild acids, and bases (Mishra and Malhotra, 2009).

The molecular weight (or size of molecules) of a polysaccharide affects its functional properties because viscosity and flow are governed by the interaction of the molecules in solution (Patel et al., 2008; Sims et al., 1998; Gidley et al., 1991). One study sought to modify tamarind seed gum's properties by breaking its polysaccharide units into smaller molecular weight materials via pressure and temperature treatment, enzymatic treatment, irradiation and other methods. The result was that the intrinsic viscosity was decreased with increasing irradiation treatment (Patel et al., 2008). This underscores the mechanism by which tamarind seed gum functions to impart viscosity and thickening to solutions: through interactions which are determined by its physical size and chemical makeup on a molecular level.

Combinations of the Substance:

The petition did not suggest that any formulants are included in tamarind seed gum (Buckley, 2017a). Tamarind seed gum is available as a pure tamarind seed polysaccharide, although some minimal solvent residues may remain in the final product from processing aids used in the purification process. More information on these processing aids is provided in *Evaluation Question #1*.

In application, additional substances such as alcohol, sugar, or oil can be mixed with tamarind seed gum in order to aid in dispersion, although the petitioner states that water alone is sufficient. Tamarind seed gum forms a gel in combination with alcohol or sugar (Chemical Book, 2017) (Nishinari, Takemasa, et al., 2007). Tamarind seed gum is also commonly mixed with other gelling agents and food additives, including xanthan gum, guar gum, pullulan, dextran, and pectin, among others (Kumar and Bhattacharya, 2008). The gelling of mixtures of various polysaccharides has been widely investigated. One study found that a mixture of tamarind seed gum and gellan gum formed a gel under conditions that would not produce gelling with either individual polysaccharide, indicating synergistic gelation (Nitta, Kim, et al., 2003; Nitta and Nishinari, 2005). Another study examined the relative concentrations of tamarind seed gum polysaccharide and saccharose in solutions for their effects on gelation properties. Gelation increased with the increase of both components and the authors suggested that the polysaccharide and saccharose likely have synergistic effects on the viscoelastic properties of the resultant gel (Salazar-Montoya, Ramos-Ramirez, and Delgado-Reyes, 2002). Similarly, in a study on the effects of mixing tamarind seed gum with tapioca starch, it was found that the gum contributed increased viscosity and heat stability to the gelatinized mixtures as compared to tapioca starch alone (R. Pongsawatmanit et al., 2006).

Status

Historic Use:

Records from the eastern Mediterranean show tamarind trees under cultivation in the fourth century BCE. It is apparently native to tropical Africa and Madagascar, but now found throughout the tropics and introduced to tropical central and South America. It is widely cultivated and has naturalized in many areas. All parts of the tree are used for medicinal purposes, from the bark and leaves to the fruit, and the fruit is widely used as a food (Kew Science, 2017; Ranaivoson, 2015; JECFA, 2017; Williams, 2006; Kuru, 2014).

The seeds have had much more limited use and were mostly discarded until the mid to late 1900s. In 1942, two Indian scientists—T.P. Ghose and S. Krishna—identified the gel-forming substance found in the seeds (Morton, 1987). Its first applications were in the paper and textile industries. Difficulty of protein removal, bitter taste and odor prevented its adoption in food applications (Whistler and Barkalow, 1993) until a process for its purification was patented calling the substance "jellose," "polyose," or "pectin" (Morton, 1987). Tamarind seed gum has been commercially available as a food additive in Japan since 1964 (DSP Gokyo Food & Chemical, 2017).

Organic Foods Production Act, USDA Final Rule:

Tamarind seed gum is not specifically listed in the Organic Foods Production Act of 1990 or in the USDA organic regulations at 7 CFR Part 205. As an agricultural substance, it may only be used as an ingredient or processing aid in or on foods labeled as "organic" if the substance itself is certified organic.

International:

Canadian General Standards Board Permitted Substances List
http://www.tpsgc-pwgsc.gc.ca/ongc-cgsb/programme-program/normes-standards/internet/bio-org/lsp-psl-eng.html
Tamarind seed gum is not permitted as an ingredient on Table 6.3 of the Permitted Substances List. The listing for Gums on this table states that "[t]he following gums are permitted: arabic gum, carob bean gum (locust bean gum), gellan gum, guar gum, karaya gum, tragacanth gum, and xanthan gum."

However, non-organic agricultural ingredients are permitted as a processing aid if organic forms are not commercially available (see CAN/CGSB 32.310 section 9.2.1(d) and 9.2.2(d)).

CODEX Alimentarius Commission, Guidelines for the Production, Processing, Labelling and Marketing of Organically Produced Foods (GL 32-1999)
http://www.codexalimentarius.org/standards/list-standards/en/?no_cache=1
http://www.codexalimentarius.org/download/standards/360/cxg_032e.pdf
Under the CODEX Alimentarius Guidelines, carob bean gum, guar gum, tragacanth gum, gum arabic, xanthan gum and karaya gum are all permitted with certain restrictions at GL 32-1999 Table 3 "Ingredients

of non-agricultural origin referred to in section 3 of these guidelines." Tamarind seed gum, however, does not appear on this table.

Section 3.4 of the guidelines states: "Certain ingredients of agricultural origin not satisfying the requirement in paragraph [3.3b, which requires agricultural ingredients to be produced organically] may be used, within the limit of maximum level of 5 percent (m/m) of the total ingredients excluding salt and water in the final product, in the preparation of products as referred to in paragraph 1.1(b); where such ingredients of agricultural origin are not available, or in sufficient quantity, in accordance with the requirements of Section 4 [organic production practices] of these guidelines." As such, agricultural forms of tamarind seed gum could be permitted under this section.

European Economic Community (EEC) Council Regulation, EC No. 834/2007 and 889/2008
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:250:0001:0084:EN:PDF
Article 28 states that non-organic agricultural ingredients listed in Annex IX to this Regulation can be used in the processing of organic food, however, tamarind seed gum is not included in on this list. Tamarind seed gum is also not listed under "Food Additives, Including Carriers" in Annex VIII, Section A of EC No. 889/2008. Other gums including carob bean gum, guar gum, Arabic gum, and xanthan gum are listed in this section.

Article 29 describes the authorization of non-organic food ingredients of agricultural origin by member states for agricultural ingredients not appearing in Annex IX. Such non-organic agricultural ingredients may be used according to the conditions laid out in Article 29, which include requirements for evidence of lack of commercial organic supply and notification, among others. Tamarind seed gum could be approved under this provision.

Japan Agricultural Standard (JAS) for Organic Production
http://www.maff.go.jp/e/policies/standard/jas/specific/criteria_o.html
Tamarind seed gum is not listed in Table 1 "Additives" of the Japanese Agricultural Standard for Organic Processed Foods Notification No. 1606, partially revised March 27, 2017. Other gums—including carob bean gum, guar gum, tragacanth gum, Arabian gum, xanthan gum and karaya gum—do appear in Table 1.

Article 4 describes provisions for lack of commercial organic supply: "In case of difficulty to obtain organic plants, organic livestock products or organic processed foods with the same categories of those used for ingredients, those prescribed in items 2 or 4 may be used." Items 2 and 4 describe plants and livestock products that are not in the same categories as organic ingredients, and have not undergone ionizing radiation or recombinant DNA technology. Tamarind seed gum, if not considered in the same category as other listed gums, could be allowed under this provision.

IFOAM – Organic International
http://www.ifoam.bio/en/ifoam-norms
Appendix 4 Table 1, "List of Approved Additives and Processing/Post-Harvest Handling Aids," lists locust bean gum, guar gum, tragacanth gum, Arabic gum, and xanthan gum. Tamarind seed gum is not included.

Section 7.2.1 states: "All ingredients used in an organic processed product shall be organically produced except for those additives and processing aids that appear in Appendix 4. In cases where an ingredient of organic origin is commercially unavailable in sufficient quality or quantity, operators may use non-organic raw materials, provided that:

a. they are not genetically engineered or contain nanomaterials, and

b. the current lack of availability in that region is officially recognized[1] or prior permission from the control body is obtained.
c. the requirements in section 8.1.3 [requirements for percentages of organic ingredients] shall be met."

Tamarind seed gum could be permitted under the above provision.

Evaluation Questions for Substances to be used in Organic Handling

<u>Evaluation Question #1:</u> 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)).

The petition specifically references tamarind seed gum manufactured under the brand name GLYLOID by DSP Gokyo, sold in the U.S. by Socius Ingredients. On the manufacturer's website, there are two forms of this particular brand name product: GLYLOID 2A (hot water-soluble) and GLYLOID 3S (cold water-soluble) (DSP Gokyo, 2017). Another brand name tamarind seed gum product, GLYATE, was not identified in the petition but is addressed in this report in a following sub-section.

Tamarind kernel powder (TKP) is the pre-purified starting material from which pure tamarind seed gum is extracted. The petitioner (Buckley, 2017a) describes its manufacturing process, beginning with the seeds of the tamarind tree. The black seeds are sieved, roasted, cooled and then put through a rotary mixer to remove the testa, or seed coat. Whistler and Barkalow (1993) noted that the temperature and duration of roasting must be controlled so as to minimize discoloration and decreased molecular weight, which can in turn lower the viscosity of the resulting gum. The light brown to creamy white endosperm is visually sorted to remove any off-color endosperm, then polished in a rotary mixer and cut. The cut endosperm is pulverized in a hammer mill and sifted with a 200-mesh filter to produce pre-purified TKP, consisting primarily of polysaccharide with residual protein, lipid, minerals and no more than 10 percent moisture.

GLYLOID

Extraction of the GLYLOID 2A includes use of methyl alcohol (hereafter referred to as methanol) and sodium hydroxide. In order to purify and remove water from the polysaccharide, the TKP is stirred into a solution of food-grade methanol (Buckley, 2017b). After stirring, food-grade sodium hydroxide is added and the mixture is again stirred at a controlled temperature. Sodium hydroxide solubilizes proteins into the methanol solution to facilitate their separation from the polysaccharide (Buckley, 2017b). The polysaccharide is then separated from the protein, lipid, and minerals by centrifugation. Food-grade citric acid is added to adjust the pH by neutralizing the sodium hydroxide. In this process, hydrogen ions from the citric acid combine with hydroxide ions from the sodium hydroxide to form water, leaving sodium and citrate ions in the methanol solution (Buckley, 2017b).

Extraction of GLYLOID 3S involves heating and then rinsing in methanol to remove the colored material prior to pH adjustment with citric acid. Citric acid is a weak acid and has no effect on the structure or composition of the gum (Buckley, 2017b).

After extraction/purification, the polysaccharide is then dewatered, dried, pulverized, and sieved through a screen (Buckley 2017a). The petitioner states that the dewatering process before drying separates the methanol solution containing sodium citrate from the polysaccharides. The residual levels of methanol in the tamarind seed gum product as reported by the petitioner are less than 50 ppm (Buckley, 2017b). More information on safety is provided in *<u>Evaluation Question #10</u>*.

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[1] This may be by inclusion on a government or certification body list of permitted non-organic agricultural ingredients.

GLYATE

Extraction of the GLYATE form of tamarind seed gum (polysaccharide) is done by treating the TKP with food-grade sulfuric acid until hydrolysis results in the desired viscosity. The solution is then neutralized using sodium hydroxide, after which it is sieved and rinsed in methanol (JHeimbach, 2014).

Other Manufacturing Processes

There are other manufacturing processes for tamarind seed gum described in the scientific literature that were not referenced in the petition. These other methods indicate a similar process to obtain the powdered kernel, but indicate a range of organic solvents that can be used to extract the polysaccharide.

In one process, tamarind seeds are roasted and the endosperm is pulverized, after which acetone is added to the TKP to remove oil and fat. The solution is stirred for 12 hours, after which it is filtered through filter paper and the filtrate is retained and dried. Distilled water is then added to the filtrate and the solution is boiled for 20 min at 80˚C, stirred for 2 hours, and centrifuged for 60 minutes at 5000-8000 rpm to remove fiber and other residues. Finally, the supernatant is freeze dried (Nagajothi et al., 2017). A similar method was described in 2012 by Joseph et al., where the TKP is soaked in water and boiled, then filtered and added to an equal amount of acetone to precipitate the polysaccharide, followed by concentration and drying.

In another process hexane extraction is used for defatting TKP, after which the TKP is boiled in water with 0.2 percent citric acid or tartaric acid for 30-40 minutes and allowed to settle overnight. Following, the supernatant is separated from the solution by decanting or siphoning off, and concentrated to 50 percent of its volume by evaporation or vacuum. It may then be added to twice its volume of alcohol in order to obtain a fibrous precipitate which is then filtered and dried (Marathe et al., 2002). The resultant product may also be pulverized in a ball mill (Kumar and Bhattacharya, 2008).

In another method, tamarind kernel powder in cold, distilled water was poured into boiling distilled water and boiled for 20 minutes with stirring in a water bath and then left to settle overnight. The solution was then centrifuged and the supernatant washed with absolute ethanol, diethyl ether and petroleum ether, after which it was dried under vacuum, ground and sieved (Mohamed, Mohamed, and Ahmed, 2015).

Joseph et al. (2012) described an enzymatic method in which the TKP is mixed with ethanol and treated with the enzyme protease. Subsequently, it is centrifuged and the supernatant is again added to ethanol to precipitate the gum, which is then separated and dried (Joseph et al., 2012). The authors note that the purity of the tamarind seed gum is determined by the absence of the protein, which in the described process can denature, forming insoluble precipitates, thus making the separation of the gum more difficult (Joseph et al., 2012).

A U.S. Patent granted in 1990 (Teraoka, 1990) for Shikibo Limited describes the organic solvent extraction process for obtaining tamarind seed polysaccharides utilizing alcohols such as methanol, ethyl alcohol, propyl alcohol, especially isopropyl alcohol, and ketones such as acetone. This patent includes comparative results of various extraction processes including not using any organic solvents. The patent provides research findings on varying levels of extractant use in order to determine minimal level of extractant needed to obtain the polysaccharide.

The JECFA report on tamarind seed polysaccharide (TSP) references the use of methanol, with additional use of acid or alkali treatment (JECFA, 2017). Manchanda (2014) describes the use of either acetone or absolute ethanol and absolute alcohol.

The first patents in the U.S. for extraction of polysaccharides from tamarind seeds were issued in the late 1960s. A patent from 1968 (Gordon, 1968) on behalf of Natural Dairy Product Corporation describes tamarind seed gum purification using a series of extractions, the first of which is with an organic solvent such as an alcohol, ketone, aldehyde or ether to dissolve and remove undesirable proteins and fats. Isopropanol was identified as the preferred extractant. The resulting filtrate still contains some protein fat and fiber of from the crude TKP, along with the polysaccharides. This filtrate is dried to prevent degradation of the polysaccharides, after which it undergoes a water extraction with 25-35 times its weight of water, heated to 205˚F. The polysaccharides are separated by filtration and recovered by roll drying or alcohol precipitation. Use of roll drying requires the addition of a parting agent such as lecithin. However, due to off flavors attributed to the added lecithin, the author recommended adding glycerol monostearate or polysorbitans as additional parting agents (Gordon, 1968). This process does not appear to be used in current commercial manufacturing of tamarind seed gum.

Differing Perspectives on the Use of Ethanol vs. Methanol as an Extractant

Although Whistler and Burkalow (1993) suggest using ethanol or isopropanol to precipitate the soluble polysaccharide from TKP, the petitioner states that the use of ethanol or isopropanol in place of methanol results in a darker color tamarind seed gum with higher levels of residual protein and fat, which impacts its functionality and lowers its dispersability in water (Buckley, 2017b). One study compared extraction methods using ethanol and an "Accelerated Solvent Extraction" in which methanol extraction was followed by an ethanol extraction. The results showed that methanol extraction yielded pure tamarind seed gum, while the ethanol extraction contained additional components as measured by nuclear magnetic resonance (NMR). Thus, the authors concluded that methanol should be the solvent used to extract TSP (Chawananorasest, Saengtongdee, and Kaemchantuek, 2016).

<u>Evaluation Question #2:</u> 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)). Discuss whether the petitioned substance is derived from an agricultural source.

Chemicals are used in the extraction of TSP; specific chemicals and processes used in various manufacturing methods are described in <u>*Evaluation Question 1*</u>. Some of the chemical processes described may be classified as non-synthetic or synthetic based on NOP Guidance 5033.

In the process described by the petitioner for the GLYLOID brand name product, the polysaccharide is not chemically modified during the purification processes described in <u>*Evaluation Question 1*</u>. In the addendum to the petition, the petitioner explains that the purpose for the use of methanol as a solvent is to remove water from the polysaccharide, which results in the polysaccharides self-associating into insoluble clumps (Buckley, 2017b), or precipitating. This claim is supported by the literature, where alcohol is widely cited for use in precipitating the polysaccharide (Marathe et al., 2002; (Joseph, et al. 2012; Gordon , 1968; Whistler and Barkalow 1993). Tamarind seed gum is insoluble in most organic solvents, including in methanol, ethanol and acetone (Sidley Chemical Co., Ltd., 2013). Thus, processes employing these solvents, where the filtrate is then filtered and/or dried, are expected to contain unmodified pure TSP with minimal solvent residues. The solvents are removed such that they do not have a technical functional effect in the final product.

The processes described for the GLYATE uses a strong mineral acid (sulfuric acid). Acid hydrolysis chemically modifies the polysaccharide; therefore, this form would be considered synthetic under NOP Guidance 5033.

TSP is a naturally occurring storage polysaccharide in the endosperm of the tamarind tree seed, which is an agricultural source.

<u>Evaluation Question #3:</u> If the substance is a synthetic substance, provide a list of non-synthetic or natural source(s) of the petitioned substance (7 CFR § 205.600 (b) (1)).

Non-acid-hydrolyzed tamarind seed gum may be classified as a non-synthetic agricultural material based on NOP Guidance 5033. However, acid-hydrolyzed forms (such as GLYATE) and/or forms that include synthetic additives (such as the patent process from 1968) would render the final product synthetic.

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.

TSP is Generally Recognized As Safe. GRAS Notice Inventory No. 503 addresses the use of TSP as a thickener, stabilizer, emulsifier and gelling agent in the following food categories: ice cream, sauces and condiments, dressings and mayonnaise, fruit preserves, desserts, beverages, pickles, tsukudani, spreads and fillings, flour products, soup, and all other food categories (JHeimbach LLC 2014). The FDA confirmed having no questions on this Industry GRAS determination on August 12, 2014 (FDA 2014).

Evaluation Question #5: Describe whether the primary technical function or 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)).

The purpose of tamarind seed gum in food is to act as a stabilizer and thickener as defined in 21 CFR 170.3(o)(28). According to the regulations, these are "[s]ubstances used to produce viscous solutions or dispersions, to impart body, improve consistency, or stabilize emulsions, including suspending and bodying agents, setting agents, jellying agents, and bulking agents, etc." This definition does not include the functional effects of a preservative.

One of the notable uses of tamarind seed gum is in fruit jams, jellies, and preserves in place of pectin. Processing fruit into these products is a form of fruit preservation. The degree of preservation, however, is related to the water activity of the product, which is determined by the sugar content. As sugar binds to water in food it is made unavailable for microbial growth (ACS, 2017). Thus, it is not the gelling—or stiffness—of the gum or pectin that preserves the food, but the sugar. Jams and jellies can be made without the use of pectin or any other gelling agent.

Many of the functions of gums as food additives can result in extending shelf life of the products in which they are used (Williams and Phillips, 2003). For example, tamarind seed gum used as a stabilizing agent of ice crystals in frozen pastry products aids in shape preservation (Sidley Chemical Co., Ltd. 2013).

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)).

Tamarind seed gum is not added to food primarily to recreate flavors, colors, textures or nutritive values lost in processing, although one of its functions as a food additive is to improve texture. The actions of stabilizing, thickening, or gelling can all contribute to improving texture. However, none of the literature reviewed for this report suggest that tamarind seed gum recreates texture quality that has been lost due to processing.

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)).

The physiological and nutritional effects of ingesting tamarind seed gum occur during transit through the stomach, small intestine, and colon where there is interaction among nutrients, enzymes, and mucosal cells, and finally fermentation by the colonic microflora. Digestion of sugars and fats may change when foods containing gums as food additives are ingested (Edwards, 2003).

Tamarind seed gum's xyloglucan polysaccharide has the same molecular skeleton as cellulose, and like cellulose, is not readily digested by enzymes found in the human digestive tract. It therefore serves as dietary fiber (Picout et al., 2003). Intake of dietary fiber has numerous health benefits, including lowering the risk for development of coronary heart disease, hypertension, stroke, diabetes, obesity, and certain gastrointestinal diseases. It can also lower blood pressure and cholesterol levels (Koraym, Waters, and

Williams, 2009). Literature has also suggested that xyloglucan oligosaccharides obtained via enzyme hydrolysis may be used as a prebiotic food ingredient to foster intestinal bacteria fermentation (Mishra and Malhotra, 2009).

Existing literature about gums' effect on mineral availability differs depending on whether the assessment was done inside or outside of the organism. One reference noted that gums can decrease mineral availability in the intestines, but that the effect of dietary fibers on mineral absorption in humans is still unclear (Baye, Guyot, and Mouquet-River, 2015). This potential was suggested based on laboratory studies that have shown how various fibers have mineral-binding properties *in vitro*. By contrast, animal and human *in vivo* studies of various soluble dietary fibers fail to demonstrate negative effects on mineral absorption, and some *in vivo* studies with fibers (e.g., pectin, fructooligosacccharides) have shown positive effects on mineral absorption. One possible reason for the difference observed between laboratory and *in vivo* studies is that fermentation of the fibers in the colon may free bound minerals and offset the negative mineral-binding effects of the fibers (Baye, Guyot, and Mouquet-River, 2015).

<u>Evaluation Question #8:</u> 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)).

No reports of residues of heavy metals or contaminants in excess of FDA's tolerances have been identified for tamarind seed gum, and no substances listed on FDA's *Action Levels for Poisonous or Deleterious Substances in Human Food* have been reported as contaminants of concern for tamarind seed gum (FDA, 2017).

The FDA response to the industry GRAS determination acknowledged the specifications for TSP, which limit lead content to less than 2 mg/kg and arsenic to less than 1 mg/kg (FDA, 2014).

The GRAS notice states that the specifications set for GLYLOID 2A and 3S do not include limits for mercury and cadmium. Nevertheless, the levels of these heavy metals were assessed and found to be consistently below the detection level of 0.01 mg/kg. Methanol residues are also tested regularly and consistently found to be under 50 mg/kg (ppm) (JHeimbach, 2014).

Information provided by petitioner, in response to questions from the NOSB, indicates non-detect levels of a wide array of agricultural pesticides in samples of GLYLOID 2A (Buckley, 2017 b).

Health Canada has proposed adding tamarind [seed] gum to its *List of Permitted Emulsifying, Gelling, Stabilizing or Thickening Agents*. In its rationale, the agency stated that "data was provided demonstrating that tamarind gum can be manufactured, following good manufacturing practices, such that it consistently meets the manufacturer's in-house specifications, including specifications for lead, arsenic, and microbial pathogens. These specifications are generally consistent with internationally-established specifications for many other food additives, including other plant-based gums" (Health Canada, 2017).

Tamarind seed gum is not presently listed in the Food Chemicals Codex (FCC).

<u>Evaluation Question #9:</u> 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)).

The utilization and cultivation of tamarind trees has been cited as having beneficial environmental impacts. As a leguminous tree, tamarind can grow in poor soils due to its nitrogen-fixing ability and it also being drought tolerant (Kumar and Bhattacharya, 2008). The trees are long-lived evergreens, providing a year-round soil cover. They store and recycle nutrients and help stabilize the soil. A mature tree may produce 330 to 500 pounds (150 to 225 kg) of fruit annually, of which seeds make up 33–40 percent. The fruit is generally harvested during the dry season, giving farmers supplemental income in the off-season, which can discourage timber harvesting (Mahapatra and Tewari, 2005) or other land conversion such as slash and burn for agriculture. The trees are widely cultivated throughout the tropics, and they readily spread and naturalize beyond their native range of Africa. They are not considered a species of concern for conservation (Kew Science, 2017; Ranaivoson, 2014). In sub-Saharan Africa, tamarind trees reportedly contribute to ecosystem stability and food security; however, planting rates are not high in that area. It has been suggested that the development of value-added tamarind products could help maximize the benefits of tamarind trees and enhance their conservation in this area (Ebifa-Othieno et al., 2017). The economic value obtained from the harvest of non-timber forest products such as tamarind has been noted for its potential in sustainable forest management (Mahapatra and Tewari, 2005). In contrast, one research article attributes overexploitation of this species to causing a decline in the number and distribution of tamarind trees within its native range of south western Madagascar (Ranaivoson, 2015).

The production of tamarind seed gum involves the use of processing aids including methanol, isopropanol, sodium hydroxide and citric acid. The petitioner states that the production line is sealed, and the methanol used in the process is recovered through distillation and is then reused. The remaining solvent solution containing sodium citrate is burned, producing water, CO_2, and ash. The petitioner maintains that incinerator emissions are minimal and meet local standards for emissions (Buckleym 2017b). No sources reviewed for this report discuss any environmental pollution resulting from the processing of tamarind seeds into the purified polysaccharide.

In the environment, tamarind seed gum can be broken down via hydrolysis by enzymes of the *Aspergillus oryzae-niger* group, as well as the cellulose decomposer *Myrothecium verrucaria* (Whistler and Barkalow, 1993). The by-products of this hydrolysis/degradation are smaller oligosaccharides, which can be further metabolized by organisms present in the environment and do not pose ecological hazards.

<u>Evaluation Question #10:</u> 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)).

Tamarind seed polysaccharides (TSPs), like other xyloglucans, are not digested by human digestive enzymes and may be regarded as part of the dietary fiber portion of the diet (Yamatoya, 2000). Tamarind seed gum is fermented by the intestinal microbiota, notably by clostridia bacteria (Hartmink, 1996). One report indicated that TSPs have a protective effect on liver functioning (Samal, 2014).

The possibility of allergic reaction to tamarind seed gum is negligible. The Health Canada proposal to allow tamarind gum as a food additive (Health Canada, 2017) notes that research data indicate that tamarind gum is not absorbed into the general circulation and there is no systemic exposure to it. The gum is broken and fermented by bacteria in the colon into individual sugars and short chain fatty acids, which are normal constituents of the diet (Health Canada, 2017).

Tamarind seed polysaccharide (gum) was considered by the Joint FAO/WHO Expert Committee Food Additives at its June 2017 meeting. The Committee noted the absence of toxicity in long-term rodent studies and lack of concern regarding genotoxicity, reproductive toxicity and developmental toxicity. They therefore established the allowed daily intake as “not specified” for TSP. The Committee concluded that the estimated dietary exposure of 75 mg/kg body weight per day based on proposed uses and use levels does not present a health concern (JECFA, 2017).

The material safety data sheet for Tamarind Gum (tamarind seed Polysaccharide) published by TCI America does not indicate any carcinogenic or mutagenic concerns, but notes that information on toxicity to humans has not been determined (TCI America, 2005).

Several toxicity studies of tamarind seed gum have been carried out on rodents. In one, rats were fed diets containing different levels of tamarind seed gum ranging from 0-120,000 ppm for 28 days. There were no mortalities, no clinical or ophthalmological signs, no findings related to body weight gain, food consumption, food efficiency, functional behavior or motor activity. There were initial decreases in body weight gain and food consumption during the first week, but these recovered by the second week of tamarind seed gum administration and were considered to be likely due to reduced palatability. The No Observed Adverse Effect Level (NOAEL) was determined to be the highest level administered: 120,000 ppm, which is equivalent to 10,597 mg/kg body weight for male rats and 10,691 mg/kg body weight for female rats (Heimbach et al., 2013).

In a carcinogenicity study, mice were given tamarind seed gum at levels ranging from 0 to 5 percent of their diet for 78 weeks. Body weight declined in female mice given 1.25 percent or 5 percent gum after 34 weeks. However, there were no treatment-related clinical signs or adverse effects on food consumption, hematology measures, organ weights or survival rate. There were also no treatment-related increases in non-neoplastic or neoplastic lesions, leading the authors to conclude that tamarind seed gum is not carcinogenic in mice for either sex (Sano et al., 1996).

Potential Health Issues from Residual Chemicals Used in Processing of Tamarind Seed Gum
Methanol is one of several solvents that may be used in the extraction of tamarind seed gum. Methanol occurs naturally in plants and animals, and is also a toxic alcohol that is, among other uses, an industrial solvent. Methanol poisoning occurs primarily as a result of ingesting contaminated food or beverages (NIOSH, 2017). Inhalation and dermal or eye contact are other routes of exposure that can have adverse health effects. Methanol toxicity results from its being metabolized via alcohol dehydrogenase to formaldehyde and formic acid. Acute methanol poisoning can produce marked metabolic acidosis, hyperglycemia, cyanosis, respiratory failure, electrolyte imbalance, delayed onset of coma, impaired vision, and blindness (WHO, 2017). The prognosis in cases of methanol poisoning correlates with the amount of methanol ingested and resulting degree of metabolic acidosis. The minimum lethal dose of methanol in adults is believed to be 1 mg/kg of body weight (Korabathina, 2017). Based on the estimated dietary exposure of 75 mg tamarind seed gum per kg of body weight an assumed maximum residual 50 mg methanol per kg of the gum would result in an estimated daily exposure of 0.00375 mg methanol per kg of body weight from the consumption of tamarind seed gum. At this concentration methanol is considered non-toxic (WHO, 2014).

The EPA Oral Reference Dose (RfD) for methanol is 0.5 milligrams per kilogram of body weight per day. This number is an estimate (with uncertainty spanning perhaps an order of magnitude) of daily oral exposure of a chemical to the human population (including sensitive subgroups) that is likely to be without appreciable risk of deleterious effects during a lifetime. It is a reference point above which the potential risk for adverse health effects increases. However, the EPA notes a lack of data on reproductive or developmental toxicity, leading it to assign only medium confidence to the RfD (EPA, 2000).

21 CFR 173.250 establishes limits on methanol as an extraction residue in spice oleoresins: not to exceed 50 parts per million. It is also limited as an extraction residue in hops to a level not exceeding 2.2 percent by weight, provided that the hops extract is added to the wort before or during cooking in the manufacture of beer, and the label of the hops extract specifies the presence of methanol. Health Canada similarly limits residues of methanol when used as an extraction solvent to 50 ppm in spice extracts and to 2.2 percent for hops extract. In steviol glycosides, the maximum residual level permitted is 200 ppm, and for meat and egg marking inks, processors are to adhere to good manufacturing practices (Health Canada 2016). In Europe, methanol may be used as an extraction solvent during the processing of raw materials, of foodstuffs, of food components or of food ingredients. Its residue is limited to 10 mg/kg for all uses and to 1.5 mg/kg when used as an extractant of natural flavoring materials according to Directive 2009/32/EC, Annex 1, Parts II and III. Methanol is a Class 2 Solvent according to USP-NF 467/ICH Q3C(R6) guidelines, meaning, it is a solvent that should be limited in pharmaceutical applications due to its inherent toxicities. Its permissible daily exposure in pharmaceuticals is 30 mg per day, and its concentration limit is 3000 ppm (ICH, 2016).

Although FDA regulations do not include a legal limit on the maximum amount of methanol residue that can remain in tamarind seed gum, the GRAS Notice for tamarind seed gum reported that methanol residues are tested regularly and are consistently found to be under 50 mg/kg (ppm) (JHeimbach, 2014), which was accepted by the FDA.

Research indicates that TSPs are not soluble in organic solvents and that processing methods, as described in numerous references, indicate separation of polysaccharides from the organic solvents used during the purification process. If any residues remain they are not expected to exceed acceptable FDA levels.

Evaluation Question #11: Describe any alternative practices that would make the use of the petitioned substance unnecessary (7 U.S.C. § 6518 (m) (6)).

A review of the literature did not provide any information describing alternative practices that would render the use of gums such as tamarind seed gum unnecessary as a food additive for the purposes for which it is presently approved in processed foods. Like other hydrocolloids, alone or in combination, it functions as a thickener, stabilizer, emulsifier, and under certain conditions a gelling agent as described elsewhere in this report.

An alternative practice could be to make the product without the additive, resulting in products with different consistencies and textures. Producers of processed organic foods could, in some instances, use alternative substances, as discussed below in response to *Evaluation Question 12* and *Evaluation Question 13*.

Evaluation Question #12: 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)).

As discussed previously, tamarind seed gum is derived from non-synthetic, natural sources and is also classified as agricultural. It has numerous potential alternatives, some of which are non-synthetic and many are also agricultural. The availability of agricultural alternatives in certified organic form will be discussed in *Evaluation Question 13*.

The National List includes the following allowed substances which, separately or in combination, may be alternatives or substitutes to tamarind seed gum:

§205.605(a) Nonagricultural, non-synthetic
- Agar-agar
- Carrageenan
- Gellan gum – high acyl form only

§205.605(b) Nonagricultural, synthetic
- Xanthan gum

§205.606 Nonorganic, agricultural
- Gelatin
- Gums – water extracted only (Arabic; guar; locust bean; and carob bean)
- Konjac flour
- Lecithin (de-oiled)
- Pectin (non-amidated forms only)
- Cornstarch (native)
- Sweet potato starch-for bean thread production only
- Tragacanth gum

Tamarind seed gum is the only xyloglucan available for commercial use (Wüstenberg, 2015; Cui, 2005), however there are numerous other natural hydrocolloids that could potentially be substituted for tamarind seed gum. These include both agricultural and non-agricultural substances. Traditional substances which are not hydrocolloids, such as starches and gelatin, can be used. The choice of gum for a particular food application is dictated by the functionalities required, but strongly influence by price and security of supply. Therefore, starches, which are very economic, are the most commonly used thickening agents, and corn starch, tapioca, wheat arrowroot and rice starches are all available in organic forms. However, starches do not provide the same function as the hydrocolloid gums. For example, tamarind seed gum imparts a viscosity similar to that of starch, however, its viscosity does not deteriorate in the presence of acids, bases, salts and heat like starch does (Sidley Chemical Co. Ltd., 2013). One study evaluated the influence of TSP on the rheological properties and thermal stability of tapioca starch. It found through different mixing ratios of the two substances, peak and final viscosities were greater for mixes with higher TSP proportions. Heat stability was improved over that of pure tapioca starch and water separation was lower than for pure TSP (R. Pongsawatmanit et al., 2006).

Gelatin is derived from partial hydrolysis of collagen fibers extracted from the bones and other body parts of domesticated animals, such as beef cattle. It is by far the most common gelling agent, but, with increasing demand for non-animal products, in particular due to the bovine spongiform encephalopathy outbreak and expansion of the vegan consumer group, processors are actively seeking to replace gelatin in both organic and non-organic food processing. Gelatin could be used as an alternative to tamarind seed gum in combination with gellan gum, but the latter can withstand higher temperatures (Williams and Phillips, 2003).

Other gums may serve as alternatives to tamarind seed gum. Tamarind seed gum has similar solution properties to those of galactomannans (Nitta 2005) such as locust bean gum and guar gum. However, guar gum is superior to tamarind seed gum in dispersion and suspension: it is readily soluble in cold water, whereas tamarind seed gum takes longer to achieve full viscosity. On the other hand, tamarind seed gum has better thermal stability than guar gum and also tolerates higher pH conditions (Chemtotal Pty Ltd., 2017).

Tamarind gum was compared with guar gum and xanthan gum and found to be at least as effective in maintaining viscosity. Data for some of the tests measuring acid resistance and freeze-thaw resistance showed that tamarind gum could be more effective (Health Canada, 2017).

Tara gum is another potential alternative. Tara gum is derived from the endosperm of the seeds of *Caesalpinia spinosa (leguminosae*), a shrub/small tree growing wild in Peru. Tara is a high molecular galactomannan, with similar cold water solubility to guar gum and similar thickening characteristics. It is odorless and tasteless compared with guar gum, improves shelf life of products, and has a smoother, less slimy texture (Silvateam, 2017).

Konjac mannan is a soluble extract of konjac flour made from a dried tuber (*Amorphophallus konjac)* used in Japan to make noodles and konnyaku for use in traditional dishes and desert jelly. It is a glucomannan. It can be combined with xanthan gum to increase gel strength in kappa-carrageenan gels (Williams and Phillips, 2003).

Xanthan gum is of microbial origin and, as another glycosyl-branched cellulosic polysaccharide, has been shown to have an extremely stiff molecular structure and is considered a weak gel. (Gidley et al., 1991). Although the length of tamarind seed xyloglucans is relatively high for polysaccharides, it is much lower than that of xanthan gum's polysaccharide length (Nishinari, Takemasa, et al., 2007) and thus it is relatively flexible as compared to xanthan gum's chains (Picout, et al. 2003) (Nishinari, Takemasa, et al., 2007).

Pectin is another alternative to tamarind seed gum; tamarind seed gum has been widely suggested as an alternative to pectin in making fruit jams, jellies and preserves. Differences between tamarind seed gum and pectin have been widely described. Fruit pectins degrade with boiling, falling to one-third of their original gelling value after one hour of boiling (Kumar and Bhattacharya, 2008). Tamarind polysaccharides, however, do not lose their gelling ability due to boiling in neutral aqueous solutions, even for long periods (Kumar and Bhattacharya, 2008). Unlike fruit pectin, tamarind seed gum can gel at a neutral pH (Marathe, et al., 2002). Tamarind seed gum is also said to show less syneresis, or weeping, than fruit pectins (R. Whistler, 1973).

Mohamed, Mohamed and Ahmed (2015) compared two tamarind seed gum extracts, from light brown and dark brown seeds, to pectin. They found the former to have higher intrinsic viscosity and molecular weight than that of pectin. They reported that the TSPs form gels over a wide range of pH in the presence of sucrose without acid and base, while commercial pectin forms gels over a narrow (acidic) range of pH in the presence of sucrose. The protein levels in polysaccharide were higher than those in pectin but did not inhibit gel formation (Mohamed, Mohamed, and Ahmed, 2015).

Viscosity

The GRAS Notice (JHeimbach, 2014) compares the viscosity of TSP with xanthan gum, guar gum, locust bean gum, and gum arabic. The comparison indicates that TSP exhibits moderate viscosity with a linear dependence on concentration, and its viscosity is negatively correlated with temperature and is independent of the intensity of shear or stirring force (JHeimbach, 2014). Graphs showing comparisons with other gums for properties such as viscosity are also provided in the petition (Buckley, 2017).

The viscosity of tamarind seed gum xyloglucan is relatively high compared to that of gums with the same contour length due to its self-aggregation (Nishinari, Takemasa, et al., 2007). Xyloglucans have been reported to have a molecular chain persistence length of 6-8 nm, which is slightly larger than that of cellulose and its derivatives. The stiffness of its chains is greater than that of galactomannan chains as found in locust bean and guar gums, but, as noted above, is relatively flexible compared xanthan gum. It's relatively higher viscosity is also due to the polysaccharide's molecular side chains, which makes it more rigid than that of other neutral polysaccharides. Its rigidity is comparable to that of alginates that have a ribbon-like structure stiffened by mutual electrostatic repulsion between adjacent residues (Gidley et al., 1991). Guar gum, another branched polysaccharide has a moderately stiff backbone and is described as having rheological properties of a simple entanglement solution (Gidley et al., 1991). Tamarind xyloglucans behave as linear flexible to semiflexible random coil polysaccharides (Picout et al., 2003) (Nishiniari et al., 2007).

Flow

Tamarind seed gum is similar to the galactomannans locust bean and guar gum in exhibiting consistent flow behavior at low concentrations and shear thinning flow behavior at higher concentrations (ca. >0.5% w/w). Their dynamic rheological properties are similar to those of random coil polysaccharides (Cui, 2005).

Stabilizer

Tamarind seed gum has been found to be comparable to tragacanth, arabic, and karaya gums in stabilizing oil emulsions (R. Whistler, 1973). Comparative stability studies have been undertaken using gum acacia as a standard emulsifying agent. TSP was found to be more effective as a stable emulsifying agent in comparison to gum acacia (Manchanda, 2014).

Other Properties

The sugar-induced gels of tamarind seed gum xyloglucan have high elasticity and display good water holding properties (Cui, 2005). These and its stability to heat, acids and shear have all been noted as unique to this polysaccharide (Mishra and Malhotra, 2009). Another defining characteristic of tamarind seed gum as compared to other gums is its non-threading (Sidley Chemical Co. Ltd., 2013).

Table 2. Comparison of properties between tamarind seed gum and other gums on §205.605-606.

Property	Tamarind seed gum	Gum arabic	Tragacanth gum	Guar gum	Locust (Carob) bean gum	Gellan gum	Xanthan gum
Low Viscosity (only becomes viscous at concentrations greater than 50%)	Moderate viscosity	X					
High Viscosity at 1 % concentration			X				
High Viscosity at low concentrations (but above 1%)						X	X
Viscosity remains unchanged over time at low shear rates	X		X				
Viscosity decreases over time at low shear rates				X			
Forms thermo-reversible gels						X	
Thermally reversible						X	X
Thermally irreversible			X		X		
Insoluble in ethanol	X	X	X	X	X	X	X
Stable under acid conditions	X		X	X	X		X
Controls syneresis (weeping)	X			X	X		X

The relationship between polysaccharides and their rheological behavior is becoming better understood (Mishra and Malhotra, 2009), opening the door to optimization of their functional properties through different combinations, proportions and conditions. As Williams and Phillips (2003) noted, mixtures of gums are commonly used to impart novel textural characteristics to food products. Thus, tamarind seed gum either alone or in combination with other gums can impart novel characteristics to processed food.

<u>Evaluation Information #13:</u> Provide a list of organic agricultural products that could be alternatives for the petitioned substance (7 CFR § 205.600 (b) (1)).

Agricultural substances that can be used as alternatives to tamarind seed gum in food processing applications include gums on the National List, and, in certain applications, pectin, starch and konjac flour, which are also on the National List at § 205.606. Water-extracted gum arabic, guar gum, locust bean/carob bean gum are permitted in non-organic form as ingredients in or on processed products labeled as "organic" when not commercially available in organic form, per § 205.606(g). The discussion in *<u>Evaluation Question 12</u>*, comparing tamarind seed gum to these alternatives also applies to the same substances in organic form. At the time of this report, the NOP Organic Integrity Database lists sources of organic locust bean gum, gum arabic/acacia gum, karaya gum, guar gum, tara gum, and konjac gum (NOP, 2017). However, little information was found as to whether the commercially available quantities would meet market demand.

No sources of organic tamarind seed gum or organic TSP are identified in the NOP Organic Integrity Database. Tamarind trees are widely cultivated in the tropics worldwide and can be certified organic. At the time of this report, there are nine sources of organic tamarind (fruit) and one source of tamarind powder listed in the NOP Organic Integrity Database (NOP 2017). However, the processing aid methanol used in the manufacture of tamarind seed gum does not appear on the National List at § 205.605, thus it may not be possible under current regulations to process TKP from certified organic tamarind tree seeds into certified organic tamarind seed gum.

Report Authorship

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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.

References

ACS. 2017. "Sugar in Food Preserving." *ACS Distance Education.* August 12. Accessed December 7, 2017. https://www.acsedu.co.uk/Info/Alternative-Living/Self-Sufficiency/Sugar-in-Food-Preserving.aspx.

Bagul, Mayuri, Sachin K. Sonawane, and Shalini S. Arya. 2015. "Tamarind seeds: chemistry, technology, applications and health benefits: A review." *Indian Food Industry Magazine 34 no. 3.*

Baye, K., J. P. Guyot, and C. Mouquet-River. 2015. "The unresolved role of dietary fibers on mineral absorption." *Criteria Reviews in Food Science and Nutrition 57 no. 5.*

Buckley, Conor. 2017a. "NOP Petition for Tamarind Seed Gum." *NOP Petitioned Substances Database.* February 13. Accessed November 28, 2017. https://www.ams.usda.gov/sites/default/files/media/TamGumPetition.pdf.

—. 2017b. "Tamarind Seed Gum: Additional Information Request from NOSB (April 6, 2017)." *NOSB Petitioned Substances Database.* August 22. Accessed November 30, 2017. https://www.ams.usda.gov/sites/default/files/media/TamGumNOSBResponseAug222018.pdf.

CAMEO. 2016. "Tamarind Seed Gum." *The Conservation and Art Materials Encyclopedia Online (CAMEO).* May 10. Accessed November 9, 2017. http://cameo.mfa.org/wiki/Tamarind_seed_gum.

Chawananorasest, Khanittha, Patsuda Saengtongdee, and Praphakorn Kaemchantuek. 2016. "Extraction and Characterization of Tamarind (Tamarind indica L.) Seed Polysaccharides (TSP) from Three Different Sources." *Molecules 21, 775* 1-9.

Chemtotal Pty Ltd. 2017. *Tamarind Kernel Powder.* Accessed December 20, 2017. http://www.chemtotal.com/oldsite/tkp.html.

CP Kelco. 2007. "KELTROL® / KELZAN® xanthan gum Book 8th Edition." *CP Kelco.* Accessed January 3, 2018. http://www.bisi.cz/cmsres.axd/get/cms$7CVwRhc3USVqgzxkKF96gI$2BChNrXcTq$2BOUdiEtz5TfYA$2B1dJUbBlKfluXdoDfiqojVRVU$2FkQ343xA$3D.

Cui, Steve W. (Ed). 2005. *Food Carbohydrates: Chemistry, Physical Properties, and Applications.* Boca Raton: Taylor & Francis Group CRC Press.

DSP Gokyo Food & Chemical. 2017. *Glyloid Tamarind Seed Gum.* Accessed November 28, 2017. http://www.dsp-gokyo-fc.co.jp/english/glyloid/.

Ebifa-Othieno, Esther, Antony Mugisha, Philip Nyeko, and John David Kabasa. 2017. "Knowledge, attitudes and practices in tamarind (Tamarindus indica L) use and conservation in Eastern Uganda." *Journal of Ethnobiology and Ethnomedicine 13 vol 5* doi: 10.1186/s13002-016-0133-8.

Edwards, C. A. 2003. "Dietary Importance." In *Encyclopedia of Food Sciences and Nutrition*, by B. Eds. Caballero and et al., 3007-3012. San Diego, CA: Academic Press.

EPA. 2000. "Methanol: Hazard Summary." *U.S. Environmental Protection Agency.* January. Accessed December 11, 2017. https://www.epa.gov/sites/production/files/2016-09/documents/methanol.pdf.

FDA. 2017. *Action Levels for Poisonous or Deleterious Substances in Human Food and Animal Feed.* Accessed December 8, 2017. https://www.fda.gov/food/guidanceregulation/guidancedocuments regulatoryinformation/ucm077969.htm#lead.

—. 2014. "Agency Response Letter GRAS Notice No. GRN 000503." *U.S. Food & Drug Administration.* August 12. Accessed November 21, 2017. https://www.fda.gov/Food/IngredientsPackaging Labeling/GRAS/NoticeInventory/ucm413748.htm.

Gidley, Michael J., Peter J. Liliford, David W. Rowlands, Peter Lang, Mariella Dentini, Vittorio Crescenzi, Mary Edwards, Cristina Fanutti, and J.S. Grant Reid. 1991. "Structure and solution properties of tamarind-seed polysaccharide." *Carbohydrate Research 214, no. 2* 299-314.

Gordon, Arthur L. 1968. Tamarind Extract. US Patent US3399189A. August 8.

Health Canada. 2016. "15. List of Permitted Carrier or Extraction Solvents (Lists of Permitted Food Additives)." *Government of Canada.* June 29. Accessed December 8, 2017. https://www.canada.ca/en/health-canada/services/food-nutrition/food-safety/food-additives/lists-permitted/15-carrier-extraction-solvents.html.

—. 2017. "Health Canada's Proposal to Enable the Use of Tamarind Gum as an Emulsifying, Gelling, Stabilizing and Thickening Agent in Unstandardized Foods and Certain Standardized Foods – Reference Number: NOP/ADP-0026." *Government of Canada.* August 15. Accessed December 8, 2017. https://www.canada.ca/en/health-canada/services/food-nutrition/public-involvement-partnerships/proposal-tamarind-gum-emulsifying-gelling-stabilizing-thickening-agent/information-document.html.

Heimbach, J. T., H. Egawa, P. A. Marone, M. R. Bauter, and E. Kennepohl. 2013. "Tamarind seed polysaccharide: a 28-day dietary study in Sprague-Dawley rats." *International Journal of Toxicology. 32 no. 3* 198-208.

Hoebler, Christine, Jean Luc Barry, Agnes David, and Jean Delort-Laval. 1989. "Rapid acid hydrolysis of plant cell wall polysaccharides and simplified quantitative determination of their neutral monosaccharides by gas-liquid chromatography." *Journal of Agricultural and Food Chemistry 37 no.2* 360–367.

ICH. 2016. "Impurities: Guideline for Residual Solvents Q3C(R6)." *International Council for Harmonisation of Technical Requirements for Pharmaceuticals for Human Use.* October 20. Accessed December 8, 2017. http://www.ich.org/fileadmin/Public_Web_Site/ICH_Products/Guidelines/Quality/Q3C/Q3C__R6___Step_4.pdf.

JECFA. 2017. "JOINT FAO/WHO EXPERT COMMITTEE ON FOOD ADDITIVES Eighty-fourth meeting Summary and Conclusions." *JECFA/84/SC.* Rome: Food and Agriculture Organization of the United Nations/World Health Organization.

JHeimbach LLC. 2014. "GRAS Notice No. 503." *U.S. Food & Drug Administration.* March 5. Accessed November 21, 2017. https://www.fda.gov/downloads/Food/IngredientsPackagingLabeling/GRAS/NoticeInventory/UCM403104.

Joseph, Joshny, S. N. Kanchalochana, G. Rajalakshmi, Vedha Hari, and Ramya Devi Durai. 2012. "Tamarind seed polysaccharide: A promising natural excipient for pharmaceuticals." *International Journal of Green Pharmacy 6* 270 - 278.

Khounvilay, K., and W. Sittikijyothin. 2012. "Rheological behaviour of tamarind seed gum in aqueous solutions." *Food Hydrocolloids 26* 334-338.

Korabathina, Kalyani. 2017. "Methanol Toxicity." *Medscape*, January 31.

Koraym, Ashraf, Valerie Waters, and Christine L. Williams. 2009. "Health benefits of dietary fiber." *Nutrition Reviews 67 no. 4* 188-205.

Kumar , Chandini S., and Sila Bhattacharya. 2008. "Tamarind Seed: Properties, Processing and Utilization." *Critical Reviews in Food Science and Nutrition 48 no. 1* 1-20.

Mahapatra, Ajay Kumar, and D. D. Tewari. 2005. "Importance of non-timber forest products in the economic valuation of dry deciduous forests of India." *Forest Policy and Economics 7 no. 3* 455-467.

Marathe, R. M., U. S. Annapure, R. S. Singhal, and P. R. Kulkarni. 2002. "Gelling behaviour of polyose form tamarind kernel polysaccharide." *Food Hydrocolloids 16* 423-426.

Merriam-Webster. 2017. *Merriam-Webster Dictionary.* Accessed November 27, 2017. https://www.merriam-webster.com/dictionary/colloid.

Milani, Jafar, and Gisoo Maleki. 2012. "Hydrocolloids in Food Industry." In *Food Industrial Processes - Methods and Equipment*, by Benjamin (Ed.) Valdez, 17-38. DOI: 10.5772/2491: InTech.

Mishra, Anuradha, and Annu Vij Malhotra. 2009. "Tamarind xyloglucan: a polysaccharide with versatile application potential." *Journal of Materials Chemistry* DOI: 10.1039/b911150f.

Mohamed, H. A., B. E. Mohamed, and K. E. Ahmed. 2015. "Physicochemical Properties of Tamarind (Tamarindus indica) Seed Polysaccharides." *Journal of Food Processing and Technology 6 no. 6* 452.

Morton, J. 1987. "Tamarind. p. 115-121. In: Fruits of warm climates." *Purdue University Center for New Crop & Plant Products.* Accessed November 28, 2017. https://hort.purdue.edu/newcrop/morton/tamarind.html.

Mudgil, Deepak, and Sheweta Barak. 2013. "Composition, properties and health benefits of indigestible carbohydrate polymers as dietary fiber: A review." *International Journal of Biological Macromolecules 61* 1-6.

Nagajothi, M. S., A. Balasubramanian, Nandhkishore Thombare, and P. R. Renganayaki. 2017. "Effect of Different Seed Sources on Tamarind Kernel Powder and Seed Gum Yield." *Int.J.Curr.Microbiol.App.Sci 6, no. 7* 318-323.

NIOSH. 2017. "Methanol: Systemic Agent." *Center for Disease Control and Prevention.* November 9. Accessed December 11, 2017. https://www.cdc.gov/niosh/ershdb/emergencyresponsecard_29750029.html.

Nishinari, K., and R. Takahashi. 2003. "Interaction in polysaccharide solutions and gels." *Current Opinion in Colloid and Interface Science 8* 396–400.

Nishinari, K., M. Takemasa, H. Zhang, and R. Takahashi. 2007. "2.19 Storage Plant Polysaccharides: Xyloglucans, Galactomannans, Glucomannans." In *Comprehensive Glycoscience*, by J. P. Kamerling, 613-652. DOI: 10.1016/B978-044451967-2/00146-X: Elsevier Ltd.

Nitta, Yoko. 2005. *Gelation and Gel Properties of Gellan Gum and Xyloglucan.* Thesis, Osaka City University: Department of Food and Human Health Sciences, Graduate School of Human Life Science.

Nitta, Yoko, and Katsuyoshi Nishinari. 2005. "Gelation and gel properties of polysaccharides gellan gum and tamarind xyloglucan." *Journal of Biological Macromolecules 5 no. 3* 47-52.

Nitta, Yoko, Bo S. Kim, Katsuyoshi Nishinari, Toshio Oomoto, and Iwao Asai. 2003. "Synergistic Gel Formation of Xyloglucan/Gellan Mixtures as Studied by Rheology, DSC, and Circular Dichroism." *Biomacromolecules 4* 1654-1660.

NOP. 2016. "NOP 5033-2: Guidance Decision Tree for Classification of Agricultural and Nonagricultural Materials for Organic Livestock Production or Handling." *NOP Handbook.* December 2. Accessed December 1, 2017. https://www.ams.usda.gov/sites/default/files/media/NOP-Ag-NonAg-DecisionTree.pdf.

—. 2017. *Organic Integrity Database.* Accessed December 12, 2017. https://organic.ams.usda.gov/Integrity/.

—. 2017. *Organic Integrity Database.* Accessed December 15, 2017. https://organic.ams.usda.gov/Integrity/.

Patel, Thrushar R., Gordon A. Morris, Anna Ebringerova, Melita Vodenicarová, Vladimir Velebny, Alvaro Ortega, Jose Garcia de la Torre, and Stephen E. Harding. 2008. "Global conformation analysis of irradiated xyloglucans." *Carbohydrate Polymers 74* 845-851.

Picout, David R., Simon B. Ross-Murphy, Neil Errington, and Stephen E. Harding. 2003. "Pressure Cell Assisted Solubilization of Xyloglucans: Tamarind." *Biomacromolecules 4* 799-807.

Pongsawatmanit, R., T. Temsiripong, S. Ikeda, and K. Nishinari. 2006. "Influence of tamarind seed xyloglucan on rheological properties and thermal stability of tapioca starch." *Journal of Food Engineering 77 no. 1* 41-50.

Pongsawatmanit, Rungnaphar , Theerana Temsiripong, Shinya Ikeda, and Katsuyoshi Nishinari. 2006. "Influence of tamarind seed xyloglucan on rheological properties and thermal stability of tapioca starch." *Journal of Food Engineering 77 vol. 1* 41-50.

Ranaivoson, Tahiry, Katja Brinkmann, Bakolimalala Rakouth, and Andreas Buerkert. 2015. "Distribution, biomass and local importance of tamarind trees in south-western Madagascar." *Global Ecology and Conservation 4* 14-25.

RheoSense. 2016. "Viscosity of Newtonian and non-Newtonian Fluids." *RheoSense.* Accessed November 17, 2017. http://www.rheosense.com/applications/viscosity/newtonian-non-newtonian.

Saha, D., and S. Battachyra. 2010. "Hydrocolloids as thickening and gelling agents in food: a critical review." *Journal of Food Sciences Technology 47 vol. 6* 587-597.

Salazar-Montoya, J. A., E. G. Ramos-Ramirez, and V. A. Delgado-Reyes. 2002. "Changes of the dynamic properties of tamarind (Tamarindus indica) gel with different saccharose and polysaccharide concentrations." *Carbohydrate Polymers 49* 387-391.

Sano, M., E. Miyata, S. Tamano, A. Hagiwara, N. Ito, and T. Shirai. 1996. "Lack of carcinogenicity of tamarind seed polysaccharide in B6C3F1 mice." *Food and Chemical Toxicology 34 no. 5* 463-467.

Sidley Chemical Co., Ltd. 2013. "Tamarind Gum." Visitchem.com. July 25. Accessed November 16, 2017. http://www.visitchem.com/tamarind-gum/.

Sims, Ian M., Alison M. Gane, David Dunstan, Gregory C. Allan, David V. Boger, Laurence D. Melton, and Anthony Bacic. 1998. "Rheological properties of xyloglucans from different plant species." *Carbohydrate Polymeres 37* 61-69.

TACC. 2004. "Secrets of Shear Thinning." *Texas Advanced computing Center.* Accessed November 17, 2017. https://www.tacc.utexas.edu/documents/13601/138850/secrets_of_shear_thinning.pdf.

Univ. Utah Chemical Engineering Dept. n.d. "A Viscosity Primer: Viscosity Definitions." *University of Utah Chemical Engineering Department.* Accessed November 15, 2017. https://www.che.utah.edu/site-specific-resources/chemical-engineering/department_equipment/Projects_Lab/A_Viscometers/ViscosityDefinitions.pdf.

Veluraja, K., S. Ayyalnarayanasubburaj, and A. J. Paulraj. 1997. "Preparation of gum from Tamarind seed and its application in the preparation of composite material with sisal fibre." *Carbohydrate Polymers 34* 377 - 379.

Whistler, R. L., and D. J. Barkalow. 1993. "Tamarind Gum." In *Industrial Gums: Polysaccharides and Their Derivatives 3rd Ed.*, by R. L. Whistler and J. N. BeMiller, 247-250. San Diego: Academic Press.

Whistler, Roy (Ed.). 1973. *Industrial Gums: Polysaccharides and Their Derivatives.* New York: Academic Press.

WHO. 2017. "Basic Analytical Technology." *International Programme on Chemical Safety.* Accessed December 11, 2017. http://www.who.int/ipcs/publications/training_poisons/basic_analytical_tox/en/index10.html.

—. 2014. "Information note: Methanol poisoning outbreaks." *World Health Organization.* July. Accessed December 11, 2017. http://www.who.int/environmental_health_emergencies/poisoning/methanol_information.pdf.

Williams, P. A., and G. O. Phillips. 2003. "Gums: Properties of Individual Gums." In *Encyclopedia of Food Sciences and Nutrition*, by B. Caballero and et al., 2992-3001. San Diego: Academic Press.

Wüstenberg, Tanja. 2015. *Cellulose and Cellulose Derivatives in the Food Industry: Fundamentals and Applications, First Ed.* Wiley-VCH Verlag GmbH & Co. KGaA.