Cultivated Seaweed Testing Guide

Overview

Kelp, a fast-growing brown seaweed that makes up the order *Laminariales*, is increasingly being farmed in North America as a sustainable input for food, agriculture, health, and materials use. Historically, seaweed has been valued for its extreme versatility and widespread availability; it is used globally for human consumption, soil improvement, and animal feed. Modern use has expanded as the food, chemical, cosmetic, and pharmaceutical industries identify valuable bioactive molecules in seaweeds that can be isolated through targeted refinement. Testing your kelp is necessary to provide technical information that informs manufacturers of the composition, safety, and unique properties of the crop.

This document outlines testing strategies designed to capture key data and effectively communicate the components of interest in minimally processed kelp (fresh, frozen, and dried). It serves as a roadmap for farmers and industry professionals seeking guidance on conducting lab analysis for their kelp.

Chemicals of Kelp

Fresh kelp is primarily water with a moisture content ranging from 85–90%; naturally, it is the remaining molecules that are of commercial interest. A considerable amount of kelp is made up of bioaccumulated minerals from the marine environment, which can be measured using combustion and expressed as “total ash” (30–50% dry weight, DW). The non-ash fraction, also known as “total organic content,” is rich in carbohydrates (40–50% DW), also referred to as polysaccharides or sugars. This class of molecules includes alginate (see Figure B), cellulose, fucoidan (see Figure C), laminarin (see Figure D), and mannitol. Except for cellulose and mannitol, which are found throughout the terrestrial plant world, these carbohydrates are unique to seaweed and present considerable industry interest for a range of functional and bioactive properties. At least 30,000 tons of alginate is produced globally to address the needs of a >$500M market. Other organic molecules found in kelp include protein (up to 20% DW), polyphenols (see Figure E, 5–12% DW), fats (1–2% DW), and pigments (<1% DW).

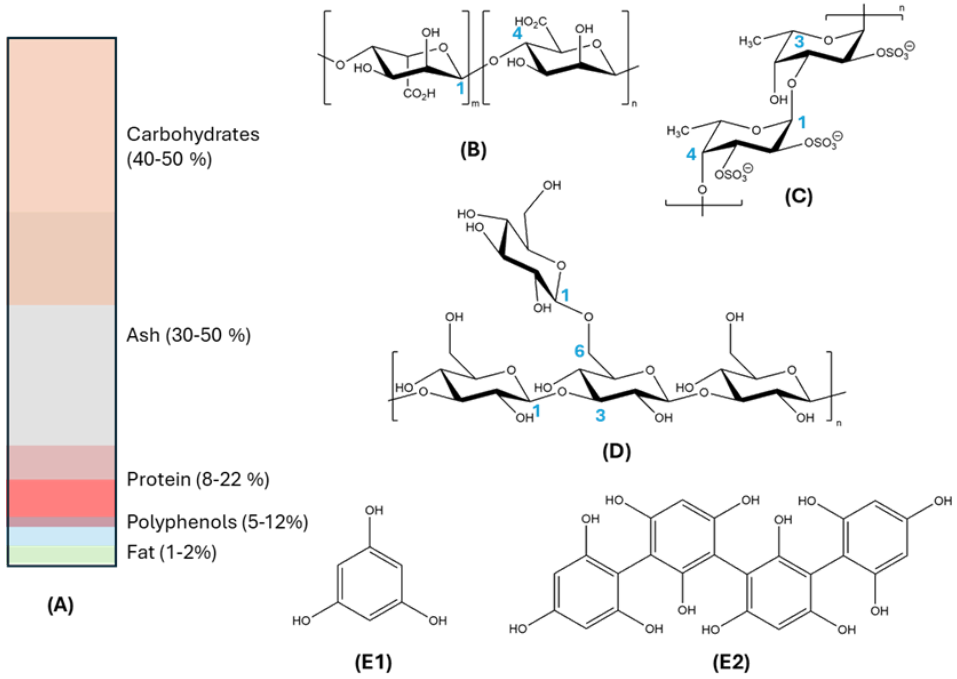
Variations in the composition are common in kelp based on the farming location, and species. Additionally, kelps stockpile different nutrients depending on the season[1]:

- Higher alginate contents occur in summer months.

[1] Schiener, P., Black, K.D., Stanley, M.S. et al. The seasonal variation in the chemical composition of the kelp species Laminaria digitata, Laminaria hyperborea, Saccharina latissima and Alaria esculenta . J Appl Phycol 27, 363–373 (2015). https://doi.org/10.1007/s10811-014-0327-1

- Mannitol/laminarin accumulates during summer and autumn to be utilized during winter.
- Protein and mineral contents are highest in winter and lowest during summer.

The range of inherent chemical complexity and variability places great importance on a kelp producer to accurately document the constitution of their biomass using testing and provides an opportunity to highlight certain specialty chemicals.



(A) Major chemicals present in kelp (all values dry weight), (B) **Alginate**, (C) **Fucoidan**, (D) **Laminarin**, and (E) **Phlorotannins**: phloroglucinol (E1) and Tetrafucol A (E2).

Testing Plan

The adoption of a testing plan offers several advantages to a seaweed farmer:

Quality Control: Ensure your seaweed meets any standards you guarantee
Safety Assurance/Regulatory Compliance: Confirm absence of potential contaminants
Market Differentiation/Trust: Evidence of high-quality standards and product knowledge
Sustainability Data: Document environmental impacts of seaweed cultivation over time

Testing can be an expensive and daunting proposition. This section is designed to simplify this process to ensure kelp achieves broad-market access for food, agriculture (plant and animal), health, and materials use. Testing results are summarized on a technical document called a

"specification sheet"[2] which outlines all important product data and information for buyers and regulators. The items to include depend on the desired product use but the general objective is to establish the quality and safety metrics your operation can guarantee. Certain components of your product will be guaranteed, such as moisture content, specific nutrients, or contaminant absence. Suggested limits for heavy metals and microbial contaminants, which are established by industry groups and government research, are discussed in later sections.

Quality. A general breakdown of major chemicals should be provided. For kelp this should include moisture, ash (total minerals), and total carbohydrates. If the kelp is intended for food or feed use, additional nutritional information such as protein, fat, and minerals should be included. The most prevalent minerals in kelp are potassium (K), sodium (Na), chloride (Cl), magnesium (Mg), and calcium (Ca).

- **Proximate analysis**: moisture, ash, carbohydrate, protein, fat by %.
- **Mineral testing**[3]: Individual metals - K, Na, Mg, Ca, Cl, etc.

Safety. Heavy metals, arsenic (As), cadmium (Cd), mercury (Hg), and lead (Pb), are chemical hazards associated with kelp. All kelp will contain *some* heavy metals. This is not an issue for human health as long as the levels are below the established maximum limits and the kelp is consumed in appropriate quantities.

Of the heavy metals, arsenic is of greatest concern in kelp products. Arsenic is incredibly common in marine environments and exists in two major forms, inorganic and organic. The inorganic forms are generally more hazardous than organic.[4] Arsenic can be found at high levels (>40 ppm) in dried kelp, but only a small percentage is inorganic in the species cultivated in the U.S.[5] These "speciation tests" (measuring organic and inorganic forms of arsenic) are comparatively more expensive than "total arsenic." Still, growers should be familiar with this distinction when discussing the arsenic levels in their kelp and collect information on inorganic arsenic levels in their products periodically (once per season).

[2] Example: Thorvin Icelandic Geothermal Kelp – Specifications.
[3] Can be completed in same testing package
[4] Kuivenhoven M, Mason K. Arsenic Toxicity. [Updated 2023 Jun 12]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2024 Jan-. Available from: https://www.ncbi.nlm.nih.gov/books/NBK541125/
[5] Yanli Yu, Alba Morales-Rodriguez, Guangming Zhou, Dolores Barrón, Àngels Sahuquillo, José Fermín López-Sánchez, Survey of arsenic content in edible seaweeds and their health risk assessment, Food and Chemical Toxicology, Volume 187, 2024, 114603, ISSN 0278-6915, https://doi.org/10.1016/j.fct.2024.114603.

Seaweed intended for fertilizer applications may be tested for additional metals per state regulations (California,[6] Oregon,[7] and Washington[8]). Microbial contaminants (e.g. *E. coli*, *Salmonella*, *Listeria*) are monitored for food and cosmetic applications to support hygienic handling claims.

- **Mineral Testing**[2]: selection of potentially toxic metals - As, Cd, Hg, Pb, etc.
- **Arsenic Speciation**: organic and inorganic forms of arsenic
- **Indicator organisms:** Coliforms, aerobic bacteria, yeast/mold, *enterobacteriaceae*
- **Pathogens**: *Salmonella spp.*, *Listeria monocytogenes, E. coli*

Unique Chemicals. The chemicals of industrial interest in kelp can be tested individually to develop unique Specification Sheets depending on target market or at the request of a consumer. These require specialized laboratories familiar with seaweed.

- **Monosaccharides**: individual carbohydrate (alginate, fucoidan) constituents
- **Amino acids**: individual protein constituents
- **Fatty acids**: individual fat constituents
- **Phlorotannins and pigments**: total phlorotannin content and pigment analysis[9]

Seaweed farming has the potential to provide many ecosystem services (ES), benefits that humans derive from the ecosystem. A major ES provided by seaweed farms is the removal of carbon and nitrogen from the near-shore water. In order to quantify and monetise the impact of a farm, the total carbon and nitrogen in the tissue at harvest must be measured. Remember each species of seaweed stores these elements at different rates, therefore you must run this analysis on all species farmed to get an accurate estimate. The formulas below can be used, on a per species basis, to estimate the amount of carbon and nitrogen removed at harvest.

Carbon Removed: Harvested Wet Weight (lbs) x (Dry Weight (%)/100) x (Carbon Content (%)/100)

Nitrogen Removed: Harvested Wet Weight (lbs) x (Dry Weight (%)/100) x (Nitrogen Content (%)/100)

Elemental Analysis: total carbon, nitrogen, hydrogen, oxygen, or sulfur.

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[6] California Department of Food and Agriculture. (n.d.). *Heavy metals in fertilizers: California regulations and best management practices*. Retrieved from https://www.cdfa.ca.gov/is/ffldrs/pdfs/HeavyMetals.pdf
[7] Oregon Department of Agriculture. (n.d.). *How to register a fertilizer product in Oregon*. Retrieved from https://www.oregon.gov/ODA/programs/Pesticides/Fertilizers/Pages/HowRegisterFertilizerProduct.aspx
[8] Washington State Department of Agriculture. (n.d.). *Heavy metals test requirements for Washington State fertilizer registration*. Retrieved from https://cms.agr.wa.gov/WSDAKentico/Documents/Pubs/707-382HeavyMetalsTestRequirements.pdf?/707-382HeavyMetalsTestRequirements
[9] To our knowledge, this type of testing is only provided by Celignis (Ireland) and NRC Halifax (Canada)

As of late there has been a growing interest in the carbon sequestration potential of farmed seaweed. This is difficult to calculate and is dependent on the application of the seaweed. If you are interested in calculating the sequestration potential of your farm, we recommend contacting a scientific expert.

Sampling Plan

A limited testing budget should be strategically used to capture information about product quality, safety, and variance most relevant to the target markets. In most cases, sampling will occur directly at harvest or after drying so results are indicative of the commercial product offered. Still, the harvest period can span weeks, and there is a large inherent internal variance in seaweed products. It is best practice to sample/test your seaweed at the same time of year each year to provide the most accurate annual comparison data.

Testing is used to demonstrate compliance and inform product labeling. For smaller operators, it may be suitable to collect only a small number of samples to provide objective test data that a product meets specifications. Variables that can greatly affect product composition—harvest location, harvest season, species, processing method—should be captured in a sampling plan. Note, samples can be stored and re-tested—it may be more prudent to complete a rapid testing plan for product composition and safety (proximate, minerals, and microbials) and engage in a more targeted chemical testing strategy later, once market needs have been established. This testing data will form the basis for annual product comparisons, market information, buyer education, and a host of regulatory compliance activities. Therefore, it is important for a grower to maintain their test data in an organized fashion complete with original copies of any laboratory provided Certificate of Analysis (COA).

Seaweed Testing Result Interpretation

A producer should collect and store data to study inherent variation in a product year-over-year and demonstrate compliance with any stated specifications. Buyers may wish to source kelp rich in specific functional components, so this data should be captured at least once per season. If budget allows, you may wish to test your kelp at the beginning, middle, and end of your season for a more robust dataset. At a minimum, a seaweed grower should monitor the major organic compounds in kelp (carbohydrates and protein). These compounds fluctuate throughout the year, but as these remain major molecules of industrial interest, they should be more frequently tested. It is useful to look at complimentary ingredients or products on the market when evaluating the chemicals of kelp. If possible, look towards journal articles or academic sources which catalog harvested kelp chemical profiles by searching a resource such as Google Scholar: e.g., "*Saccharina Latissima* chemical composition".

Kelp intended for food, animal feed, and cosmetics applications needs to comply with FDA regulations, and companies/individuals who grow, process, or market kelp have a legal responsibility to ensure the safety of their products. Kelp intended for use in human food, as a flavor enhancer or adjuvant, is defined in the U.S. Code of Federal Regulations 21 CFR 184.1120(a) and must meet requirements established in the table below.[10] No criteria exist for "cosmetic-grade" seaweed, so the FDA guidelines below offer a reasonable starting point for chemical contaminants. Inorganic arsenic, as discussed previously, is only a small fraction of the total arsenic in kelp. Still, a grower should collect at least one data point annually to show their product meets FDA targets.

Analysis	Limit
Arsenic (as As, inorganic)	3 ppm
Ash (Total)	45 %
Heavy Metals (as Pb)	0.004 %
Iodine	0.1 % - 0.5 %
Lead	10 ppm
Moisture Content	13%

Figure 1: Food-Grade Seaweed Requirements. Food Chemicals Codex, 3d Ed. (1981), p. 157

Kelp intended for use in animal feed should follow guidelines established by government research bodies or regulators, described below. Kelps will often exceed the limits for arsenic due to natural bioaccumulation in the environment, but note that these are "as-fed" limits. Kelp is not fed at a high percentage of the animal diet (>10%), so a producer may adopt a higher tolerance threshold for its use in a mixture of feed ingredients.[11]

Analysis	Limit, NRC[12]	Limit, FDA[13]	Limit, California[14]
Arsenic	30 ppm	12.5 ppm	50 ppm
Cadmium	10 ppm		45 %
Mercury	0.2 ppm	0.3 ppm	0.004 %
Lead	10 ppm		30 ppm
Iodine	5-400[15]	N/A	N/A

Figure 2: Animal Feed Seaweed Requirements

Other hazards, such as microbial contaminants, should be measured in alignment with the intended product use and future processing. For example, a seaweed being sold raw and intended for further processing (e.g. cooking) is not expected to be free of aerobic bacteria or yeast/mold, whereas seaweed dehydrated at 140°F (cooked) will have a much stricter microbial

[10] Food Chemicals Codex, 3d Ed. (1981), p. 157
[11] Evans, F. D., & Critchley, A. T. (2013). Seaweeds for animal production use. Journal of Applied Phycology, 26(2), 749-758. https://doi.org/10.1007/s10811-013-0162-9
[12] Mineral Tolerance of Animals, 2d Ed. (2005)
[13] Target Animal Safety Review Memorandum, FDA (2011)
[14] Cal. Code Regs. Tit. 3, § 2680 - Heavy Metals Prohibited
[15] Depending on animal type

tolerance because it is considered a “ready to eat” food. Sea Grant Alaska[16] and Sea Grant Connecticut[17] published a summary of food hazards associated with seaweed and possible tolerance levels. Still, seaweed is inherently low-risk with respect to microbial contamination: The only known foodborne outbreak related to seaweed was in 2016 for *Salmonella* linked to a tank-based aquaculture farm in Oahu, Hawaii.[18]

Food intended to be consumed raw is commonly tested for pathogens (*Salmonella, Listeria, Staphylococcus aureus,* and *E. coli O157*) and indicators of hygiene (Coliforms, generic E. coli, aerobic colony count, and yeast/mold). A set of guidelines for these microbes based on guidance from Health Canada is provided below. Health Canada suggests “as a base testing panel, the following parameters are recommended when testing a food sample: *Escherichia coli*, *Salmonella spp.*, *E.coli* O157, *L. monocytogenes*, and Coagulase positive staphylococci.”

Test	Satisfactory	Marginal	Unsatisfactory
Aerobic Colony Count[19]	$<10^4$ CFU/g	$<10^5$ CFU/g	$\geq 10^5$ CFU/g
Coliforms[12]	$<10^2$ CFU/g	$<10^3$ CFU/g	$\geq 10^3$ CFU/g
Generic *E. coli*	<10 CFU/g	<100 CFU/g	≥100 CFU/g
Salmonella spp.	Not detected in (NDI)		Detected
E. coli O157	NDI		Detected
L. monocytogenes	NDI	<100 CFU/g[20]	≥100 CFU/g[21]
Coagulase positive staphylococci	<20 CFU/g	<100 CFU/g	≥1000 CFU/g

Figure 3: Health Canada. (2013). Microbial guidelines for ready-to-eat foods: A guide for the conveyance industry and environmental health officers (EHO). Health Canada.

https://publications.gc.ca/collections/collection_2014/sc-hc/H164-167-2013-eng.pdf

[16] Good, M., & Ancheta, J. (2023). Seaweed Hub report for seaweed parameter testing resources. Alaska Sea Grant. https://alaskaseagrant.org/wp-content/uploads/2023/04/Seaweed-Hub-report-for-seaweed-parameter-testing-resources-report.pdf

[17] Concepcion, A., DeRosia-Banick, K., & Balcom, N. (2020). Seaweed production and processing in Connecticut: A guide to understanding and controlling potential food safety hazards. Connecticut Sea Grant. https://seagrant.uconn.edu/wp-content/uploads/sites/1985/2020/01/Seaweed-Hazards-Guide_Jan2020_accessible.pdf

[18] Banach JL, Hoek-van den Hil EF, van der Fels-Klerx HJ. 2020; Food safety hazards in the European seaweed chain. Compr Rev Food Sci Food Saf. 19:332-364

[19] Guidelines provided for Category 1 (cooked) foods. Raw/fresh ingredients are considered Category 3 and do not have an Aerobic Colony Count/Coliforms tolerance.

[20] Foods intended to have a prolonged shelf-life should contain no detectable level of *L. monocytogenes*

[21] Detection of *L. monocytogenes* is also considered to be potentially hazardous if the food is to be served to “high risk” populations.

Standard Operating Procedure - Sampling and Testing

- Samples should be collected that are representative of the ingredient being sold (time of year, maturity, format, stabilization, biofouling).
- Prepare clean, appropriately labeled bags for each sample. Label should include:
    - Species Name
    - Collection Site
    - Sampling Date
    - State: Fresh, Frozen, or Dried
    - Mass (g): Can be added after sampling.
- For testing plan and suggested test sample size requirements, refer to the following table. Always confirm with the laboratory prior to beginning a sampling plan.

Test Type(s)	**Sample Size (g)**	
	Fresh/Frozen	Dried
Chemical Testing		
Proximate Analysis[a]	200	100
Minerals[b]	500	100
Heavy Metals[b]	500	100
Unique Chemicals (Arsenic specification, Amino acids, fatty acids, seaweed carbohydrates, polyphenols, phlorotannins)	100–200, per chemical class	
Biological Testing		
Indicator Organisms (Aerobic Colony Count, total coliforms/ Generic *E. coli*)	75	
Pathogens (*L. monocytogenes*, *Salmonella spp.*, *E. Coli* O157, *S. aureus*)		
Unique Chemicals	100–200, per chemical class	
[a]Proximate Analysis includes 'Ash', which is used to estimate total minerals. [b]Heavy metals can be included in most standard Minerals analysis		

1. For fresh/wet samples, adhere to the following sampling guidelines:
    a. Each test provider will require a separate sample of the minimum amount above.
    b. Chemical Testing: Samples should be frozen until ready for submission. Limit the amount of air in sealed sample bags to minimize frost formation.

c. Biological Testing: All samples should be collected to minimize contamination from microbes in the environment (clean/sanitized equipment and gloves). Check with the laboratory for specific handling/shipping guidelines. In general, samples should be kept in the state in which they are intended to be stored:
    i. Refrigerated samples: Maintain the sample between 32–45°F (0 to 7°C), ideally at a maximum of 40 °F (5°C). Do not freeze samples.
    ii. Frozen samples: Maintain the sample <32 °F (0°C) to maintain freeze.

2. For dried samples, adhere to the following sampling guidelines:
    a. Each test provider will require a separate sample of the minimum amount above.
    b. Chemical Testing: Samples can be stored at ambient temperature until ready for submission/further processing.
    c. Biological Testing: All samples should be collected aseptically. Check with the laboratory for specific handling/shipping guidelines.

Selection of North American Laboratories with Seaweed Testing Experience and Related Capabilities

A producer should identify a suitable lab with required technical expertise, location, and capacity to deliver whatever testing package they wish. The following is a script that may be used when reaching out to a laboratory representative about testing:

Introduction

"Hello, my name is [Your Name], and I am contacting you on behalf of [Your Company]. We are a seaweed ingredient supplier, and we're looking for a laboratory to perform testing on our raw and/or dried seaweed products. I'd like to ask a few questions to determine if your lab is equipped to handle our specific requirements."

1. Testing Capabilities

"Could you tell me more about the specific tests your lab offers for seaweed products? Specifically, I'm looking for tests on [test types]:"

Examples: Nutritional levels, mineral, heavy metals, iodine, microbial contaminants.

Goal: Confirm they test for all the required analyses you're interested in. You may need multiple labs for more sophisticated testing plans.

2. Methodology and Equipment

“Do you routinely test for compliance in [market, location]:”
Example: food products in North America, animal feed in the United states

Goal: Confirm they have tested to compliance standards of your target market.

“Could you confirm if your lab holds any certifications, such as ISO 17025, to ensure the accuracy and reliability of your results?”

Goal: Certain products, specifically food, will require results obtained from ISO 17025 certified laboratories. The tests you require will need to be on the lab’s “accreditation scope.”

“What is the turnaround time for completing these tests?"

Goal: Does the lab timeline meet your requirements. Are there faster, more capable providers?

3. Sample Requirements

"Could you let me know the requirements for sample submissions? My product will be in [form].”
Example: frozen, fresh, dried

Goal: Confirm how much seaweed needed for testing, and what are the storage and transport requirements to maintain the sample’s integrity.

4. Reporting and Data Interpretation

"I’d also like to understand what kind of reporting we would receive after testing.”

Goal: All data should be provided in a certificate of analysis (COA) with the results and all important lab information (testing method, accreditation).

“Would it clearly indicate whether the seaweed meets safety standards?”

Goal: Few labs will be able to offer interpretation of results, especially for seaweed, but it is worth asking to see if the lab provides written confirmation that products meet some standard.

5. Costs and Payment Terms

"Could you provide details on the payment terms and methods?”

Goal: Determine if the laboratory requires payment up-front or a completed credit application.

“Could you give me a breakdown of the costs for individual tests or any bundled test options you might have?”

Goal: Labs may provide a bulk or testing bundle price reduction. Depending on your testing strategy, you may be able to do a single test submission and save money.

6. Wrap-Up and Quote Request

"Thank you very much for answering my questions. I appreciate your time and look forward to receiving any additional information you can provide on your testing capabilities and pricing. If possible, could you email me a summary of the services we discussed today?"

Below is a non-exhaustive list of labs that have worked with seaweed before, and are well-suited for certain aspects of seaweed testing.

	Food + Animal Feed[1]	Minerals + Heavy Metals + Iodine[1]	Microbial[2]	Amino Acids + Fatty Acids[1]	Seaweed Carbohydrates[1]	Pigments + Phlorotannins[1]	ISO 17025[22]
Celignis	✓	✓	✓	✓	✓	✓	✓
Eurofins	✓	✓	✓	✓	✓		✓
NREL Laboratories	✓				✓		✓
Medallion Labs	✓	✓	✓	✓			✓
NRC Halifax	✓				✓	✓	
SGS Labs	✓	✓	✓	✓			✓
Anresco Labs	✓	✓	✓				✓
ALS Global	✓	✓	✓	✓			✓
Intertek	✓	✓	✓				✓
BV Labs	✓	✓	✓				✓
EMSL Food Testing	✓	✓	✓				✓
A&L Labs Canada	✓	✓	✓				✓
RL Food Testing	✓		✓				✓

[1]: Chemical test methods; [2]: Biological test method

[22] ISO 17025 is an international standard that enables laboratories to demonstrate that they operate competently and generate valid results, thereby promoting confidence in their work both nationally and around the world. It is a common requirement for food testing.

Filling in a Data/Specification Sheet

Certificates of Analysis (COA) are provided by laboratories and can be traced to specific product lots or formulations. These documents should be well organized so that they can be easily provided to support any claims for any product types. These COAs will inform your data/specification sheet to provide this information to prospective buyers. See below for guidelines on writing your own data/specification sheet:

(1) Letterhead + Company Name/Location: Provide descriptive company information detailing registered address and logo, if available.

(2) Product Name, Species: Provide a name for your ingredient. Can include seaweed species (or family), cultivation location, and form. Example: “Alaskan Saccharina latissima, dried whole.”

(3) Product Description: Provide descriptors to familiarize a buyer/regulator with your product. This should include:

   (a) cultivated species (or mixture) in Latin and common name

   (b) part of seaweed harvested (frond, stipe, mix)

   (c) processing method/stabilization form (frozen, fresh, dried)

   (d) physical descriptions of the product

   (e) storage considerations

   (f) certificates (food safety, farm certificates, etc.)

(4) Guaranteed Analysis: Certain components of your product will be guaranteed, such as moisture content, specific nutrients, or contaminant absence. This section should include important characteristics you define your ingredient around. Suggested limits for heavy metals and microbial contaminants have been included based on FCC and Health Canada standards, respectively.

(5) Representative Analysis: The complete testing results of all components of a single lot of product. This provides consumer confidence that you are achieving your guaranteed results.

(6) Description of Product and Applications: Describe how the seaweed was grown, how the product was made, specific quality protocols that were followed, suggested applications, and other distinguishing features. Include a picture, if possible.

Please make a copy of this template data/specification sheet and add your own data.