

# IDEA position paper – Applications of microalgae biomass

Within the Interreg NWEurope IDEA project, the enrollment of algae value chains in Europe was investigated. Microalgae are a diverse group of microorganisms, the majority being unicellular and photosynthetic microorganisms producing oxygen and assimilating carbon dioxide by obtaining nutrients from aquatic environments. Microalgae play an important role in the marine food chain as the primary source of omega-3 fatty acids. They are found in waste, ocean, and brine waters; have a high growth rate and productivity, do not compete with agricultural land, and have high CO<sub>2</sub>-fixing efficiency. They may be a potential, environmentally friendly solution to the requirements of the global population for more sustainable ingredients for foods, feed, cosmetics, and other applications. This document summarizes the views of the IDEA consortium on a number of questions related to applications of algae biomass.

## Are microalgae an appealing source of biobased ingredients?

- The sustainable nature of algae (direct conversion of CO<sub>2</sub>, light & nutrients into complex molecules) and their rich nutritional profile make them a good source of biobased ingredients.
- The growth and processing of microalgae need to be a viable process that can compete economically with processing methods used for traditional ingredients. It is important to identify USPs that help to differentiate algae-based ingredients from currently used compounds and to justify their higher costs that initially may be a reality.
- Points of attention that are important for potential users of algae-based ingredients are 1) the cost of algae biomass which is high to very high (20 to 150 euro/kg dry biomass) compared to other biomass types, and 2) the availability of sufficient amounts.

## What are possible applications for algae biomass and algae-based ingredients?

- As microalgae species differ in composition, algae biomass is a potential source for diverse compounds like proteins, fatty acids (incl. omega-3 fatty acids), carbohydrates, colorants, and antioxidants. The richness in algae species and compounds offers potential for multiple application areas, like cosmetics, feed, food, agro-applications (bio-actives), bio-based materials (plastics), and energy. Whole algae biomass as well algae fractions can be used. (Photo: VITO)
- Smart selection of target markets is recommended. Currently, considering the high algae biomass price and relatively limited available amounts, high-value markets that require only limited amounts of algae have the highest potential. Within time, a shift is expected to be possible towards markets that require higher amounts of algae biomass at a lower price.
- Within IDEA, high-value algae ingredients were envisioned for the feed, food, and cosmetic markets. In the IDEA capitalization part, also bioactive ingredients for the agro-market are considered. Some algae composition data (dry matter based) are shown in the table below.



Algae species (whole cells)	Protein content	Oil content	Carbohydrate content	Specific (minor) compounds present (examples)
<i>Nannochloropsis gaditana</i>	21-28 %	17-32 %	16-34 %	EPA, ...
<i>Porphyridium purpureum</i>	11-29 %	14-19 %	42-51 %	EPS, phycoerythrin, ...
<i>Chloromonas thyplos</i>	10-33 %	22-23 %	37-38 %	Carotenoids
<i>Chlorella</i> species	39-40 %	5-22 %	16 %	
<i>Scenedesmus</i> species	26-53 %	5-18 %	45 %	
<i>Spirulina</i>	40-46 %	1-2 %		Phycocyanin, ...

- Besides macro compounds, most algae species are also rich in minerals and vitamins like Vitamin B12. The latter is thought to be the only one that must be obtained from animal foods or supplements. However, its presence in some algae species can give algae products a unique selling point, as algae products can be offered as a vegan, vitamin B12-rich alternative.

### What is the potential of microalgae for use in food?



- Microalgae are rich in proteins and are a potential alternative to soy for use in human foods. Microalgae can be used as additives to provide natural pigments, carotenoids, and polyunsaturated fatty acids in foods, and may have a positive functional effect or a positive health impact. Moreover, the use of microalgae as prebiotics merits attention, especially as prebiotics have gained much interest from consumers in recent times. Prebiotics are being explored as potential ingredients to help combat the effects of inflammation and diseases associated with the same such as IBD and Crohn's disease. The carbohydrate and particularly the beta-1-3-glucan fraction of specific microalgae hold potential for the development of prebiotic ingredients based on several studies carried out to date.
- **Compositional analysis of IDEA sourced microalgae.** In the IDEA project, several microalgae cultivated in North-Western Europe were characterized for their composition of proteins, fats, carbohydrates, and minerals.
- **Beyond nutritional benefits.** Beyond basic, human and animal nutrition, bioactive peptides derived from algal proteins and other small molecules can affect human health in a beneficial way. Microalgal functional food ingredients offer a commercial opportunity for algal growers and processors to enter the functional food/nutraceutical marketplace. Several algae and extracts screened in IDEA had bioactivities associated beneficially with the prevention of diseases linked to metabolic syndrome including high blood pressure, type 2 diabetes, and inflammation.

### Which microalgae species are allowed for food applications?


- Several algae species were on the market as a food or food ingredient and consumed to a significant degree before 1997. Therefore, their access to the market is not subject to the Novel Food Regulation (EU) 2015/2283 and they can be used in food products. These species are part of the Novel Food catalogue and include: *Arthrospira platensis*, *Aphanizomenon flosaquae* var. *flosaquae*, and several *Chlorella* sp. (*Auxenochlorella protothecoides*, *Auxenochlorella pyrenoidosa*, *Chlorella sorokiniana*, *Chlorella vulgaris*, *Jaagichlorella luteoviridis*, *Parachlorella kessleri*).
- Furthermore, a series of algae species and algae fractions were approved as novel foods under specific conditions: (i) Algal oil from the microalgae *Ulkenia* sp., (ii) dried *Tetraselmis chuii* microalgae, (iii) *Schizochytrium* sp. oil rich in DHA and EPA, (iv) *Odontella aurita* microalgae, (v) astaxanthin-rich oleoresin from *Haematococcus pluvialis* algae is approved for use as food supplement (not as a food), and (vi) dried *Euglena gracilis*. The use of these algae (fractions) is narrowly restricted. Their use is only approved for specific foods and at defined maximum levels (ANNEX Regulation (EU) 2017/2470 - UNION LIST OF NOVEL FOODS (lexparency.org)).

### Microalgae as food supplements, health beneficial, and functional ingredients in foods

- Due to the excellent nutritional properties of several microalgae (rich amino acid profile, source of bioactive peptides with antihypertensive health benefits, high content of PUFAs), they are ideal for use as **food supplements**. Besides, microalgae (extracts) can find applications in the food industry as **techno-functional ingredients** to replace existing ingredients that provide emulsion or foaming activities. Such functional ingredients can be used to make egg-free mayonnaise and

salad dressings. However, the sensory attributes of microalgal-containing products are a limiting factor in their development in food products.

- Within IDEA, *Spirulina* sp., *Chlorella* sp., and *Nannochloropsis* sp. were included in biscuits at concentrations between 2-4 %. Sensory analysis carried out with consumer panels found that the overall acceptability of the products was hampered by the color and mouth feel of the products. Selection of the correct food carrier for microalgae is essential to their use.
- Jelly sweets, bounce ball energy treats, yoghurts and trail mix seed products were also made in IDEA. Target consumers (children) were largely accepting of microalgae (*Spirulina* sp.) inclusion in sweets and biscuits (Figure 1) but both contained either Stevia or sugar to mask microalgal flavors. (Photos: TEAGASC)
- Overall, the selection of food carriers for whole microalgae is an important determinant of product success with microalga. Use of microalgae in fat-containing products such as mayonnaise is successful to date and companies including Algama in France and the Good Spoon in the US sell mayonnaise made using *Chlorella* sp. currently to vegan consumers primarily.



**Bounce ball control formulation (100g):**

- 75 g peanut butter
- 15 g seed/nuts
- 10g honey/nectar

**Test sample:**

- 15 g of peanut butter substituted with microalga or microalgal protein

**Apple protein dessert control formulation (100g):**

- 40 g apple puree
- 30 g water
- 10g whey protein
- 10 g sucrose
- 5 g vegetable oil
- 5 g stabilizer (2.5 g pectin, 2.5 g agar)

**Test sample:**

- 10 g whey protein substituted with microalgal protein

### What is the potential of microalgae in feed?



- As algae are claimed to be rich in bio-active compounds, they can potentially improve animal health even when consumed in low amounts. Currently, some microalgae are used in feeds for livestock, especially pigs and poultry as well as in shellfish and fish farming. Companies including ADM, DSM, and Evonik, Corbion and Devenish Nutrition produce aquaculture and animal feeds containing the European Food Safety Authority (EFSA) approved food ingredients *Spirulina* sp. and *Chlorella* sp.
- Microalgae are credited with increasing the health of poultry when included in feeds and enhancing shell strength and yolk color of eggs. *Chlorella vulgaris*, *Cyanobacteria Spirulina maxima*, and *Haematococcus pluvialis* are the dominant species used in animal feeds. In addition, microalgae use in the pet feed/treat sector is a growing market sector. Species currently used include, *Spirulina* sp., *Chlorella* sp., *Dunaliella* sp., *Haematococcus* sp., *Cryptocodinium* sp., *Schizochytrium* sp., *Euglena* sp., and *Nannochloropsis* sp.

Within IDEA, several animal trials were performed to evaluate the impact of algae inclusion in feed.

- **Dogs:** Health-promoting dog snacks were formulated and tested. *Spirulina* sp. and *Nannochloropsis* sp.-based ingredients were included independently in biscuit treat products and were fed to dogs (Figure 2). The health benefits of the developed treats were determined against regular treats and treats made using antihypertensive dairy protein hydrolysates. Initial results indicate that these microalgae help to maintain normal blood pressure (*Spirulina* sp.), help to increase appetite (*Nannochloropsis* sp.) and may have anti-inflammatory benefits for pets. (Photo: TEAGASC)



- **Dogs:** Also health promoting dog feed was formulated and produced with algae-based ingredients. More specifically, *Chloromonas* and *Porphyridium* based ingredients that were shown to generate a positive immune response via in vitro trials, were formulated in dog feed which was subsequently tested in an in vivo dog trial. The impact on the immunity was monitored by fecal IgA measurements. The IgA level was the highest in the group with the *Chloromonas* feed, showing a positive trend (P=0.07) compared to the control feed. *Porphyridium* did not show a significant difference when compared to the control feed. This suggests that adding *Chloromonas* in dog feed has a positive effect on the immune system of the dog.
- **Chickens:** Researchers from the Interreg NWE IDEA and Interreg 2seas Valgorize research projects joined forces to investigate the impact of algae inclusion (1-2%) in chicken feed. Three types of defatted algae biomass (defatted *Chlorella*, defatted *Chloromonas*, and defatted *Nannochloropsis*) were included in broiler feed and the impact on broiler growth, gut health, and gut morphology was evaluated. Animal weight and daily growth tended to be higher for animals that received algae-supplemented diets. Feed intake was similar among treatment groups over the entire experimental period, except for the control animals, which had a somewhat lower feed intake. Feed conversion ratio tended to be lower for several treatment groups than for control animals. Significant differences were noted in the gut morphology of the animals.
- **Pigs:** A preliminary pig trial with promising results was performed.

### Use of algae in the cosmetic industry?



- Algae biomass has short-term potential as feedstock for cosmetic ingredients because the threshold amount to start a cosmetic line matches with the algae biomass that is currently available. From an algae farmer point of view, the higher priced cosmetic ingredients are attractive to come to an economic viable production. Moreover, the cosmetic industry is looking for sustainable non-animal-based ingredients, which algae biomass can provide.
- Algae components that are suitable for cosmetic application comprise algae oil (for e.g. skin care products) and sugars (for e.g. hair care products). Ingredients need to be tailored towards the needs of the envisioned application, comprising for instance removal of odor and color.
- Within IDEA, major attention was given to algae oil. Algae oil was extracted from different algae



(Photo: VITO)

species, each with its own, specific oil composition. At pilot scale, larger amounts of deodorized and decolorized oil samples were produced. The defatted biomass was used for feed and food application enabling maximal valorization of the algae biomass.

**In conclusion**, the IDEA consortium demonstrated that algae biomass (whole and fractionated) can be used as active ingredient in food, feed, and cosmetic applications. The results can be used to explore the applications further and come up with marketable compounds.



Full IDEA partners:



IDEA - Implementation and development of economic viable algae-based value chains (NWE639)  
 Duration: 9/2017 – 10/2021, capitalisation till 12/2023  
 Website: [www.nwseurope.eu/IDEA](http://www.nwseurope.eu/IDEA)

Lead partner: VITO, Belgium



Increased green feed production | Sustainability value handling | Processing into marketable compounds | New sustainable products