United States Department of Agriculture
Agricultural Marketing Service | National Organic Program
Document Cover Sheet
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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.

Agar-agar
Handling/Processing

Identification

Chemical Names:
agar; agar-agar

Other Names:
Chinese gelatin; gelose; grass jelly; Japan isinglass; kanten; seaweed jelly; vegetable gelatin

Trade Names:
Gelagar, Unbleachagar (B&V srl); Grand Agar, Ecoagar (Hispanagar); Quick Soluble Agar (INA); Speed Agar 80 (Mitsui Sugar)

CAS Numbers:
9002-18-0 (agar-agar)
9046-34-8 (agaropectin)
9012-36-6 (agarose)

Other Codes:
E Numbers: E406 (agar)
EC (EINECS) Numbers: 232-658-1 (agar)

Summary

This limited scope technical report provides updated information to the National Organic Standards Board (NOSB) to support the sunset review of agar-agar, listed at 7 CFR 205.605(a)(2). For the remainder of this report, we will refer to the material simply as "agar." Agar is currently allowed as a nonsynthetic nonagricultural substance for use in organic processing and handling. This report focuses on the manufacturing processes used to make the substance. We also discuss whether other materials can be used as alternatives in place of agar.

The NOSB initially reviewed agar in 1995 (NOSB, 1995a, 1995b). It was included on the National List of Allowed and Prohibited Substances (hereafter referred to as the "National List") with the publication of the first National Organic Program (NOP) final rule, *National Organic Program* (65 FR 80548, December 21, 2000). The NOSB recommended its renewal in 2007, 2012, 2016, and 2021 (NOSB, 2007, 2012b, 2016b, 2021a).

In 2011, the NOSB Handling Subcommittee considered adding agar to § 205.605(b) while simultaneously maintaining the listing at § 205.605(a) (NOSB, 2012b). The subcommittee supported this action through a unanimous vote (NOSB, 2012b). However, public comments noted that proper classification required the finalization of the *Classification of Materials* document (later finalized as Guidance NOP 5033-1) (NOSB, 2012a). The NOSB Handling Subcommittee then revised its proposal to renew agar at § 205.605(a) and revisit its classification after finalization of NOP 5033-1 *Decision Tree for Classification of Materials as Synthetic or Nonsynthetic* (NOSB, 2012a). In 2016, the NOSB Handling Subcommittee stated once again that agar might need to be reclassified, but that they would wait until after the NOP finalized NOP 5033-1 (NOSB, 2016a). In 2021, the NOSB repeated the idea that agar could also be listed at § 205.605(b), but voted to retain its listing at § 205.601(a) (NOSB, 2021b). The NOSB noted that the availability of nonsynthetic agar may be limited (NOSB, 2021b).

Due to the NOSB's interest in the reclassification of agar, this report offers considerable analysis of those manufacturing process steps [see *Evaluation Question #1B* and *Evaluation Question #1(C)* in particular].

Characterization

Composition of the Substance:
Agar is a mixture of polysaccharides derived from red algae (seaweed). The two main fractions, designated agarose and agaropectin, are both repeating chains (polymers) with each unit (monomer) composed of two alternating galactose molecules (Alba & Kontogiorgos, 2019; Nasrollahzadeh et al., 2021; Sarkar et al., 2024) (see *Figure 1*). Agarose is a long, linear polysaccharide with a neutral charge. It is formed from the following two alternating units linked by glycosidic bonds (Hernández-Carmona et al., 2013; Sarkar et al., 2024):

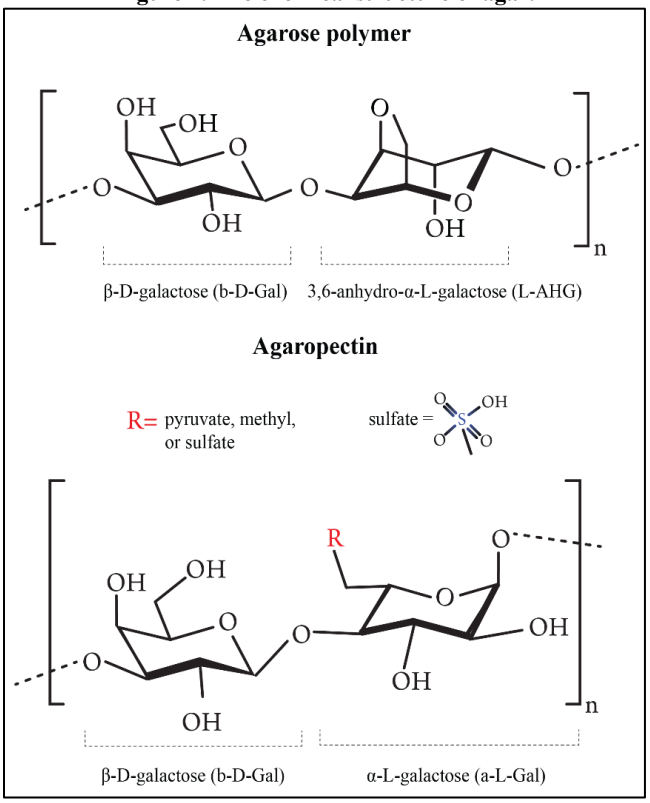
- β-1,3-linked D-galactose (b-D-Gal)
- α-1,4-linked 3,6-anhydro-L-galactose (L-AHG)[1]

[1] The numbers in the molecule names communicate the location of substituent groups. The number is relative to a specific carbon in the 6-carbon ring. For example, 3,6-anhydrolactose means that there are functional groups at carbons 3 and 6 of the ring.

Agarose also contains very small amounts of pyruvate (Xiao et al., 2020). Agarose has a high molecular weight, often exceeding 150,000 Daltons (Da), and is mainly responsible for agar's gelling function (Armisén & Galatas, 2009). Processed agar products contain roughly 70% agarose (Khalil et al., 2018).

Agaropectin exists within the algal cell wall as relatively shorter, branched chains of variable charge (Sarkar et al., 2024). It has a backbone with alternating units of b-D-Gal and α-L-galactose (a-L-Gal) (Alba & Kontogiorgos, 2019). Roughly every 10th unit is modified with acidic side-groups such as pyruvate, sulfate, or methyl groups (Imeson, 2010; Lee et al., 2017; United States Pharmacopeial Convention, 2025). Agaropectin cannot form gels; it provides texture and elasticity in the agar, and its molecular weight is usually below 20,000 Da (Armisén & Galatas, 2009). The two fractions (agarose and agaropectin) often exist in the same polymer chain (Arnott et al., 1974). However, the higher the number of sulfate groups and other side chains, the higher the proportion of agaropectin and the shorter the overall polymer. Arnott et al. (1974) note that scientists named both structures after extracting the "more pure" agarose; the remainder was designated agaropectin.

Figure 1. The chemical structure of agar.



Source or Origin of the Substance:

Agar polysaccharides occur naturally in the inner cell walls of algae (Sarkar et al., 2024). They create a flexible structure that helps algae withstand the varying stresses of currents and wave motion (Hernández-Carmona et al., 2013; Lee et al., 2017). They also serve as the algae's reserve of energy for cell function and growth, embedded in a strong, stable structure of crystallized cellulose fibers (Armisén & Galatas, 2009). Agar polysaccharides may also help maintain cellular ionic equilibrium and protect against pathogens, desiccation, and extremes in salinity, pH, and temperature (Lee et al., 2017).

Although scientists are still working to understand agar formation, they have described three stages of formation that occur mainly in the chloroplast and Golgi apparatus of the algal cell (Lee et al., 2017; Sarkar et al., 2024):[2]

1. galactose monomer creation
2. monomer chain construction
3. side chain modifications

Algae take in atmospheric carbon dioxide as part of their normal metabolism. They use this carbon to form the precursors for building the agar polysaccharides (Sarkar et al., 2024). Fructose-6-phosphate (F6P), and glucose-6-phosphate (G6P) are the major precursors required to make the intermediates GDP-L-galactose and UDP-D-galactose in the cytosol. These intermediates are transported into the Golgi apparatus, where enzymes called

[2] The chloroplast is a type of organelle that conducts photosynthesis. The Golgi apparatus (or complex) is an organelle responsible for chemically modifying proteins and packaging them into vesicles for transport throughout the cell. Cell wall material also passes through it.

galactosyl transferases, specialized for the linkages between the monomer units, catalyze the D- and L-galactose chain assembly (Sarkar et al., 2024).[3]

In subsequent side-chain substitutions, some of the galactose units are modified with acidic methoxyl, sulfate, or pyruvate groups, at different positions along the main chain, depending on the algal species (Lee et al., 2017; Nasrollahzadeh et al., 2021; Sarkar et al., 2024).

1. In sulfation, a sulfate group joins one of the hydroxyl (OH) groups of the linked a-L-Gal unit, forming L-galactose 6-sulfate (L-Gal6S).
2. The Golgi apparatus secretes this intermediate, sulfated form of agar.
3. And a final enzymatic step desulfates L-Gal6S to produce L-AHG, converting the chain mostly into agarose.

The rest remains in the form designated as agaropectin, which commonly contains 5-8% sulfate (Armisén & Galatas, 2009). The amount of desulfation activity, and therefore the final agarose content, varies with species and environmental factors including (Sarkar et al., 2024):

- light intensity
- temperature
- carbon dioxide concentration
- nutrient availability

For example, Armisén & Galatas (2009) reported that rhizoid cells are more numerous in one algal species where surrounding water currents are stronger.[4] Rhizoid cell walls are especially thick, and may contain more agar polysaccharides than other cells (Imeson, 2010). Higher overall cell count indicates more numerous cell walls and therefore a higher agar content.

To produce food-grade agar, manufacturers use algal species mainly from the genus *Gracilaria* (Hernández-Carmona et al., 2013; Khalil et al., 2018). The cultivated species are genetically diverse, but are not numerous (Vieira et al., 2025). Compared to agar from species in the *Gelidium* and *Pterocladia* genera, *Gracilaria* algae produce agar that is generally more sulfated (*i.e.,* has a higher prevalence of sulfate groups on the linked a-L-Gal units) and contains more agaropectin (Alba & Kontogiorgos, 2019; Hernández-Carmona et al., 2013). Red algae synthesize these L-Gal6S units as a biological precursor of L-AHG, and then enzymatically convert them to the anhydrous form (as described above). *Gracilaria spp.* do not naturally perform the amount of desulfation necessary, during their lifetime, for commercial agar production (Armisén & Galatas, 2009), meaning these algae naturally produce agar with less gel-forming capability than agars from the other genera. Consequently, agar manufacturers pretreat *Gracilaria spp.* with alkali solutions to promote gel strength through chemical desulfation reactions (Imeson, 2010). The enzymatic desulfation process is much more naturally active in *Gelidium* and *Pterocladia spp.* (Hernández-Carmona et al., 2013; Sarkar et al., 2024).[5]

Gracilaria spp. accounted for 91% of all agar production in 2015 (Porse & Rudolph, 2017). Manufacturers rarely produce food-grade agar from *Gelidium* spp. (Santos & Melo, 2018). Scientists typically use agar extracted from *Gelidium* spp. in pharmacology and microbiology applications (Porse & Rudolph, 2017). *Gelidium* and *Pterocladia* spp. produce agar with higher gel strength and lower gelling temperatures than those from *Gracilaria* spp. (Hernández-Carmona et al., 2013). This is an essential characteristic for scientific applications. Scientific demand is consistently strong because these species are much more difficult to cultivate than *Gracilaria* algae, and shortages have occurred (Khalil et al., 2018; Porse & Rudolph, 2017).

Evaluation Questions

Classification of the Substance:

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

Red macroalgae (seaweeds) produce agar polysaccharides in their cell walls (Sarkar et al., 2024). Although red macroalgae include some freshwater species, the agar-producing species live in marine environments (Kang et al., 2022). Some species can only be wild-harvested, but most food-grade agar comes from cultivated species (Porse & Rudolph, 2017). Agar is extracted from a naturally occurring organism; however, technically speaking, that organism is not a plant or animal (NOP, 2016b). Historically, the NOP has applied the term “aquatic plants” broadly to marine macroalgae, seaweed, and marine vegetation (NOP, 2025).

[3] Details on the precise functions of galactosyl transferases remain under study (Sarkar et al., 2024).
[4] A rhizoid is a projecting structure on seaweed that enables it to anchor itself to a sandy substrate.
[5] Ongoing reorganization of biological taxonomies due in part to advances in genetic analysis has caused name changes for some agar-producing algae, resulting in some inconsistency in the literature. Where this report mentions specific species, we also provide former names as needed.

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

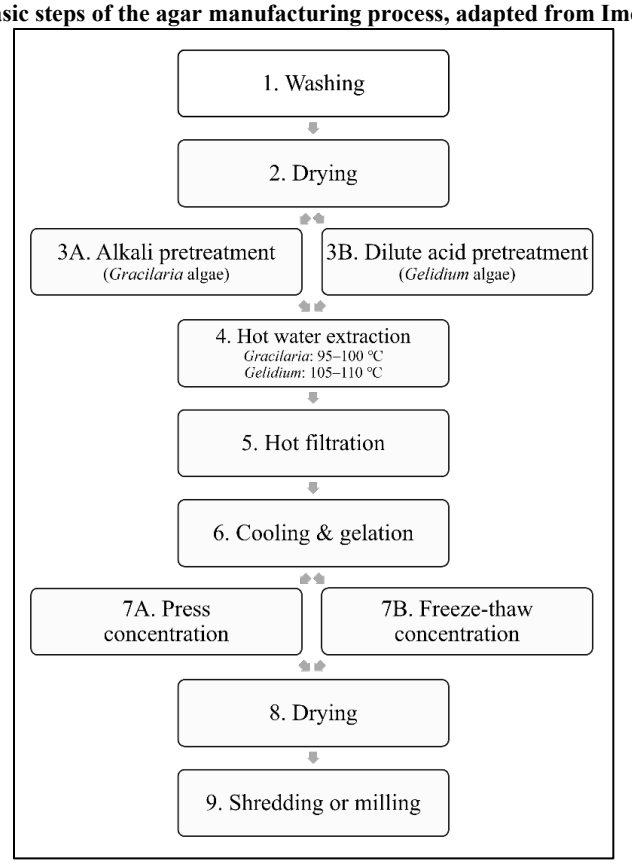
Extracting agar from red algae typically involves several common steps (see *Figure 2*). Manufacturers may use a wide variety of adjustments and materials according to the particular species, growing conditions, and desired agar properties (Yousefi et al., 2013). The amount and composition of the agar is highly variable within and across individuals, species, locations, and time of year (Michalak & Chojnacka, 2014).

Aside from these variable adjustments, the basic processing steps are as follows (Armisén & Galatas, 2009; Arnott et al., 1974; Imeson, 2010; McHugh, 2003; NOP, 2011; Santos, 1990):

1. Macroalgae are harvested, washed, and dried.
2. *Gracilaria* algae are generally pretreated with an alkaline solution; other types receive mild acidic pretreatments.
3. The pretreated algal material is boiled or soaked in hot water to extract the agar.
4. The liquid is filtered to remove algal material, then allowed to cool.
5. The gelled agar is then concentrated to 12-20% by pressing, or more rarely, with cycles of freezing and thawing.
6. The gel is dried, shredded or milled, and packaged.

Literature reviewed for this report indicates that agar's basic manufacturing processes have not changed substantially since publication of the 2011 technical report (NOP, 2011).

Figure 2: Basic steps of the agar manufacturing process, adapted from Imeson (2010).



Harvesting, washing, drying

Producers cultivate most *Gracilaria* algae on farms (McHugh, 2003; Porse & Rudolph, 2017; Santos, 1990). Near-shore operations use floating bamboo rafts with netting or bottom cultivation; inland producers use tanks or ponds (Sugumaran et al., 2022). They may harvest by hand or use a variety of tools such as nets and rakes (McHugh, 2003). They also use suction tubes and cutting machines (McHugh, 2003). Alternatively, producers may gather algae that washes ashore (McHugh, 2003). The following process details are relevant to *Gracilaria spp.*, except where specified.

1. Next, they wash the algal biomass in seawater to remove foreign matter. Depending on the farm configuration or wild-harvesting conditions, they may sort by species (Santos, 1990).

2. The algae is then dried either in an oven or by the sun, to 15-20% moisture (Santos, 1990). Manufacturers do this quickly because *Gracilaria* spp. produce hydrolyzing enzymes that can begin breaking down the agar (Imeson, 2010; Santos, 1990).

At some point in the process, the algae may be ground or cut to about 250 µm to maximize the surface area in contact with solvents (Michalak & Chojnacka, 2014).

Pretreatment

Specific agar manufacturing details are proprietary, but researchers have documented a wide variety of different pretreatments.

3A. In most cases, the lightly processed algae are pretreated with an alkali solution (see *Table 1*) (Hernández-Carmona et al., 2013). This pretreatment improves the gel strength and purity of agar extracted from *Gracilaria* algae by desulfating the agar before the main gel extraction step (Khalil et al., 2018) (see *Agar's chemical changes during pretreatment and extraction*, below, for more information on this chemical process). However, alkali pretreatment also reduces the agar yield, likely by hydrolyzing links in the agar polymers (Cebrián-Lloret et al., 2024; Sarkar et al., 2024; Yousefi et al., 2013). The alkali concentration, temperature, and soaking time are therefore adapted to each species to maximize desulfation without reducing yield (Hernández-Carmona et al., 2013; Santos, 1990; Yousefi et al., 2013). Additionally, some *Gracilaria* agars contain sulfate groups that are alkali-stable and cannot be converted by this method (Santos, 1990; Xiao et al., 2020).

3B. Agar from the less-sulfated *Gelidium* and *Pterocladia* species does not require strong pretreatment (Armisén & Galatas, 2009; Hernández-Carmona et al., 2013). Manufacturers using these species can adjust the pH with dilute sulfuric or other acid to make extraction more efficient in the next step (Armisén & Galatas, 2009). However, the limited availability of *Gelidium* and *Pterocladia* and the strong demand for their use in biotechnology and microbiology likely prevents their widespread use in food-grade agar (Porse & Rudolph, 2017).

Pretreatments can remove impurities such as proteins, lipids, and ash from the algae (Cebrián-Lloret et al., 2024). They can also disrupt cells to release the polysaccharides and make treatments more effective (Michalak & Chojnacka, 2014). Researchers have described so many specific pretreatments that it is difficult to clearly delineate between pretreatment and main gel extraction in a generalized process description (see *Table 1*).

Table 1: Pretreatment techniques used in agar production.

Objective	Method	References
Remove impurities	Alkali solution	(Khalil et al., 2018; Martínez-Sanz et al., 2019)
Bleaching, promote gel strength	Alternating sun-drying and sprinkling with lime suspension	(Santos, 1990)
Encourage cell lysis	Acid or alkali solvents	(Michalak & Chojnacka, 2014)
Promote gel strength[6]	1-2 hours in sodium hydroxide solution (0.5%-7%) at 85–90 °C	(Hernández-Carmona et al., 2013; Khalil et al., 2018)
Promote gel strength	1 hour in 2-5% sodium hydroxide at 85–90 °C	(Imeson, 2010; McHugh, 2003)
Promote gel strength	3 days in sodium hydroxide (20%) at room temperature	(Santos, 1990)
pH adjustment	Various	(Khalil et al., 2018)
Eliminate phycoerythrine pigment; macerate to raise extraction efficiency (*Gelidium* spp. only)	Mild alkali solution, usually sodium carbonate	(Hernández-Carmona et al., 2013)
Raise extraction efficiency (*Gelidium* spp. only)	Dilute sulfuric or other acid	(Armisén & Galatas, 2009; Imeson, 2010)
Promote gel strength (*Gracilariopsis lemaneiformis*)	60-90 minutes in sodium hydroxide (3-5%) at 95 °C*	(Santos, 1990)
Purification in sonication and ultrasound experiments	2 hours in sodium hydroxide (10%) at 90 °C*	(Martínez-Sanz et al., 2019)
Promote gel strength	Steam explosion*	(Murano et al., 1993)

* Reported as experimental method only.

Manufacturers may wash the algae again, or add a weak acid to adjust pH before the next processing step (Hernández-Carmona et al., 2013). G. A. Santos (1990) describes an additional step of soaking with acetic acid for 30 minutes at a pH of 5.6-6.0 just before the main extraction step.

[6] Convert unstable sulfated molecules into 3,6-anhydro-L-galactose to increase gel strength in the final product (see *Source or Origin of the Substance*).

Gel extraction

4. Manufacturers soak the pretreated algal mass in hot or boiling water to separate the polysaccharides from the cell structure. (Hernández-Carmona et al., 2013; McHugh, 2003; Santos, 1990; Sarkar et al., 2024). Soaking for 2-4 hours at 95 °C is a typical extraction step. However, controlling pH helps maximize yield (Armisén & Galatas, 2009) because the strong alkali pretreatment may hydrolyze the linkages holding the agar polymers together (Murano et al., 1993). Hernández-Carmona et al. (2013) note that acid may be added to reach pH 6.3-6.5. Additionally, extraction under pressure can shrink processing time (Hernández-Carmona et al., 2013).

Filtering

5. Filtering separates the vegetative residue from the solution of water and agar (Armisén & Galatas, 2009). This step may happen at room temperature, but filtering while the solution is still hot is more common (Armisén & Galatas, 2009; Santos, 1990). Manufacturers often filter under pressure (Armisén & Galatas, 2009); they may use a filtering aid such as diatomaceous earth, or filter with cotton or muslin bags (Armisén & Galatas, 2009; Martínez-Sanz et al., 2019).

6. The filtered crude extract gels as it cools. It may be further treated with bleach (for color) or amylase, or precipitated in isopropanol to remove remaining algal residue and further purify the agar, and it may be washed once more (Khalil et al., 2018; Murano et al., 1993). This gel contains roughly 1% agar (Hernández-Carmona et al., 2013). The following concentration step serves to expel the remaining water and concentrate the agar.

Gel press concentration

7A. Applying force to expel water from the gel network is the most common way to concentrate the agar content (Cybercolloids LTD, n.d.; Imeson, 2010). The agar gel is packed between porous filter cloths and squeezed in an automated hydraulic press to push water out of the gel (Armisén & Galatas, 2009; Hernández-Carmona et al., 2013).[7] The press progressively applies 5–10 kg/cm^2 over 24 hours (Imeson, 2010; McHugh, 2003).

Freeze-thaw concentration

7B. Cycles of freezing and thawing are also effective for extracting water from the agar gel, as each successive thaw allows more water to exit the gel (Armisén & Galatas, 2009). Freezing must occur slowly enough for the ice to separate and form large crystals (Imeson, 2010). But manufacturers can shorten the thawing time by spraying the frozen agar with water (McHugh, 2003). This technique was developed in the 1650s, and it persists on a small scale (Armisén & Galatas, 2009). Manufacturers may strain the concentrated gel by centrifugation, to reach a 10-12% agar (Armisén & Galatas, 2009).

The freeze-thaw method is energy intensive; producing one ton of agar may require the energy equivalent to producing 80-100 tons of ice (Armisén & Galatas, 2009; Hernández-Carmona et al., 2013). It also requires time; ice crystals forming too quickly can prevent the gel mesh from forming (Gunasekera, 1963). Additionally, drying the thawed gel requires more energy because of the higher starting water content relative to the press method (McHugh, 2003) The freeze-thaw method removes both water and soluble impurities less efficiently than the press method, yielding a final product with more impurities (Hernández-Carmona et al., 2013). The press method can produce a gel of 20% dry extract weight, or almost twice the concentration achieved with freezing-thawing (Armisén & Galatas, 2009).

G.A. Santos (1990) additionally describes a hybrid process, applied to smaller samples, with a single freezing and thawing step followed by manual squeezing.

Drying, milling and packaging

8. Manufacturers may use sun drying, freeze drying, ovens, or additional treatments such as isopropanol to shorten drying time (Santos, 1990).

9. The agar is then shredded, flaked, or made into bars or strips (Imeson, 2010). Alternatively, it can be milled into a powder and then sieved, usually to a size of 80-100 mesh, before packaging (McHugh, 2003).

Alternate manufacturing methods

In general, industrial agar production requires large quantities of both alkali materials for pretreatment and energy to sustain high temperatures for several hours (Hernández-Carmona et al., 2013; Khalil et al., 2018). The typical process takes 2-4 hours for extraction, and consumes energy and water (15–20 times the weight of dry algae used,

[7] Some researchers have called this process *syneresis*, a term that more commonly applies to the phenomenon of a finished gel product losing water or "weeping" due to certain properties or conditions. The term generally denotes the separation of liquid from a gel (McHugh, 2003).

not including washing or freeze-thawing) (Khalil et al., 2018). It also requires manufacturers to control various waste products generated at different stages (Mendes et al., 2024). These materials are costly in terms of waste disposal and exposure to employees and the environment.

Alternative agar extraction methods described in literature could potentially reduce solvent and energy use. According to researchers, these methods can produce agar similar to commercial products in the lab (Martínez-Sanz et al., 2021; Murano et al., 1993; Sarkar et al., 2024). However, we found no evidence that manufacturers currently use these methods for commercial agar production. Mendes et al. (2024) observed that research on improving extraction methods continues, but some proposed techniques are still early in development, and some studies omit consideration of scaling up to industrial level. We also note that production processes generally remain confidential. We describe some of the alternative manufacturing methods for agar below. Alternative materials or substitutes for agar in processed foods are described later in this report.

Murano et al. (1993) investigated a steam explosion pretreatment and reported that exposing agar to 150 °C for 15 seconds produced a higher agar yield than the typical alkali pretreatment.

Enzyme-assisted extraction can be performed at room temperature, with the potential to reduce both energy and solvent requirements for agar producers with lower risk of agar degradation (Kang et al., 2022; Michalak & Chojnacka, 2014). However, enzymes are not generally used for cell lysis or agar extraction because they are costly compared to other options (Michalak & Chojnacka, 2014; Porse & Rudolph, 2017). In addition, algal cell walls are heterogeneous, chemically and structurally, compared to other types of cells (Michalak & Chojnacka, 2014). The challenge of finding or engineering the appropriate enzymes for agar extraction are therefore more complex (Michalak & Chojnacka, 2014). Although enzyme development continues, these techniques are not yet being applied to agar extraction.

Microwave- and ultrasound-assisted extraction (MAE and UAE) procedures are low-cost and have been used effectively in large-scale commercial chemical extractions (Mendes et al., 2024; Michalak & Chojnacka, 2014). Both methods can potentially accelerate extraction (Khalil et al., 2018; Michalak & Chojnacka, 2014) while using less energy and solvent and generating less waste (Hernández-Carmona et al., 2013). In an experiment, Sousa et al. (2013) produced commercially acceptable agar in 5 minutes with MAE, while the traditional hot water extraction took 2 hours. Additionally, newer specialized microwave systems offer researchers more control over pressure and temperature than the familiar domestic devices they used in early experiments (Sousa et al., 2013).

Alkali extraction techniques currently used for improving gel strength are also known to reduce agar yield (Hernández-Carmona et al., 2013; Rhein-Knudsen & Meyer, 2021). Large temperature changes can also cause sub-optimal extraction and loss of product (Kang et al., 2022). Researchers have investigated lower-temperature processes that consequently require less energy (Armisén & Galatas, 2009; Cebrián-Lloret et al., 2024) and carry less risk of product damage. For example, G. A. Santos (1990) reported a procedure that used very strong alkali, up to 45% sodium hydroxide. This method consisted of soaking the algae in the cold solution for up to 40 days, which produced a 10-fold increase in the agar gel strength.

Agar's chemical changes during pretreatment and extraction

To improve gel strength of agar produced from *Gracilaria spp.,* producers use the typical alkali pretreatments to remove sulfate groups from the naturally occurring L-galactose 6-sulfate (L-Gal6S) units and raise the proportion of 3,6-anhydro-L-galactose (L-AHG) (Khalil et al., 2018; Rhein-Knudsen et al., 2015). Heating agar in strong alkaline media ionizes the hydroxyl (-OH) groups in position 3 and displaces the sulfate groups in position 6 of the L-Gal6S (Hernández-Carmona et al., 2013). This reaction is highly specific, affecting no other sulfate group (Hernández-Carmona et al., 2013) (see *Synthetic or nonsynthetic classification* and *Figure 3*). Removing the sulfate groups and creating more L-AHG units is essential for forming a strong and stable gel that is suitable for commercial applications (Rhein-Knudsen et al., 2015). This is a chemical change (NOP, 2011; Rhein-Knudsen et al., 2015).

This process also enables the formation of a three-dimensional helix structure and subsequent gel formation (Lee et al., 2017). Within the algal cell wall, the polysaccharides may resemble tangles or balls (Alba & Kontogiorgos, 2019). Without alkali pretreatment, the existing sulfate groups can disrupt helix formation and aggregation with their positive charge (Hernández-Carmona et al., 2013) and branched structures that "kink" the polysaccharide chain (Rees, 1969; Rhein-Knudsen et al., 2015). In this way, desulfation of L-Gal6S to create L-AHG allows the agar polysaccharides to more easily aggregate into helices and form a gel matrix during the hot water extraction.

When heated, the chains untangle and loosen into random coil conformations. Cooling the system to gelling temperature (33–45 °C) triggers a transition with two steps (Alba & Kontogiorgos, 2019):

1. Randomly distributed, single agarose coils join to form double-helical associations through intra-molecular hydrogen bonding.
2. Double helices aggregate through inter-molecular hydrogen bonding into a three-dimensional gel network.

The agar gel network is stabilized exclusively by hydrogen bonding between the L-AHG units of the chains (Alba & Kontogiorgos, 2019). This flexibly-bonded structure affects many of agar's physiochemical properties that are important to food processors, such as (Onyeaka & Nwabor, 2022; Qin, 2018):

- high melting point
- ability to gel without additional ions or solutes, or high sugar content
- thermo-reversibility (the gel melts with heating and gels again on cooling)
- wide range between gelling and melting temperatures (see *Evaluation Question #10*)

Evaluation Question #1(C): Based on the information provided on (A) and (B), the definition of synthetic at 7 U.S.C. 6502(22), NOP 5033-1 (Decision Tree for Classification of Materials as Synthetic or Nonsynthetic), and NOP 5033-2 (Decision Tree for Classification of Agricultural and Nonagricultural Materials for Organic Livestock Production of Handling), describe if this substance can be classified as agricultural or nonagricultural.

Agricultural or nonagricultural classification

Here we evaluate agar according to NOP 5033-2 Guidance: *Decision Tree for Classification of Agricultural and Nonagricultural Materials for Organic Livestock Production or Handling* (NOP, 2016c).

1. *Is the substance a mineral or bacterial culture as included in the definition of nonagricultural substance at section 205.2 of the USDA organic regulations?*

No. Agar is neither a mineral nor a bacterial culture.

2. *Is the substance a microorganism (e.g., yeast, bacteria, fungi) or enzyme?*

No. Agar is a material extracted from specific types of red macroalgae.

3. *Is the substance a crop or livestock product or derived from crops or livestock?*

Yes. Agar is extracted from the cell wall of red algae, an organism which may be farmed or harvested as a wild crop.

4. *Has the substance been processed to the extent that its chemical structure has been changed?*

Yes. Especially in agar from *Gracilaria* species, alkali extraction raises the proportion of 3,6-anhydrogalactose (L-AHG) within the polysaccharide to enhance gel strength in the final agar product. Heating the polysaccharide in strong alkaline media ionizes the hydroxyl group in position 3, and displaces the sulfate group in position 6 (see *Figure 3*) (Hernández-Carmona et al., 2013). This reaction is highly specific and affects no other sulfate group (Hernández-Carmona et al., 2013). Agar from a less-sulfated species does not require such strong treatment (Rioux & Turgeon, 2015). Hypothetically, if this treatment were applied to these algae, the same changes would occur on a smaller scale. The limited availability of less-sulfated algal species and the strong demand for their use in biotechnology and microbiology likely prevents their widespread use in food-grade agar (Porse & Rudolph, 2017).

Additionally, in the absence of the positively-charged sulfate groups, the agar polysaccharides more easily aggregate into helices through hydrogen bonding (Hernández-Carmona et al., 2013). The helix structure is important for agar gel formation, and can be disrupted by charged elements such as sulfates (Hernández-Carmona et al., 2013).

5. *Is the chemical change a result of naturally occurring biological processes such as fermentation or use of enzymes; or a result of mechanical/physical/biological processes described under section 205.270(a)?*

No. The chemical changes result from adding alkali pretreatments during the manufacturing process. Because *Gracilaria* spp. serve as the source for the majority of agar used in food, this extraction technique is used with most food-grade agar. Agar can be extracted using hot water alone and concentrated with the common mechanical methods of freezing-thawing and pressing (Khalil et al., 2018). However, a gel of lower strength would result even with the rarer *Gelidium* spp. The most widely available *Gracilaria* spp. produce gel of unacceptably low strength when extracted without alkali pretreatment (Imeson, 2010). Researchers are investigating enzyme-assisted extraction techniques (Khalil et al., 2018; Rhein-Knudsen et al., 2015); however, based on publicly available information, manufacturers are not using this method to produce agar commercially.

Therefore, agar should be classified as a nonagricultural substance.

Synthetic or nonsynthetic classification

Historic classification of agar

Agar has appeared on the National List at § 205.605(a) since the first publication of the NOP Final Rule (see *Summary*). Reviewers in the 1995 TAP report briefly outlined the main steps of agar extraction and found the substance to be natural, but did not specifically identify the pretreatment step using alkali (NOSB, 1995a). The NOSB voted that same year to allow agar to be used in organic processing (NOSB, 1995b). The board's discussion acknowledged the TAP review, but records from the NOSB meeting contain no other details regarding the

classification of agar or if only certain forms were considered nonsynthetic (NOSB, 1995b). The classification recommended by the NOSB in 1995 was not based on Guidance NOP 5033-1: *Decision Tree for Classification of Materials as Synthetic or Nonsynthetic*, which was not published until 2016.

In 2011, 2016, and 2021, the NOSB voted to maintain the listing at § 205.605(a) while also noting that the material may need to be reclassified (NOSB, 2012b, 2016b, 2021b). The NOSB Handling subcommittee proposed to revisit its classification after NOP 5033-1 was finalized (NOSB, 2012a). Citing information presented in the 2011 technical report and public comments, the NOSB Handling subcommittee noted that questions persisted regarding the availability of non-alkaline treated agar (NOSB, 2016a, 2021b).

At the current time, certifiers do not always review whether agar undergoes alkaline pretreatment, and may allow agar from such sources.

Classification by NOP 5033-1

With the exception of direct production of agar from hot water or enzyme assisted extraction, all the manufacturing processes we describe in this report are based on the same premise: manufacturers combine red algae with an alkali solution to produce commercial food-grade agar.

Here we evaluate agar according to NOP 5033-1 *Guidance*: *Decision Tree for Classification of Materials as Synthetic or Nonsynthetic* (NOP, 2016a).

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

Yes. Agar is extracted from the cell walls of red algae.

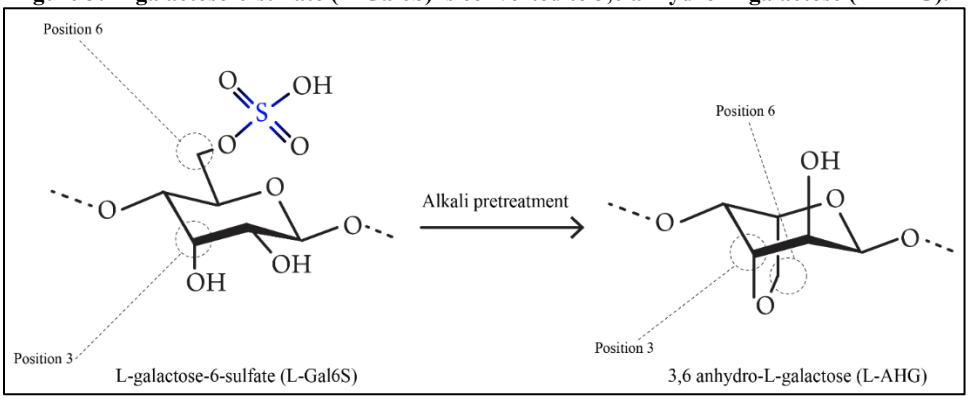
2. *Has the substance undergone a chemical change so that it is chemically or structurally different than how it naturally occurs in the source material?*

Yes. The agar polysaccharide undergoes a chemical change and is chemically and structurally different from how it naturally occurs in the algae (NOP, 2011). Agar used for food applications (from *Gracilaria* spp.) has been treated with a synthetic sodium hydroxide solution to increase gel strength (Lee et al., 2017; McHugh, 2003; NOP, 2011; Yousefi et al., 2013). This process removes sulfate groups originally present in the lightly processed red algae and changes the proportions and chemical structure of the constituent galactose units; in other words, L-galactose-6-sulfate (L-Gal6S) is converted to 3,6 anhydro-L-galactose (L-AHG) (Imeson, 2010; NOP, 2011; Yousefi et al., 2013).

Both L-Gal6S and L-AHG are naturally present in agar before alkali pretreatment (Lee et al., 2017). However, manufacturers increase the proportion of L-AHG in the agar structure by using the heated alkali pretreatment (Hernández-Carmona et al., 2013; Lee et al., 2017; Yousefi et al., 2013). The alkali causes the following reaction steps (see *Figure 3*) (Hernández-Carmona et al., 2013):

1. Sodium hydroxide ionizes the hydroxyl (-OH) group in position 3 of the L-Gal6S ring.
2. Because of this disturbance (ionization), electrons shift to maintain carbon ring stability.
3. The electron shift displaces the sulfate group in position 6, producing L-AHG.

Figure 3: L-galactose-6-sulfate (L-Gal6S) is converted to 3,6 anhydro-L-galactose (L-AHG).[8]



The removal of sulfate groups from the polysaccharide structure allows for a higher quality agar product (Yousefi et al., 2013). L-AHG forms helices through hydrogen bonding, creating a strong gel structure (Yousefi et al., 2013). The sulfate groups prevent helix formation (Rees, 1969; Rhein-Knudsen & Meyer, 2021). The proportion of L-

[8] To clearly show the changed elements in this conversion, the orientation of the galactose molecules appears inverted compared to those in Figure 3.

Gal6S units converted to L-AHG depends on the concentration of sodium hydroxide, time, and temperature (Yousefi et al., 2013). Manufacturers adapt these variables to the species they are extracting [see *Evaluation Question #1(B)*].

2b. At the end of the extraction process, does the substance meet all the criteria described at 4.6 of NOP 5033?
No. The substance has undergone a transformation into a different substance via chemical change, as described above.

3. Is the chemical change created by a naturally occurring biological process, such as composting, fermentation, or enzymatic digestion; or, by heating or burning biological matter?
No. The chemical change is created through treatment with alkali solutions during the manufacturing process (NOP, 2011). Agar can be extracted using hot water alone and concentrated with the common mechanical methods of freezing-thawing and hydraulic pressing (Khalil et al., 2018). However, this process results in a gel with lower strength, especially when used with the most available *Gracilaria* species (Imeson, 2010). Researchers have investigated enzymatic assisted methods, but these methods are not common in industrial use (Khalil et al., 2018). According to the decision tree, a chemical change caused by adding an alkaline substance results in a synthetic material.

Some certifiers and material review organizations may consider all agar to be allowed on the National List at § 205.605(a). In the case of the Accredited Certifiers Association, the organization considers agar a low-risk material (Accredited Certifiers Association, 2026). Given that the historic classification of agar may conflict with the outcome of classification using the Guidance NOP 5033-1 decision tree, we note the importance of the NOSB's role in ultimately determining classification and any necessary recommendations to the USDA for regulatory amendments.

Evaluation Question #1(D): Does this substance in its raw or formulated forms contain nanoparticles?
According to NOP Policy Memo 15-2, nanotechnology is conducted at the nanoscale, which is about 1 to 100 nanometers (nm) (NOP, 2015). The NOP uses the term "incidental nanomaterials" to refer to substances that are byproducts of other manufacturing (*e.g.,* homogenization, milling) or that occur naturally (NOP, 2015).

We found no references to nanotechnology being used in the production of agar. We did find instances where agar and other algal polysaccharides are used in combination with other materials in medical and pharmaceutical nanotechnology. However, these materials are used as drug carriers, not food additives (Mendes et al., 2024; Sarkar et al., 2024; Varshosaz et al., 2015).

Evaluation Question #1(E) Does this substance in its raw or formulated forms contain ancillary substances?
According to EU regulations, gel strength may be standardized by the addition of dextrose and maltodextrin or sucrose. Although manufacturers use various treatments at different points throughout the production process, these steps are all followed by washing. In addition, the purpose of the concentration step is to purge water, which makes up 99% of the gel, along with as many impurities as possible.

After filtering of the crude gel, researchers mention the possible use of bleach or amylase, or precipitation with isopropanol to remove algal residue (Khalil et al., 2018).

Evaluation Question #1(F): Is this substance created using excluded methods?
We found no information related to the current use of excluded methods to produce agar or its biological source material, red algae.

Opportunities for genetic manipulation might exist because much of the world's food-grade agar comes from cultivated species. In one experiment, scientists isolated specialized cells from a fragment of algal thallus tissue and cultured the cells to produce uniform algal seedlings, ideal for seedstock (Jiksing et al., 2022). They then induced separate sets of algal cells to fuse using polyethylene glycol or electrically with a cell fusion system (Jiksing et al., 2022). The authors gave no indication that red algae producers could use these methods commercially. Otherwise, methods to manipulate algae genetically remain far behind those developed for commonly used bacteria, fungi, and higher plants (U.S. DOE, 2010). Existing scientific studies on the genetics of algae appear strongly focused on biofuels and pharmacology (U.S. DOE, 2010).

Alternatives

Evaluation Question #9: Are there alternative nonsynthetic (natural) source(s) of the substance [7 CFR 205.600(b)(1)]?
While agar can be extracted using hot water, this method produces agar with less gel strength than alkali extracted agar (Cebrián-Lloret et al., 2024; Khalil et al., 2018). There are alternative extraction methods that could possibly

avoid or reduce the usage of solvents (see *Alternative manufacturing methods*). However, we found no evidence that manufacturers use these methods to produce food-grade agar at this time.

The quality of agar produced from both *Gelidium* and *Gracilaria* spp. is affected by alkali treatment before extraction (Hernández-Carmona et al., 2013). Alkali pretreatment increases gel strength in *Gracilaria* agar and increases extractability for *Gelidium* agar (Hernández-Carmona et al., 2013). Native agars (agar extracted without the use of an alkali) extracted from *Gracilaria* species have poor gel strength and do not meet commercial gel strength requirements (Khalil et al., 2018). In terms of quality, native agars are not equivalent to agars extracted using an alkali pretreatment.

Cebrián-Lloret et al. (2024) compared agar gels formed using alkaline pretreatment to gels formed without pretreatment. Of the three species samples, agar from alkaline-treated *Agarophyton chilensis* and *Gracilariopsis longissima* showed the greatest stiffness and resistance to fracture during compression (cohesiveness).[9] *Gelidium corneum* was the best untreated candidate for forming a gel. The researchers concluded that without alkaline pretreatment, extracted agar is more appropriate as a thickener rather than a gelling agent (Cebrián-Lloret et al., 2024).

NOP-certified organic agar products are commercially available (see *Table 2*). We were unable to confirm the species and/or processes manufacturers use to produce these agar products.

Table 2: Commercially available certified organic agar, based on a search of the USDA Organic Integrity Database (USDA, 2025). Current as of September 24, 2025.

Product name(s)	Manufacturer
Agar Agar Powder	FOODS ALIVE Inc 1600 Wohlert Street Angola, IN 46703 United States of America
Agar	Colony Gums, LLC 2626 Executive Point Drive Monroe, NC 28110 United States of America
Kanten (Agar-Agar)	Ina Food Industry Co., Ltd. 5074 Nishiharuchika, Ina-shi, Nagano Japan
TICorganic® Agar 600-B; TICorganicÂ® Agar 600-B	Ingredion Incorporated 5 Westbrook Corporate Center Westchester, IL 60154 United States of America
AGAR- Powder type gelagar	Lodaat LLC 1415 W 22nd ST, Tower Floor Oak Brook, IL 60523 United States of America
Kanten Flakes	Mitoku Co., Ltd. Hamarikyu Intercity, 1-9-1 Kaigan, Minato-ku, Tokyo Japan
Kanten Flakes	MUSO Co. Ltd. Minamishimmachi, Chuo-ku, Osaka Osaka, 5400024 Japan
Powders (Agar Agar Powder)	Rita & Madison LLC 203 SW 159th Terr Pembroke Pines, FL 33027 United States of America
Food agar; Gracilaria soft agar; Gracilaria Quick soluble agar; Nature Agar G700; Quick soluble agar	Setexam SARL Km 7 route de Tanger BP 210 Usine El Assam Kenitra, Kenitra 14000 Morocco

Availability of traditional, natural agar

Most food-grade agar that is commercially available worldwide is sourced from *Gracilaria* rather than *Gelidium* (Hernández-Carmona et al., 2013; Khalil et al., 2018). However, *Gelidium* algae produce a higher quality native (unprocessed) agar than *Gracilaria* algae (Khalil et al., 2018). According to Armisén and Galatas (2009), agar was

[9] *Gelidium corneum* (formerly *Gelidium sesquipedale*), *Agarophyton chilensis* (formerly *Gracilaria chilensis*), and *Gracilariopsis longissima* (formerly *Gracilaria verrucosa. G. corneum* and *A. chilensis* were chosen because they are commercially used in agar extraction. *G. longissima* is not commonly used for agar production; however, it was chosen because it is cost-effective to cultivate.

traditionally sourced from *Gelidium amansii*. Extraction involved boiling *G. amansii*, and using vinegar or sake as pH adjustors. Currently, *Gelidium* is available as a wild harvested product only, and it is difficult to cultivate (Khalil et al., 2018; Mendes et al., 2024).[10] In contrast, *Gracilaria* is harvested as well as cultivated, making it more available around the world. It is unclear to us whether manufacturers produce food-grade agar using these methods.

Modern-day manufacturers using this method of extraction use dilute sulfuric acid [see *Evaluation Question #1(B)*] (Armisén & Galatas, 2009). The product is sold as "natural agar," "natural food and functional seaweed product," strip agar (Ito-Kanten), or square agar (Kaku-Kanten) (Armisén & Galatas, 2009; Hernández-Carmona et al., 2013). Agar produced with this extraction method is used to prepare traditional Japanese dishes and is limited to small-scale production (Armisén & Galatas, 2009).

Evaluation Question #10: Describe all nonagricultural nonsynthetic (natural) substances or products which may be used in place of this substance [7 U.S.C. 6517(c)(1)(A)(ii)]. Identify which of those are currently allowed under the NOP regulations.

Agar's primary function is as a gelling agent and thickener (Qin, 2018). Agar is a desirable food additive because of the large difference between its gelling (above 40 °C) and melting (above 85 °C) temperatures (Hernández-Carmona et al., 2013). This wide temperature gap makes agar a uniquely stable gel over a relatively large temperature range (Qin, 2018). Once cooled, agar is a clear, colorless, and odorless gel (Hernández-Carmona et al., 2013; Saha & Bhattacharya, 2010). These physiochemical properties help prevent chipping, cracking, or sweating of icings, toppings, and glazes in baked food (Cui et al., 2013; Qin, 2018). Agar's wide stable temperature range also allows for its use in canned meat products, where autoclaving is a part of product processing (Qin, 2018). Agar is an additive in (Himashree et al., 2022; NOP, 2011):

- bakery products, fillings, and icings
- custards and puddings
- confections and soft candies
- jellies, jams, and marmalades
- dairy desserts and dairy products
- prepared soups
- canned meat and fish products
- processed meat products
- vegetarian meat substitutes

Agar is a hydrocolloid (Himashree et al., 2022; Khalil et al., 2018; Saha & Bhattacharya, 2010). Hydrocolloids are materials that consist of polysaccharides (or proteins) that swell when exposed to water (Pirsa & Hafezi, 2023). The swelling produces a thickening effect that impacts the final commercial product's functionality, sensory perception, and physical appearance (Himashree et al., 2022; Pirsa & Hafezi, 2023). Before introducing a food product into the market, manufacturers asses hydrocolloids for their impact on the product's rheological and textural properties (Himashree et al., 2022).[11]

The hydrocolloid additive's effect on food products depends on the total composition (formula), pH, and overall temperature requirements of the food product (Saha & Bhattacharya, 2010). For example, texture is affected by the hydrocolloid to water ratio (Rawat et al., 2024; Rhein-Knudsen et al., 2015). Hydrocolloids interact with water, and an improper ratio between the two components can result in undesirable textures. Some hydrocolloids may not be usable under certain conditions (Koko et al., 2023; NOP, 2018; Saha & Bhattacharya, 2010). Additionally, very few hydrocolloids form gels (Pirsa & Hafezi, 2023). Processors interested in an alternative to agar should consider that agar is:

- thermoreversible (a gel at higher temperatures and a solid at lower temperatures) (Pirsa & Hafezi, 2023)[12]
- water-soluble (Banerjee & Bhattacharya, 2012)
- used in small quantities (Banerjee & Bhattacharya, 2012)
- texturally preferred by some consumers (Hernández-Carmona et al., 2013; Khalil et al., 2018)
- derived from a non-animal source (Pirsa & Hafezi, 2023; Rawat et al., 2024)
- low calorie (Pirsa & Hafezi, 2023; Rawat et al., 2024)

We highlight individual hydrocolloid use limitations when discussing the specific details of that substance.

Agar's specific gelling characteristics are not present in other seaweed hydrocolloids (*e.g.,* alginate and carrageenan), food gums, or gelatin (Qin, 2018). Substituting one hydrocolloid (*e.g.,* agar) in a product formula may require a combination of hydrocolloids to provide an equivalent or similar effect (Rawat et al., 2024).

[10] As a result, *Gelidium* is more typically used for non-food additive products like bacteriological agar and agarose gel for gel electrophoresis (Hernández-Carmona et al., 2013).
[11] Rheology in food refers to consistency characteristics like viscosity and elasticity (Ishaq et al., 2024).
[12] In the context of hydrocolloids, reversibility refers to the ability to fluctuate between more than one physical state (Pirsa & Hafezi, 2023).

We found no data suggesting that any nonagricultural, nonsynthetic materials are a direct substitute for agar as a gelling agent and thickener for the same range of processed food products. However, processors may be able to use carrageenan or gellan gum as alternatives to agar in some instances. Carrageenan appears on the National List at § 205.605(a)(9) while gellan gum appears at § 205.605(a)(13). Consequently, nonagricultural, nonsynthetic forms are allowed. We describe hydrocolloids available as organic agricultural products in *Evaluation Question #11*.

Alternatives that function as gelling agents and thickeners

Carrageenan

Carrageenan, like agar, consists of a group of linear polysaccharides derived from red seaweed (sulfated galactans) (Hernández-Carmona et al., 2013). Specifically, it is derived from seaweed species where carrageenan comprises up to 50% of the dry weight (*e.g., Kappaphycus*, *Gingartina*, *Eucheuma*, *Chondrus*, and *Hypenea*) (Rhein-Knudsen et al., 2015). Like agar, these seaweeds are commonly treated with an alkali solution as part of the extraction process.

Carrageenan is a thermoreversible gelling agent (Khalil et al., 2018). Like agar, producers use it as a gelling agent and thickener in a wide variety of products (*e.g.,* gummy candies, fruit gels, fruit juices, jams and marmalades, and bakery products) (Hernández-Carmona et al., 2013; Rhein-Knudsen et al., 2015). However, carrageenan is more widely used because it has a higher production volume and is more available than agar (Rhein-Knudsen et al., 2015; Williams, 2016). We did not find any studies comparing agar and carrageenan across identical products.

Compared to agar gels, carrageenan gels are two to ten times weaker in strength (Rhein-Knudsen et al., 2015). Additionally, carrageenan gels are functional at a narrower temperature range. Carrageenan melts at 50 – 70 °C and gels at 30 – 50 °C, while agar melts at 85 – 95 °C and gels at 32 – 45 °C (Khalil et al., 2018; Rhein-Knudsen et al., 2015). Carrageenan gels are more viscous than agar at temperatures below 60 °C (in solution) (Rhein-Knudsen et al., 2015).

There are three types of carrageenan that manufacturers use to create a texturizing agent in food products (Qin, 2018; Rhein-Knudsen et al., 2015):

- kappa
- iota
- lambda

Like agar, carrageenan is used for its gelling abilities. Kappa- and iota-carrageenan are used as thermoreversible gels in puddings, milkshakes, and tofu (Saha & Bhattacharya, 2010). Kappa-carrageenan forms strong, rigid gels in the presence of potassium ions, while iota-carrageenan forms soft gels in the presence of calcium ions (Qin, 2018). Lambda-carrageenan does not form a gel and is more appropriate for use as a dairy product thickener (Qin, 2018).

Carrageenan can also be used in baked goods (Ishaq et al., 2024). Researchers note that agar and carrageenan improve the quality of bread when compared to more traditional texturizing agents like gelatin. This quality improvement is more substantial in gluten-free bread, where water retention and gelatinization is typically compromised (Ishaq et al., 2024). However, researchers consider agar to be superior to carrageenan (Saha & Bhattacharya, 2010).

Alternatives that function as thickeners

Gellan gum

Gellan gum is a polysaccharide produced by the bacterium *Auromonas elodea* (Cui et al., 2013). The gum is processed to yield two product types: high acyl and low acyl gum. High acyl gellan gum is a nonagricultural, nonsynthetic substance and appears on the National List at § 205.605(a)(13). Low acyl gellan gum appears on the National List as a nonagricultural, synthetic substance at § 205.605(b)(18).

In the context of agar substitution, gellan gum is more akin to a thickener than a gelling agent. Producers use gellan gum as a weak gelling agent, yielding a “fluid” gel solution (Banerjee & Bhattacharya, 2012; NOP, 2018). Specifically, high acyl gellan gum produces soft, elastic, transparent liquid gels at concentrations higher than 0.2% (Cui et al., 2013; NOP, 2018). These gels are thermoreversible (Himashree et al., 2022; Saha & Bhattacharya, 2010) and set when cooled (Banerjee & Bhattacharya, 2012). Producers can control its thickening effect by increasing the presence of cations, like calcium and sodium (Cui et al., 2013; NOP, 2018). Like agar, producers use gellan gum in water-based fruit-flavored jelly confections (Saha & Bhattacharya, 2010). Producers also use both substances in dairy products (Cui et al., 2013).

Evaluation Question #11: Provide a list of organic agricultural products that could be alternatives for this substance [7 CFR 205.600(b)(1)].

As discussed in *Evaluation Question #10*, substances used as alternatives to agar are typically described as hydrocolloids. Producers considering alternatives evaluate the functionality, sensory perception, and physical appearance the alternative has on the final product when compared to the original substance. We found no data suggesting that any organic agricultural materials are a direct substitute for agar as a gelling agent and thickener for the same range of processed food products (see *Table 3*).

Table 3: Agricultural substances for use as alternatives to agar. (Hernández-Carmona et al., 2013; Himashree et al., 2022; Ishaq et al., 2024; Pirsa & Hafezi, 2023; Rhein-Knudsen et al., 2015; Saha & Bhattacharya, 2010; Tedjani et al., 2025; USDA, 2025; Williams, 2016)

Substance	Food product application	Primary function	Certified organic products available?
Gelatin	Dairy products, jams, jellies, puddings, bakery products	Gelling agent	Yes
Guar gum	Cake toppings, dairy products, soups, sauces	Thickener	Yes
Konjac mannan	Bakery products, meat products	Thickener	Yes
Locust bean gum	Bakery products, dairy products, processed fruit products	Thickener	Yes
Pectin	Jams, jellies, frozen products	Gelling agent	Yes
Tara gum	Frozen products, sauces	Thickener	Yes
Tragacanth gum	Bakery products, dairy products	Thickener	No
Starches	Frozen products, fruit fillings	Thickener	Yes

In the context of Western cuisines, producers frequently use agar as an alternative to gelatin in products meant to be free from animal-sourced ingredients (*e.g.,* vegan/vegetarian, kosher, and/or halal products) (Karim & Bhat, 2008; Menaka & Wijesekara, 2025; Rawat et al., 2024). Researchers comparing non-animal origin hydrocolloids discuss alternatives in relation to gelatin. Manufacturers use agar (or other hydrocolloids) as an alternative to gelatin in products such as jelly confections, milk-based desserts, dessert creams, and meat products (Saha & Bhattacharya, 2010). We did not find a direct comparison between agar and other gelatin alternatives. Below, we discuss the agricultural hydrocolloids that are theoretical alternatives to agar, in the context of their common properties.

Culinary pursuits are a combination of art and science. The substances we list below are summarized from scientific discussions of hydrocolloids that producers use in overlapping product types. This list does not include artistic discussions (*e.g.,* food blogs, recipe books, etc.) of alternatives.

Alternatives that function as gelling agents and thickeners

Gelatin

Gelatin is a traditional thickening and gelling agent derived from the hydrolysis of animal bones and skin (*i.e.,* cattle, pigs, and fish) (Cebrián-Lloret et al., 2024; Pirsa & Hafezi, 2023; Williams, 2016). Because of its animal origin, there is commercial interest in substituting gelatin with other substances. For example, the emergence of bovine spongiform encephalopathy ("mad cow disease") increased public concern about infected animal parts being used in food products (Karim & Bhat, 2008). Gelatin is therefore not a suitable alternative for products that are meant to be free from animal products (Cebrián-Lloret et al., 2024).

Gelatin is used in a wide variety of products, such as ice cream, jams, jellies, and pudding (Pirsa & Hafezi, 2023). Like previously mentioned, producers may prefer using agar (or other hydrocolloids) instead of gelatin in these types of products (Saha & Bhattacharya, 2010). Like agar, gelatin may also be used in baked goods. However, agar produces higher-quality products (Ishaq et al., 2024; Saha & Bhattacharya, 2010). Specifically, researchers note that bread (including gluten-free bread) produced with agar has a higher nutrient content, lowered staling rate, and higher loaf volume, expansion and density (Ishaq et al., 2024).

Nonsynthetic gelatin appears on the National List at § 205.606(h). Certified organic gelatin products are available (USDA, 2025).

Pectin

Commercial pectin products are obtained from apple pomace or citrus fruit peels (Williams, 2016). Pectin is classified as high methoxy- or low methoxy-pectin, depending on its degree of esterification (Banerjee & Bhattacharya, 2012). Producers interested in using either high or low methoxy-pectin as an alternative to agar must consider the pH of the product mixture and the overall composition of the final product (Banerjee & Bhattacharya, 2012; Qin, 2018).

High methoxy pectin forms a gel only when the product's sugar content is above 65% (Banerjee & Bhattacharya, 2012; Qin, 2018). It is not thermoreversible at high acidic pH (Saha & Bhattacharya, 2010). Low methoxy pectin

gels form only in the presence of divalent cations like calcium (Banerjee & Bhattacharya, 2012). Low methoxy pectin is thermoreversible at acidic pH (Saha & Bhattacharya, 2010).

Pectin is primarily used as a gelling agent in jams and jellies (Saha & Bhattacharya, 2010; Williams, 2016). Like agar, low methoxy pectin is used in milk-based desserts and glazes (Saha & Bhattacharya, 2010). Low methoxy pectin is also discussed for use as an alternative to gelatin in confections (Karim & Bhat, 2008).

Non-amidated nonsynthetic pectin appears on the National List at § 205.606(o). Certified organic pectin products are available (USDA, 2025).

Alternatives that function as thickeners

Galactomannans, a subtype of hydrocolloid, may be appropriate alternatives to agar in certain contexts. Like agar, producers typically use galactomannans as thickening agents in dairy products, baked goods, and certain fruit products (see *Table 3*) (Saha & Bhattacharya, 2010; Tedjani et al., 2025). The galactomannans used as thickeners in food products are:

- guar gum
- locust bean gum
- tara gum

Galactomannans are polysaccharides (sugars) sourced from the endosperms of leguminous seeds (Williams, 2016). These substances are structurally similar to one another but vary in their mannose to galactose ratio (Tedjani et al., 2025). The composition ratio affects properties like water solubility and gel strength. A lower galactose content (higher mannose to galactose ratio) means the substance has a lower water solubility and forms a stronger gel (Tedjani et al., 2025). A higher galactose content (lower mannose to galactose ratio) means the substance has a higher water solubility and forms a weaker gel. Once galactomannans dissolve, they form highly viscous solutions at 1% concentration, making them ideal thickeners (Williams, 2016).

Galactomannans generally do not form gels and require additional substances to form the gel texture (Tedjani et al., 2025). Common substances used in combination with gums include agarose, carrageenan, starches, and xanthan gum (Tedjani et al., 2025). Gels formed by these combinations are a result of cross-linking interactions (Himashree et al., 2022). Xanthan gum appears on the National List at § 205.605(b)(38) and is permitted as a nonagricultural, synthetic substance.

Other hydrocolloids that may be appropriate alternatives to agar are:

- tragacanth gum
- konjac mannan
- starches

Guar gum

Guar gum is the most commonly used galactomannan (Tedjani et al., 2025). It is mechanically obtained from guar plant seeds or cluster beans (*Cyamopsis tetrabonoloba*) (Himashree et al., 2022; Williams, 2016). Guar gum has the lowest mannose to galactose ratio among the natural galactomannans available in the market (Tedjani et al., 2025). Its high molecular weight and structure make it a high-viscosity gum, which is a stable, fast-coagulating material (Himashree et al., 2022). Additionally, it is readily soluble in cold water (Williams, 2016). Like agar, producers use guar gum in cake toppings, ice cream, soups, and sauces (Himashree et al., 2022). Producers combine guar and xanthan gums for use in bakery goods, fillings, and sauces.

Certified organic products are available (USDA, 2025). Guar gum also appears on the National List at § 205.606(j).

Locust bean gum

Locust bean gum is also known as carob gum (Williams, 2016). Manufacturers source locust bean gum from *Ceratonia siliqua* endosperm seeds (Williams, 2016). It is a high viscosity gum (Himashree et al., 2022) and does not form a gel when used alone (Tedjani et al., 2025; Williams, 2016). Locust bean gum has the highest mannose to galactose ratio of the commercial galactomannan substances and forms a gel when it interacts with other similarly structured materials (*e.g.,* carrageenan, agarose, and xanthan gum) (Tedjani et al., 2025). These gels are elastic, transparent, and thermoreversible (Williams, 2016).

Locust bean gum must be heated to dissolve entirely in water (Williams, 2016). Once dissolved, it forms viscous solutions at 1% concentration.

Like agar, locust bean gum is used as a thickener in dairy products, baked goods, and processed fruit products (Himashree et al., 2022; Williams, 2016). However, it becomes partially insoluble after it is frozen, making any gels

created thermally irreversible after freezing (Tedjani et al., 2025; Williams, 2016). Therefore, it may not be an appropriate alternative for frozen products.

Certified organic products are available (USDA, 2025). Locust bean gum also appears on the National List at § 205.606(j).

Tara gum

Tara gum is sourced from *Caesalpinia spinosa* endosperm seeds (Tedjani et al., 2025; Williams, 2016). It is considered an alternative to guar gum and locust bean gum when the latter materials are in short supply (Tedjani et al., 2025). Tara gum's applicability to food is more limited than guar and locust bean gums because of its higher molecular weight. However, in contrast to locust bean gum, it is stable during freeze-thaw treatments (Tedjani et al., 2025). Like locust bean gum, tara gum can be combined with xanthan gum to form a gel (NOP, 2018).

Certified organic tara gum products are available (USDA, 2025).

Tragacanth gum

Tragacanth gum is the dried exudate from sap collected from the tap root, stems, and branches of *Astragalus* legumes (NOP, 2018). Manufacturers use this medium viscosity gum as a thickening agent (Himashree et al., 2022; Saha & Bhattacharya, 2010). Tragacanth gum swells rapidly in cold or hot water but does not form a gel (Saha & Bhattacharya, 2010). It is stable in high acidity mixtures (NOP, 2018). However, its viscosity decreases irreversibly on heating (Williams, 2016). Like agar, tragacanth gum can be used in ice cream as a texturizing agent and in decorative icings for cakes (NOP, 2018; Williams, 2016).

Due to its high cost and limited availability, producers have largely replaced the use of tragacanth gum with other gums, such as xanthan gum (Williams, 2016). Tragacanth gum appears on the National List as an agricultural substance with the CAS number 9000-65-1 at § 205.606(s).

Konjac mannan

Konjac mannan (or konjac glucomannan) is a soluble extract of konjac flour (Williams, 2016). It is a glucomannan (another type of hydrocolloid) rather than a galactomannan. Manufacturers source konjac mannan from dried *Amorphophallus konjac* tubers (Williams, 2016). It maintains viscosity in the presence of salts but forms thermally irreversible gels with alkali (Saha & Bhattacharya, 2010). Konjac mannan is more commonly sold in the irreversible gel form, as blocks of gel (konnyaku) for use in traditional Japanese dishes and as a dessert jelly (Sim et al., 2011; Williams, 2016).[13] However, producers also use konjac mannan as a thickener in baked goods and meat products (Sim et al., 2011).

Certified organic konjac flour, konjac gum, and konjac extract products are available (USDA, 2025).

Starches

Starches are hydrocolloids sourced from plant materials such as potato, rice, cassava, pea, tapioca, and wheat (Williams, 2016). Starches are commonly used as thickeners in food products and are often combined with xanthan gum (Himashree et al., 2022; Saha & Bhattacharya, 2010). Natural starches form turbid gels upon heating and cooling, and are generally prone to syneresis (NOP, 2018; Williams, 2016). As a result of this effect, producers modify most commercial starches and create derivatives of the starch product instead (Williams, 2016). We did not find evidence of native starches being used as a gelling agent in food products.

Producers use rice starch (as rice flour) and tapioca starch as thickeners in refrigerated or frozen products, and fruit fillings (Himashree et al., 2022). Certified organic starch products are available (USDA, 2025). Native cornstarch appears on the National List at § 205.606(e).

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[13] While both konjac mannan and agar are used in Japanese desserts, agar is used in different types of block desserts like anmitsu, yokan, mitsumame, and tokoroten (Banerjee & Bhattacharya, 2012; Saha & Bhattacharya, 2010).

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

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