

F3FIN Micro and Macro Algal Database

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Introduction

[The Feed Innovation Network](#) (FIN), is an international group dedicated to the idea of sustainable feed for aquaculture. Currently, fish are harvested from the open ocean as feed for farmed fish. With increasing populations and more intensive aquaculture practices, this feed model is not sustainable. Shaped and inspired by the [F3 \(Fish-Free-Feed\) challenge](#), FIN finds and tests ingredients that can serve as nutritional substitutes for forage fish, facilitates their testing, and communicates findings. This database investigates one of the most sustainable resources in the world: algae. Algae are autotrophs or mixotrophs, meaning they all possess the ability to harvest sunlight for energy like terrestrial plants. Many single cell and, more complex, multicellular alga exhibit rapid generation times and growth rates. These abilities make algae an ideal candidate as a sustainable feed supplement. Within the dataset, promising species of algae are listed and reviewed for nutrient content, market value, availability, and ecological information. The goal of this dataset is to give aquaculture feed designers and producers more information on fish alternatives and where they can be purchased.

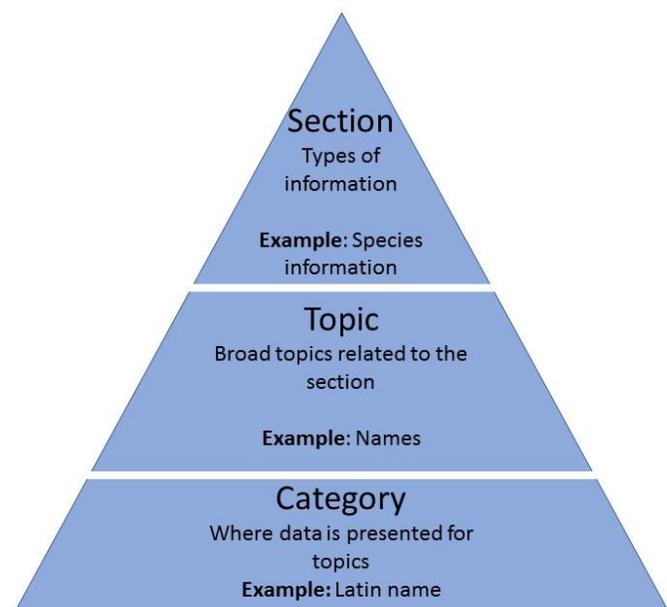
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Database Layout

General database outline

The database structure follows a pyramid form. Starting from the top, is the most broad subject which breaks into more detailed parcels of information as you move down to the base. Below is an incomplete example of the informational hierarchy within the database. The database is broken into **sections** (numeric), each section has **topics** (alphabetic), and every topic has **categories** (Roman numerals). Categories are the lowest level classification and is where actual data is populated. These are the terms that will be used throughout this document.



Example:

- 1) Species information (Section)
 - a) Names (Topic)
 - i) Cited name (category)
 - ii) Latin name (category)
 - iii) Common name (category)
 - b) Ecology (Topic)
 - i) Micro or macrophyte (category)
 - ii) Marine or freshwater inhabiting (category)
 - iii) Distribution (category)
 - iv) Detailed locations found (category)
 - c) Market information (Topic)Commercial use (category)

Database Sections

Species information:

This section is broken into 4 topics: taxonomy, ecological information, and market information. The first topic is broken into 5 categories: ingredient, cited name, taxonomically recognized name, synonyms, and common names. The cited name includes an ingredient and Latin / scientific name (genus and species). Early botanists and phycologists separated species by morphology. With technological advances in the 1900s, and the genetics boom of the 1980s-2000s, many species have been renamed many times over. This adds complication when researching algae and great care must be taken. All cited names (names commonly used internationally) in this database were cross referenced in Algaebase.org, Integrated Taxonomic Information System (ITIS), World Register of Marine Species (WoRMS), and GenBank. The currently recognized genus and species name was reported in the taxonomically recognized name category. Any older Latin names found were reported in the synonyms category. An added complication to algae names across cultures are vernaculars. Many cultures have their own common name for species and groups of species. From a professional (phycologist) standpoint, these terms are relatively meaningless, exercise caution when using them. For instance the vernacular “wakame” typically refers to *Undaria pinnatifida* in commerce, however, wakame literally translates to “seaweed” in Japanese, and therefore, can be any macroalgae. All common names found for any one alga was listed in the common name category with their language of origin. Listing all the synonyms and common names allows for more robust searches, and ensures that using an older name will get you to the right product. All other sections of the database will only contain the taxonomically recognized name, therefore, the species information section is the searching springboard to other sections of the database.

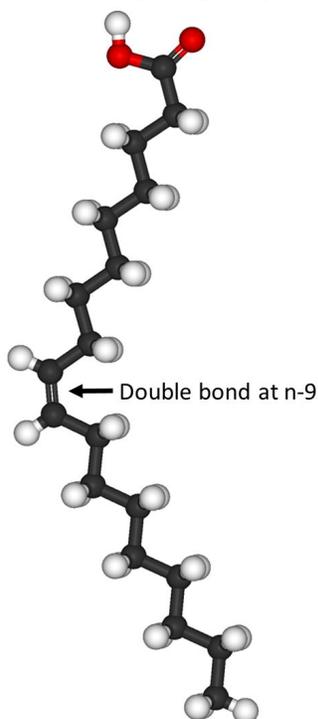
The next topic in the species information section addresses alga descriptions and ecological information. This is broken into 8 categories: micro/macro, Genbank, aquaculture species, location found, detailed locations, consumed by, and ecological related notes. These descriptions are useful for a number of reasons, first and foremost, for the purchaser of any product. It's invaluable for the consumer to know where certain species naturally grow, and if the species is an micro or macroalga. Microalgae is almost certainly a product of land based aquaculture, and macroalgae are likely subjected to the open ocean environment. These should always be taken into account for potential pollution or environmental concerns. The Genbank

category offers a link to genetic information about the species, this information is typically used for specific proteins produced or species genetic identification. The ecological notes category offers some insight into the type of environment the species inhabits, or if the species is a habitat itself. Lastly, the market information category includes information on commercial uses of the alga or derivatives derivatives.

Algal nutrients:

This section contains nutrient profiles for most species within the database. All of the profiles came from peer-reviewed primary literature with the citation noted in the reference category. It's rare that any one paper reported all nutrients for a species, therefore, many of the profiles are a combination of papers. When taking nutrients into consideration, please note the growth conditions category as the nutrient profiles can vary in different growth conditions.

Oleic acid (18:1, n-9)



The algae nutrients section contains five topics: macronutrients, fatty acids, amino acids, minerals, and sugars. Macronutrients are what you would expect to find on the side of a store bought food item: calories, carbohydrates, fiber, protein, as well as a few other categories such as, ash, moisture, and lipids. The fatty acids topic contains (currently) 52 categories. Each category represents a different lipid / fatty acid denoted in their molecular nomenclature (C : D, n - x), where C:D is the ratio of carbohydrates to double bonds and n-x describes the location of a double bond, as illustrated in the figure of oleic acid. The common names of fatty acids were used if one could be found, i.e. oleic acid. All fatty acids are presented in percent of total fatty acids.

Amino acids are organic compounds containing amine (-NH₂) and carboxyl (-COOH) functional groups. This topic is currently broken into 18 categories and is reported in percent of total amino acids. The minerals topic contains 13 categories and is presented in ppm (parts per million). The last topic is sugars, which at current date contains 36 categories. This category currently contains the least amount of information as different methods produce different units of molecules, and the species of a chemical structure that fall under umbrella terms makes reporting difficult. Sugars were added to the database later than other nutrients because of the increasing interest in the rapidly progressing field of prebiotics. Prebiotics are nondigestible food ingredient that promotes the growth of beneficial microorganisms in the intestines. Research has been shown that some indigestible sugars have prebiotic effects and some of these sugars are found in algae. What is less known, is the ability of the animal to receive the prebiotic effects while consuming the alga whole instead of the extracted sugars. This topic requires more research to

fully understand the gut biome of aquaculture species and ability to utilize natural algal derived sugars.

Suppliers:

The supplier section of the database includes a list of international alga producers and distributors. Keeping in mind the intended use of the database, the suppliers were selected by criteria that would be most useful for animal feed producers/ designers, and aquaculturists. Illustrated below, is a simplified flow diagram of criteria used in selecting suppliers.



The initial goal of the suppliers section was to list a number of suppliers of each alga species in different geographical locations and various forms: dry, fresh, whole, cut, powdered, and extracts. Multiple online search engines and markets were used in locating suppliers: Google, Alibaba.com, Globalsources.com, Amazon.com, TradeKorea.com, Indiamart.com, Made-in-china.com, and All.biz. The decision to add a supplier was made using a combination of the criterion against other suppliers of the same product. Therefore, the more suppliers for any one species the more critical the selection process. The following subsections describe the rationale of each criterion.

1. Correct species

"The beginning of wisdom is to call things by their proper name." - Confucius

It's vital for the purchaser of a product to be sure they receive the desired product. When feed designers are formulating ingredients from nutrient profiles, it's critical that they get the product that they accounted for. With this in mind, the first search criterion is the name of the product. At this first step, common names are completely disregarded unless they also specify a genus or species name. It's noteworthy to mention that conducting searches for the common name can be useful, however, a more exact name was required for database entry. Some

microalgae are challenging to identify to species without genetic testing or electron scanning microscopes. It became apparent that many suppliers of microalgae used only the genus name. To give the user the most options as possible, suppliers only providing a genus are not excluded from the database but are less preferred to a full genus and species name. When a scientific name of a species changes, for various reasons, cultures can be slow to adopt the new name. For this reason, older synonyms are acceptable for database entry.

While searching for suppliers, if anything seemed out of place or incorrect, that supplier was excluded from the dataset. One issue commonly encountered was an incorrect reference image representing the quoted species. This may have been a mistake by the company, but it caused doubt in the accuracy and knowledge of their product. Other red flags include, inadequate responses to inquiries, product origin from a place where the species doesn't exist, and using the exact same information for multiple species (the copy paste issue).

2. Price of product

Pricing is accurate at time of last update

supplier & pricing update- 2/11/2017

For current pricing please contact the seller as the database prices are for comparison and general reference

The cost of the product was weighed heavily in determining a suppliers addition into the database. Feed producers will undoubtedly be price selective when considering ingredients. To switch from standard feed ingredient to a more sustainable alternative, the ingredient needs to not only be ecologically sustainable but economically sustainable as well. This means that the final product needs to deliver the same nutritional effects while also staying cost effective. The price is listed in terms of dollars/kg within the product topic- price category. Some prices are converted from other international currencies and these exchange rates may change rapidly, please check the current exchange rate if purchasing from Europe, Thailand, and India. Some companies provide a price range for a product; the range is due to harvest variability, and bulk order pricing. If purchasing in bulk (metric tons), price negotiations should take place.

3. Algal physical forms for purchase

Various physical forms of algae exist for purchase: fresh, dried whole/ chopped, dry powder, pressed, extractions, and oils. The product form for feed applications is probably irrelevant, however, if the final product is powdered, then purchasing a powdered form can save on processing costs. The advantage of purchasing fresh, is you know the quality of the alga, you can see if there are epiphytes or pigment loss. The downside however, is the price of transport with refrigeration capabilities and increased weight by water. Choosing dried whole or chopped forms can ensure that you are getting the entire thallus (body) of the alga. Nutrient profiles will sometimes refer to only a portion of the plant (blade, stipe). The product too, might

only refer to a part of the alga. Therefore, when choosing powdered or chopped forms, ensure that the whole alga or the part of interest is mentioned. Some trading sites have product forms listed as part of the plant, providing powdered leaf or root. These terms are relatively meaningless as algae are not plants and lack true leaves and roots. However, these terms are ubiquitous on certain sites and are believed to be from a list of variables to choose from when adding your product. These errors were ignored in supplier selection, but note that leaf=blade and root = holdfast or stipe, as those terms will be found in nutrients and species information sections.

Presses, extractions, and oils are other forms that can be readily found. The concept of alga being pressed, typically refers to forms for human consumption. Traditionally micro and macro-algae vary by the pressed form. The most common pressed macro-algae is nori (*Porphyra*). Many know this as the seaweed wrap for sushi, which has been blended and pressed into fine sheets for Asian cuisines. Micro-algae are commonly pressed into a pill or tablet form. These are typically labeled as a dietary supplement and are commonly sold in first world nations. It is clear that in most cases companies located in first-world nations purchase bulk powder from producer nations. Then press the powder product into pill form and implement a substantial price hike. Therefore, pressed forms of algae are nothing more than expensive alternatives for feed applications. Oils and extractions are commonplace when an alga has a known valued molecule of interest. In macroalgae, pigments and sugars are targeted. Within the category "Extracted pigments" the target molecule is noted. The extracts can vary by percent/volume and often the company will have a selection of concentrations for you to choose from or can make custom orders at any level. In microalgae, the solvents are typically to break the cell open and the extracted pigments are the contents of the cell. This is what is meant by the term "cracked cell."

4. Company overview

In order for the product to be found the supplier must have some online presence. Either the company had a webpage, or their product was displayed in an online marketplace. Once a product was found, and passed other criteria listed previously in the selection flow chart, the company was investigated for contactability and reliability. Being able to contact the supplier was rated as a high priority. The ability for the purchaser to negotiate a price or contract will be critical to any feed producer wishing a repeatable steady flow of goods. If the supplier provides multiple means of contact: email, webpage, phone number, then the supplier was likely added to the database.

Another key parcel of information is if the company is a distributor or producer. Producers are defined as the algae farmers, and the place of product origin. Producers are always preferred over suppliers as every link in the chain of supply is an additional cost inflation to the final product. Producers were also preferred because of the ability to contact directly yields more detailed information about the product than contact with a distributor. That being

said, many of the suppliers within the database are distributors and keep their sources close to the vest, so to speak.

The last criteria for company investigation was reputation and stability. Company reputation was measured by ratings and reviews. Online markets typically include the ability for other users to leave comments and or ratings. In some cases the companies can even be rated by the online platform itself. Ratings can be a combination of, number of sales, number of repeating sales, response time, customer grievances/ complements, and various other parameters. Companies that had higher ratings across the board were chosen over those that had lower scores. If the company had existed for over 5 years, the company was considered mature. It's well known that the first few years of a company's existence is the hardest and rarely turn a profit. Therefore, companies that were under two years old were considered risky and were not selected when a more mature company was comparable in all other aspects.

NIH DV

This brief section of the database was added to aid in the understanding of some nutritional labeling. The national institute of health (NIH) with the food and drug administration (FDA) has reported their recommended daily value (DV) of nutrient uptake for adults over 4 years of age. On most store bought food items you will see some nutrients reported in terms of % of DV. Having the actual weights in grams for DV allows for back calculating the amount of nutrients in grams within the product.

Future progress

The goal of this project going into the future is to create a aquaculture feed resource engine (AFIRE). The contents of this database is to be a single branch (algae) in a growing platform. During the database construction a limited number of suppliers were selected as a starting point. In the future, we invite producers and suppliers to submit their own products by simply filling out necessary information and providing contact information by webform.

Database upkeep

We are committed to the database staying relevant and up-to-date. Periodically, a staff member will diagnose the overall health of the database by checking for broken links, company mortality, price changes, and species name changes. When the database is updated, the technician will manually update the analytics section indicating the date in which the last update occurred. All other values within the analytics automatically update in real time.

Other resources

Located below are other online platforms for commercial algae.

The National Center for Marine Algae <https://ncma.bigelow.org/products/algae/>

ALGIX <http://algix.com/products-services/where-to-buy-algae/>

Aquafind <http://aquafind.com/Seaweed-Wholesalers.php> **In need of updating**

Definitions

Terms are defined in the context of biological processes, specifically the field of phycology. All terms are broken down by Section → Topic → Categories in order that they appear in the database.

Species Information

Taxonomy

- **Taxonomy**- the branch of science concerned with classification, especially of organisms; systematics.
- **Ingredient**- The common or scientific name used by the supplier of the alga.
- **Genus**- A principal taxonomic category that ranks above species and below family, and is denoted by a capitalized Latin name.
- **Species**- A group of organisms having many characteristics in common and ranking below a genus. Species is the highest taxonomic resolution in the database.
 - **SP or SPP**- Refers to when the species name is not given of some genus and acts as a placeholder.

- **Taxonomic Status-** Is in reference to the cited name used and if said name is accepted as the true current name.
 - **Good-** The cited name is the currently accepted latin name.
 - **Lectotype-** This species is the organism used to describe the genus.
 - **Holotype-** A single type specimen upon which the description and name of a new species is based
 - **Synonym-** The species has been reorganized into another group or name
 - **Species unverified-** Either no species name was given, or the species was split into multiple species making it impossible to verify without a sample.
 - **Variety unverified-** A species may have a number of varieties associated with it. It's impossible to determine the variety without a detailed description.
- **Synonym-** A list of old names that may refer the the same species.
- **Other Common Names-** A list of names that are commonly used in trade of that species or genus. Country of origin are included.

Ecological Information

- **Macro/Micro-** The physical size the the alga.
 - **Macro-** Able to see with the naked eye, composed of multiple cells.
 - **Micro-** Observation requires a microscope, typically single celled or a joining of single cells.
- **GenBank[®]-** The NIH (National Institute of Health) genetic sequence database, an annotated collection of all publicly available DNA sequences.
- **Aquaculture species-** Is this species known to be actively cultivated either in a laboratory or offshore.
- **Marine/Fresh-**
 - **Marine/Fresh-** A species that can survive in either marine and freshwater environments or some combination of the two (brackish).
 - **Marine-** A species that only survives in a marine environment.
 - **Fresh-** A species that only survives in fresh water systems such as lakes and rivers.
- **Location found-** The general global location of the species.
- **Detailed locations-** A list of locations were the species has been observed.
- **Consumed by-** A list of organisms that are known to feed on the alga.
- **Ecology related notes-** Any information pertaining to where the alga inhabits.

Market information

- **Market information-** A list of known commercial applications of the alga

Alga Nutrients

Taxonomy

- **Taxonomy**- the branch of science concerned with classification, especially of organisms; systematics.
- **Ingredient**- The common or scientific name used by the supplier of the alga.
- **Genus**- A principal taxonomic category that ranks above species and below family, and is denoted by a capitalized Latin name.
- **Species**- A group of organisms having many characteristics in common and ranking below a genus. Species is the highest taxonomic resolution in the database.
 - **SP or SPP**- Refers to when the species name is not given of some genus and acts as a placeholder.

Source

- **Source**- The literature where the information was taken from.
- **Growth Conditions**- The reported growth conditions that yielded the nutrient profile.
- **Reference**- The author and article/book title where the nutrient data was derived.

Macro Nutrient

- **Fiber**- Fiber is a type of carbohydrate that the body can't digest.
- **Soluble fiber**- Fiber which dissolves in water, is readily fermented in the colon into gases and physiologically active byproducts, and can be prebiotic.
- **Carbohydrate**- Biological molecule consisting of carbon (C), hydrogen (H) and oxygen (O) atoms. Carbohydrates are commonly called by their synonym 'saccharide', a group that includes sugars, starch, and cellulose.
- **Protein**- molecule is very large compared with molecules of sugar or salt and consists of many amino acids
- **Lipid**-organic compounds including fats, oils, hormones.
- **Moisture**- The presence of slight to moderate amount of liquid, especially water.
- **Ash**- The residual material after combustion of organic material, consisting mainly of salty, inorganic constituents.

Fatty acid

- **Fatty Acid**- Molecules that are long chains of lipid-carboxylic acid found in fats and oils and in cell membranes as a component of phosphate.

Amino acid

- **Amino Acid**- Are organic compounds containing amine (-NH₂) and carboxyl (-COOH) functional groups, along with a side chain(R group) specific to each amino acid.

Minerals

- **Minerals**- A naturally occurring chemical compound, usually of crystalline form and abiogenic in origin.

Sugars

- **Sugars**- Sugar is the generalized name for monosaccharides (short-chain) and polysaccharides (long-chains) carbohydrates.

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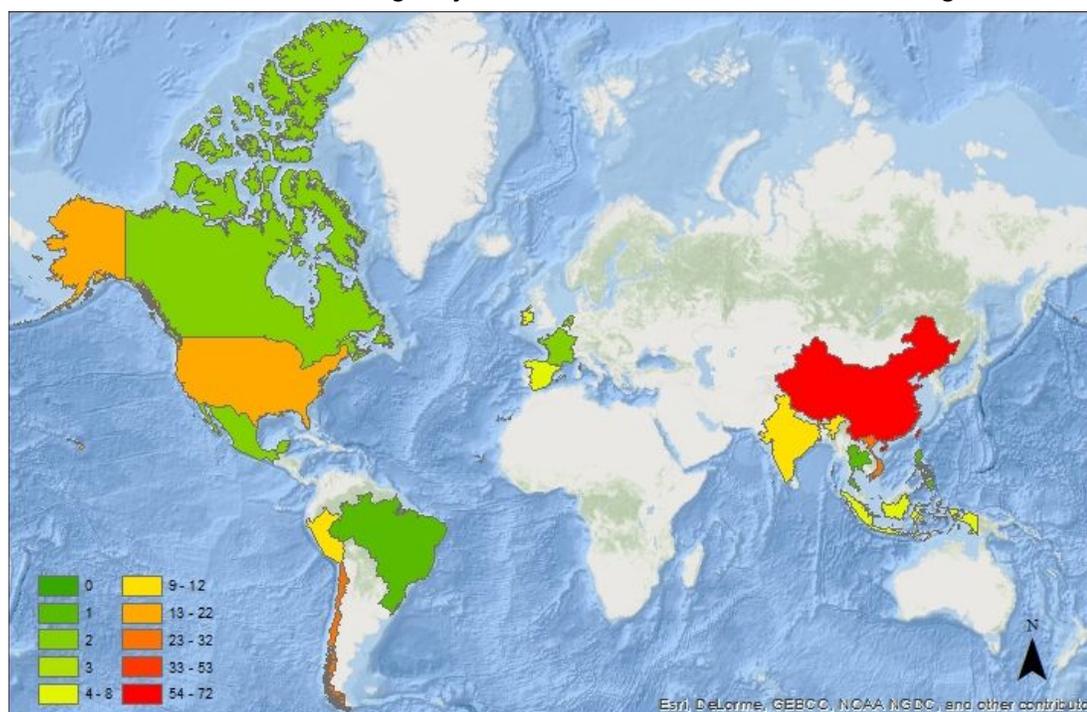
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Mapping

Using ArcGIS® Arc Map™ (v. 10.5) software, suppliers were mapped for algal species supplier distribution and number of suppliers per-country. This was a side project to help identify patterns in global algal supply. The suppliers from the database were georeferenced by countries of origin ISO2 Code (International Organization for Standardization alpha-2) and plotted on a World_Countries layer. The rationale behind using a country code instead of a higher resolution map (i.e. States or cities) is the added complication of some countries using different zoning structure. China may have a province where the United States might use States or Counties. Some suppliers also failed to list the product origin to the city, or state level. Therefore, country codes were used for maximum data representation.

In future mapping projects, it's suggested that individual country layers be applied to the map; doing so will allow each country to have its own georeference hierarchy and specific regions can be mapped using a different set of ISO codes. Mapping to a higher geographical resolution would be beneficial to locating major areas of industrial seaweed farming.



Database Analytics

Below is a live link to the current status of the database entries and updates.

Number of species	88
Number of entries on "Species information"	1075
Number of suppliers	141
Number of entries on "suppliers"	3239
Number of entries on "Nutrients"	2460
Total database Entries	6774
Last updated	2/10/2017
supplier & pricing update	2/11/2017

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