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

Document Type:

☐ **National List Petition or Petition Update**

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

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

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

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

☒ **Technical Report**

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

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

Contractor names and dates completed are available in the report.

Aquatic Plant Extracts

Crops

Identification of Petitioned Substance

Chemical Names:
Aquatic plant extracts; kelp extracts; liquid seaweed fertilizer; seaweed concentrate; seaweed extracts

Other Names:
Agar; alginic acid; *Ascophyllum nodosum* extracts; calcium alginate; carrageenan; *Durvillaea potatorum; Ecklonia maxima; Fucus serratus.; Kappaphycus alvarezii; Laminaria* spp.; macroalgae extracts; *Macrocystis* spp.; marine algae extracts; rockweed; sea algae extracts; sodium alginate; *Sargassum* spp.; *Ulva* spp.

Trade Names:
Acadian Organic Liquid Seaweed Concentrate 0.1-0-5; Acadian® Marine Plant Extract Powder 0.5 l 0.0 l 17; AscoStar 0-0-17; ASL Technical Ingredients Soluble Seaweed Extract Powder 0.5-0.0-17; BioAtlantis SuperFifty 0-0-8; Kelpak 24201 Liquid Fertiliser; Maxicrop Soluble Seaweed Powder 0-0-17; Pro-Pell-It! Micronized Kelp Meal 2-0-4; Seasol® Seaweed Concentrate; numerous others

CAS Numbers:
84775-78-0 (extracts of *Ascophyllum nodosum*); 9002-18-1 (agar); 9000-07-1 (carrageenan); 9005-32-7 (alginic acid); 9005-35-0 (calcium alginate); 9005-38-3 (sodium alginate)

Other Codes:
EC No. 283-907-6

Summary of Petitioned Use

This limited scope technical report provides information to the National Organic Standards Board (NOSB) to support the sunset review of aquatic plant extracts, listed at 7 CFR 205.601(j)(1). This report focuses on the extraction processes used to make aquatic plant extracts (APEs). APEs are used in organic crop production as plant and soil amendments.

APEs were included on the National List of Allowed and Prohibited Substances (hereafter referred to as the "National List") with the first publication of the National Organic Program (NOP) Final Rule (65 FR 80548, December 21, 2000). The NOSB has continued to recommend their renewal in 2006, 2010, 2015, and 2020 (NOSB, 2009, 2010, 2015, 2020).

As APEs are listed at § 205.601(j)(1), synthetic forms are allowed. The annotation for APEs specifies the following: "Aquatic plant extracts (other than hydrolyzed)—Extraction process is limited to the use of potassium hydroxide or sodium hydroxide; solvent amount used is limited to that amount necessary for extraction." While the annotation notates "other than hydrolyzed", discussion at the Fall 2004 NOSB meeting clarified this was a transcription error (see page 4044; NOSB, 2009). The language from the NOSB crops materials review during the Spring 1995 NOSB meeting denotes the original intent for inclusion of hydrolyzed aquatic plant extracts on the National List (see page 344; NOSB, 2009). Based on this information, this report is prepared with the understanding that synthetic hydrolyzed aquatic plant extracts are allowed as a crop input material when manufactured via alkali extraction with either of the allowed solvents: potassium hydroxide or sodium hydroxide. This understanding is also consistent with the "Aquatic Plant Products" entry in NOP 5034-1 *Guidance: Materials for Organic Crop Production* (NOP, 2016b).

A small number of APEs are also allowed as inert ingredients in pesticide formulations [§ 205.601(m)], because they are included in the 2004 EPA List 4, such as extracts from the seaweed *Ascophyllum nodosum*, and carrageenan (an extract from red algae).

Aquatic Plant Extracts Background

Farmers use aquatic plant extracts (APEs) as soil conditioners, mineral sinks, and plant biostimulants (Ali et al., 2021; Mughunth et al., 2024).

The major bioactive compounds of APEs include the following (Ali et al., 2021; Michalak & Chojnacka, 2014; Stirk et al., 2020):

- polysaccharides (e.g., laminarin and fucoidans)
- auxins (e.g., indole-3-acetic acid and indole-3-acetyl-L-aspartic acid
- abscisic acid
- brassinosteroids (e.g., brassinolide and castasterone)
- cytokinins (e.g., Z and tZ)
- gibberellins (e.g., GA_1 and GA_3)
- betaines (e.g., glycine betaine and laminine)
- ethylene
- sterols (e.g., fucosterol and campesterol)
- carotenoids (e.g., β-carotene and lutein)
- minerals (e.g., phosphorus and potassium)
- polyphenolics and phlorotannins (e.g., bromophenols and flavonoids)
- lipids (e.g., betaine lipids and glycolipids)
- oxylipins (e.g., hydroxy and hydroperoxy fatty acids)
- protein, peptides, and amino acids (e.g., phenylalanine and proline)

APEs are biologically complex and contain many bioactive ingredients (Ali et al., 2021; De Saeger et al., 2020). The biological mechanisms and pathways by which seaweed extracts evoke their stimulatory effects remain an area of continuing research (El Boukhari et al., 2020; Goñi et al., 2020).

Most commercial APEs are produced via an alkaline hydrolysis method. In alkaline hydrolysis, complex polysaccharides are broken down into shorter polysaccharide chains and novel compounds not initially present in the seaweed (Craigie, 2011; Zhang et al., 2024). The interaction of alkali and algal metabolites usually results in partial or complete degradation of certain amino acids as well (Echave et al., 2021; Kadam et al., 2017; Kapoore et al., 2021).

In practice, the production of APEs may include the following steps (Michalak & Chojnacka, 2014):

- pretreatment
- extraction
- formulation

<u>Pretreatment</u>

Pretreatments vary, but typically involve washing, drying, and milling the raw algal material. The raw algal material is usually dried and milled to obtain a homogeneous sample with a higher surface-to-volume ratio ideal for solvent extraction (Michalak & Chojnacka, 2014). Milling is a mechanical process that typically involves a mill or homogenizer. The dried algae material is then sorted through a sieve to obtain appropriate size (Michalak & Chojnacka, 2014).

At this point, the algal material undergoes a cell wall lysis (rupture) step to optimize the extraction yield (Michalak & Chojnacka, 2014). The cell walls need to be ruptured to release the bioactive compounds found within the cell wall structure and release the cell cytoplasm and its contents into the extraction media.

NOP 5033-1 *Guidance: Decision Tree for Classification of Materials as Synthetic or Nonsynthetic*, the NOP defines “extract” as follows (NOP, 2016a): “To separate, withdraw, or obtain one or more constituents of an organism, substance, or mixture by use of solvents (dissolution), acid-base extraction, or mechanical or physical methods.” Extraction, as defined in NOP 5033-1, then is not limited to the extraction step itself, but also realistically includes the cell lysis process that is a component of the pretreatment step when the cellular cytoplasm is withdrawn from the cell wall structure.

Cell lysis can be achieved by several methods, however, they all involve one of three general mechanisms (Garcia-Vaquero et al., 2017; Michalak & Chojnacka, 2014):

- mechanical-physical
- chemical
- enzymatic

Mechanical lysing methods apply shearing forces to rupture cells. Manufacturers use bead milling, high-pressure extrusion, and less commonly ultrasonication to achieve this on industrial scale (Michalak & Chojnacka, 2014). Thermal or heat treatment is a physical method commonly performed in a drum dryer and achieves cell lysing, while also removing residual water.

The pretreatment step can also involve the application of acidic or alkali solvents (Michalak & Chojnacka, 2014). This is a separate step, distinct from the application of similar solvents to the algal material in the extraction step that is described below. The application of acidic or alkali solvents during the pretreatment step serves to rupture the algal cell. The extraction step by contrast serves to isolate the targeted bioactive compound(s) released either from the cell wall structure or cytoplasmic contents during pretreatment. We found no evidence that this is common with APEs used in organic crop production as plant and soil amendments.

Enzymatic cell lysis as a pretreatment is not widely practiced in the industry at the present time because cell lysing enzymes are costly (Michalak & Chojnacka, 2014).

Extraction

The specifics of extraction methodologies are often confidential (El Boukhari et al., 2020). The most common publicly documented methods involve heating seaweed in alkaline sodium or potassium solutions. The reaction temperature may be elevated by pressurizing the vessel (Craigie, 2011; Stirk et al., 2020). Alternatively, seaweed may be liquified at ambient pressure (Craigie, 2011; Stirk et al., 2020). Pressurized alkaline extraction is advantageous in that it improves the extraction of polysaccharides, with only moderate degradation (Ali et al., 2021). Polysaccharides (e.g., laminarin and fucoidans) are common targeted components of seaweed extracts due to their association with a variety of plant metabolic pathways (Ali et al., 2021; Kapoore et al., 2021).

Additional extraction methods that manufacturers use to produce APEs for organic crop production include water-based extraction, cell-burst extraction, and enzymatic extraction (Craigie, 2011; OMRI, 2024; Stirk et al., 2020). Water-based extraction is a process that typically involves blending and hydrating dried seaweed meal in the presence of water (Shukla et al., 2019). Related to cell-burst extraction, we found limited details available describing this. However, this method involves manufacturers applying a combination of high velocity and low pressure to the algal material, and no heating or freezing occurs (Craigie, 2011; Kelp Products International, 2023; Stirk et al., 2020). Enzymatic extraction involves the application of cell wall degrading enzymes (e.g. cellulase) to algal material to improve the bioavailability of the targeted bioactive compounds (El Boukhari et al., 2020; Kadam et al., 2017). This process requires maintaining the pH and temperature of the production environment in a manner that optimizes enzymatic activity.

Innovative methods that appear in the literature for the production of APE biostimulants include (Kapoore et al., 2021; Michalak & Chojnacka, 2014):

- ultrasound-assisted extraction
- supercritical fluid extraction
- microwave-assisted extraction
- pressurized-water extraction

However, we found no evidence of manufacturers currently using these methods for commercial applications to produce APEs for plant and soil amendments.

Formulation

APEs are available commercially without further formulation. There are also soil amendments and biostimulants available that combine APEs with additional fertilizers and micronutrients ingredients (Ali et al., 2021; Craigie, 2011). One advantage of adding APEs to a formulated input product is that these materials have natural chelating properties that can improve the bioavailability of micronutrients in the formula (Battacharyya et al., 2015; Craigie, 2011). Optimization of formulated biostimulant products including additional biological components (*e.g.,* microorganisms and plant extracts) is an area of continuing research (Ali et al., 2021).

Evaluation Questions for Substances to be used in Organic Crop Production

Evaluation Question #1: What is the typical final pH range for alkali extracted aquatic plant extract products?

The final pH range of alkali extracted aquatic plant extracts (APEs) is wide. Craigie (2011) reports a pH of 7–10 as the typical final pH range for alkali extracted APEs. Although some manufacturers produce APEs at an acidic pH (~4).

We surveyed a subset of OMRI Listed products containing APEs. We found that a pH of 8-11 is common for products marketed as fertilizers and soil amendments used in organic crop production (OMRI, 2024). However, products exist with pH values as low as 4 and as high as 12.5. We found no clear evidence revealing any intent or purpose to explain the outlying extreme final pH values.

Evaluation Question #2: What are the considerations when determining what amount of alkali is necessary for extraction?

We found no evidence of industry specific considerations when determining what amount of alkali is necessary for extraction of aquatic plant extracts (APEs) manufacturers use in plant and soil amendments. The extraction process is one aspect that manufacturers use to claim a competitive advantage and so internally-developed methodologies are often the subject of professional secrecy (El Boukhari et al., 2020). Furthermore, it is unclear, from the information we found, the level of investment that manufacturers give this question, if any. Unlike the extraction of a specific singular compound, such as a polysaccharide or pharmaceutical, aquatic plant extraction for use as a plant and soil amendment is more complex because it involves a manufacturer optimizing multiple factors with the aim to guarantee a maximum yield of biologically active molecules (El Boukhari et al., 2020). The amount of alkali necessary for extraction is of particular interest to the organic sector, but it is unclear if this translates explicitly to considerations in the manufacturing sector.

From a review of academic literature, we found that in laboratory environments, there are variables that can impact the amount of alkali necessary for extraction of APEs. These factors include the characteristics of the targeted compound(s) for extraction and the extraction process (Battacharyya et al., 2015; El Boukhari et al., 2020; Stirk et al., 2020).

Characteristics of the targeted compound(s)

Polysaccharides are the primary component of seaweed. The high content of cell wall polysaccharides generally found in seaweeds complicates the extraction of intracellular metabolites (Michalak & Chojnacka, 2014). One advantage of alkaline extraction at high pressure is the high level of extractability and moderate degradation of polysaccharides into oligomers (Ali et al., 2021). The undegraded polysaccharides are some of the most biologically active components of seaweed extracts (Ali et al., 2021). Plant hormonal molecules may also be degraded by alkaline extraction.

Alginate is a structural polysaccharide found in the cell wall of brown seaweeds (*Phaeophyceae*) and alkaline treatments break down the structural integrity of the cell wall, releasing the alginate component

(Stirk et al., 2020). Using alginate oligosaccharides (a type of APE) as a soil amendment, researchers observed a range of beneficial biostimulant activities, including (Stirk et al., 2020):

1) root-growth promoting activity
2) increased seedling fresh (wet/not dried) plant weight
3) promote plant defense pathways against tobacco mosaic virus

The conversion rate of the alginate is partially dependent on alkali concentration. In one study, researchers sundried and milled *M. pyrifera* to make alkaline hydrolyzed extracts in a range of temperature (40°C, 60°C, 80°C) and pH (pH 8, 9, 10, 11 and 12) combinations using potassium hydroxide (KOH) to achieve the required pH values. Extracts produced at higher pH values and subsequently higher concentrations of alkali solvent initially had a higher viscosity due to solubilization of alginate and other polysaccharides. Higher viscosities are one attribute researchers use to demonstrate that an extract contains the maximum amount of soluble components (Briceño-Dominguez et al., 2014).

Extraction process

The chemical composition of extracts largely depends on the method of extraction and the chemical products used during the production process (Battacharyya et al., 2015; Craigie, 2011; Stirk et al., 2020). Therefore, the biological activity of extracts of the same raw seaweed material obtained by different extraction processes may be considerably different.

Alkali extraction also has the potential to generate compounds not present in the original algal material. Mechanisms involved in this process can include degradation, rearrangement, condensation, and base catalyzed synthetic reactions (Craigie, 2011). The type and concentration of these reaction by-products depends on the composition of the polymers originally in the seaweed as well as the processing conditions used to manufacture the soluble extract. For example, dilute sodium hydroxide (NaOH) concentrations of 0.1M or 0.5M, can convert 27% to 56% (temperature dependent) of purified alginic acid into a variety of products, some of which are known plant metabolites (Craigie, 2011).

Kadam et al. (2017) observed there is no statistical differences ($p>0.05$) found in the yield of protein recovery from *A. nodosom* extracts using a range of NaOH concentrations (0.1 M, 0.2 M or 0.3 M). However, the researchers observed higher recovery of proteins using alkali extraction compared to acid extractions (HCl solvent) at comparable concentrations. Researchers hypothesize this may be explained due to alkaline conditions facilitating solubilization of water insoluble seaweed proteins. Another team of researchers observed further evidence of the effect of pH on protein extraction from *Nannochloropsis* sp. (microalgae) where an increase in the pH from 8.5 to 11 resulted in double the amount of proteins extracted when assisted by ultrasound (Kadam et al., 2017).

Current methods to evaluate amount of alkali necessary for extraction of APEs

Organic certifiers and material review organizations typically consider the amount of alkali necessary for extraction with the objective to verify compliance with the annotation at § 205.601(j)(1), which requires the solvent amount used be limited to the amount necessary for extraction. We interpret the intention here to be that one should not use extractants for their nutrient content.

According to the latest Accredited Certifiers Association document *Best Practices for Common Material Review Issues*, certifiers commonly address the question of nutrient fortification with one of two methods: the declaration method, or the calculation method (Accredited Certifiers Association, 2024).

The declaration method requires one of the following:

- an attestation from the manufacturer declaring the use of a nonsynthetic extractant
- an attestation from the manufacturer declaring the use of KOH or NaOH in limited amounts necessary for extraction
- an explanation from the manufacturer of why the amount of synthetic extractant is used

The reviewing body (certifier or material review organization) assesses whether the explanation provided demonstrates compliance and subsequently decides whether to allow or prohibit the material in organic production, within the scope of their oversight. The evaluation process may be subject to additional internal compliance policies specific to the review body (Accredited Certifiers Association, 2024).

Alternatively, the calculation method is used. This method is only used for products extracted with KOH (Accredited Certifiers Association, 2024; OMRI, personal communication, April 25, 2019).[1] This method requires collecting a formulation statement that includes the amount of raw aquatic plant material, and the amount of KOH combined in the extraction process. APEs may be considered fortified with synthetic potassium when the ratio of aquatic plant material to KOH is below 3.20:1. The calculation method derives from OMRI policy, in which 20% potassium claimed on the label was historically seen as the upper limit of what is acceptable in organic production. Since KOH is the typical alkaline material contributing to the K_2O analysis value, the ratio is standardized to that material, considering the proportions with respect to molecular weight (%K in x grams of KOH/ K_2O). APEs with higher ratios would be considered low risk for fortification (Accredited Certifiers Association, 2024; OMRI, personal communication, April 25, 2019).

Evaluation Question #3: Are there any nonsynthetic alkali materials used to extract nutrients from aquatic plants?

There are few alkali materials that manufacturers use as extractants for aquatic plant extracts (APEs), and the nonsynthetic options are particularly limited.

Sodium carbonate

Sodium carbonate (Na_2CO_3) is an alkali material that can be isolated nonsynthetically. However, we did not find any literature describing exploratory or commercial methods using sodium carbonate to extract seaweed for the purposes of producing a plant or soil amendment.

However, sodium carbonate is associated with a common production method used to isolate alginate, another APE that is more highly processed than those manufactured as plant and soil amendments. This process involves a step where manufacturers combine ground algae with a heated solution of sodium carbonate to form sodium alginate. The sodium alginate is then isolated to remove seaweed residues and cellulose (Bojorges et al., 2023; Rioux & Turgeon, 2015).

Other methods

While alkali treatment is a common method that manufacturers use to cause cell lysis for commercial APEs, it is not the only method (see Aquatic Plant Extracts Background). After surveying OMRI Listed products containing APE ingredients, we found examples of biologically mediated extractions, using either microorganisms and/or enzymes. These are currently available in commercial products.

We also found examples of OMRI Listed APE products that only involve physical-mechanical pretreatment by milling and/or pressurized extraction without further processing (OMRI, 2024).

[1] Use of both NaOH and KOH are limited by the APE annotation to the amount necessary for extraction, but fortification is not a concern when NaOH is used. While potassium is a common plant nutrient input, if an APE material contains high concentrations of sodium, crops may suffer (e.g., foliar damage, decreased plant growth) due to their sensitivity to salt (NOP, 2006). Furthermore, seaweed as a raw material can contribute a substantial amount of salt naturally (Suresh Kumar et al., 2015). The combination of these facts make it unfavorable for manufacturers to fortify an APE material with NaOH.

Report Authorship

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

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

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