Microalgae as a novel food

Potential and legal framework

Tomke F. Prüser, Peggy G. Braun, Claudia Wiacek

Abstract

Microalgae such as *Chlorella* and spirulina have high dietary potential, because they contain a large number of nutrients which seem to make them predestined for use in human nutrition. They are characterised by fast growth and enable low-resource production of important nutrients, such as n-3 fatty acids.

Alongside a few approved species of microalgae, there are several thousand microalgae that are not used in human nutrition despite their interesting nutrient profile. The reasons for this are explored in this outline paper and can be traced back to Europe's legal framework for consumer protection. As a result of the Regulation on novel foods, foods are only approved for use on the European market after a time-consuming investigation process, in order to protect consumers from unsafe foodstuffs.

Keywords: microalgae, novel food, Novel Food Regulation, n-3 fatty acids, vitamin B_{12}

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Corresponding author

Tomke Friederike Prüser
Institut für Lebensmittelhygiene
Veterinärmedizinische Fakultät, Universität Leipzig
tomke_friederike.prueser@vetmed.uni-leipzig.de

Microalgae

The name "algae" is a collective term for a large polyphyletic group of living things including both plants and bacteria. What they almost all have in common is that they contain chlorophyll and are thus also able to produce energy from light, carbon dioxide and water through oxygenetic photosynthesis [1]. They differ from mosses and ferns in that algae are not specialised for life on land [2]. Even this very general definition is incomplete and excludes whole taxa of algae which have lost the ability to photosynthesise over the course of their development [1, 2].

The algae group is divided into microalgae and macroalgae, whereby macroalgae are multicelled organisms visible to the naked eye which form stems and leaves. Microalgae on the other hand are microscopically small, single-celled organisms which are however visible macroscopically when collected together in groups [3]. These microalgae include green algae and diatoms, but also lesser-known groups like the dinoflagellates and *Eustigmataceae* [1, 4]. There is at present still no consensus among phycologists on the classification of cyanobacteria within the group of microalgae, since, like all eukaryotic microalgae, they have the ability for oxygenic photosynthesis, but are on the other hand prokaryotic [4, 5]. Most of the metabolic products known as algal toxins are produced by this group [6]. The heterogeneity within the group of microalgae makes it necessary to adapt cultivation conditions for the individual species of algae and their uses in order to create the ideal growth conditions for specific species [7].

Cultivation is done either in closed photobioreactors and fermenters or in open systems, known as open ponds [4, 8]. It is possible to cultivate algae autotrophically or allow them to grow heterotrophically with external carbon sources [7]. The proportions of the microalgal components can also be changed by the cultivation method and thus optimised for the specific use. This is how algae accumulate under conditions where there is a limited supply of nutrients e.g. triglyceride and starch [9, 10].

Microalgae in the food industry

Microalgae such as *Chlorella* and spirulina have considerable dietary potential due to their spectrum of nutrients. They thus became a focus of research as early as 1950 and the first microalgae were cultivated and marketed on a commercial scale from 1960 [8]. Since then interest in microalgae has steadily increased due to their adaptability and the number of different constituents which can be obtained from them [8, 11]. Whereas initially microalgae were sold mainly as nutritional supplements in the form of powders, capsules, and tablets, today they are also incorporated into various products like pasta, smoothies, soft drinks, chocolate, and ice cream [12, 13]. In 2018 the global market volume for microalgae products was already USD 9.9 billion and with a projected annual growth rate of over 7% market volume could reach USD 14.99 billion by 2024 [14]. There are large production plants in countries such as Israel, United States, Australia and China. In Germany too there are at least 13 plants producing microalgae [15].

The algae marketed as spirulina algae are *Arthrospira platensis* and *Arthrospira maxima*. Both are spiral-shaped cyanobacteria, with *Arthrospira platensis* being the more common [16]. Since these are blue-green algae, i.e. bacteria capable of photosynthesis, it is not correct to classify these species as microalgae, even though they are marketed as such [5]. Spirulina is promoted mainly for its protein and vitamin B_{12} content. Tablets of dried spirulina have a vitamin B_{12} content of 120–240 μg/100 g, although 83% is in the form of non-bioavailable pseudovitamin B_{12} [17]. The protein content in spirulina is around 50–60% of the dry mass with a biological value of 50–70 [18]. The biological value of the proteins also depends on the preparation of the algae, boiled spirulina algae have a biological value of 48–54, the raw value is 60–65 and when dried the biological value even rises to 68–78 [18, 19]. What is less well-known is the use of phycobiliproteins, in particular phycocyanin extract from spirulina, as a natural blue colourant [8]. In 2018 this had achieved a market value of USD 112.3 million [20] and was approved by the European Food Safety Authority (EFSA) as a colourant.

Three species of the green algae genus *Chlorella* are approved; these are *Chlorella luteoviridis*, *Chlorella pyrenoidosa* and *Chlorella vulgaris* [21]. *Chlorella vulgaris* was described by Beijerinck in 1890 and at the time was the first microalgae species propagated in a pure culture [22, 23]. Its protein content is similar to that of spirulina at 51–58% of dry mass [9]. Unlike cyanobacteria, eukaryotic microalgae cannot themselves produce vitamin B_{12} [24]. *Chlorella* spp. are however able to absorb and accumulate the bioavailable vitamin B_{12} which is produced by bacteria and present in the ambient medium [25, 26]. This means that they can serve as a vegan source of vitamin B_{12}.

Marine dinoflagellates of the species *Crypthecodinium cohnii* are cultivated heterotrophically with various external carbon sources like glucose or ethanol. They can produce large quantities of n-3 fatty acid docosahexaenoic acid (DHA) [27]. This unsaturated fatty acid has an anti-inflammatory, neuroprotective effect and is important for development of the brain and visual acuity in infants [28]. For this reason, unsaturated n-3 fatty acids are added to many baby milk products. The production of unicellular oils from oil-producing microalgae like *Crypthecodinium cohnii* represent an alternative to fish oils otherwise widely used.

However, even microalgae not approved up to now have major potential. For instance, not only does the dry mass of *Phaeodactylum tricornutum* contain 1.7-5.0% of eicosapentaenoic acid (EPA) [29], it also contains the carotenoid fucoxanthin [30]. The extract from this alga also has anti-inflammatory effects on human blood cells [31].
The microalga *Microchloropsis salina* also stores EPA (up to 9% of its dry mass) and forms alpha tocopherol, a form of vitamin E [32, 33].

This paper explores why up to now comparatively few of the over 200,000 species of microalgae are commercially available [34]. One reason is that with effect from 15 May 1997 novel foods may only be introduced to the European market after exhaustive testing. The legal basis for this is the Regulation on novel foods (Regulation (EU) 2015/2283), which is intended to protect consumers from insufficiently tested and potentially unsafe foodstuffs [35].

Legal situation in the European Union

Legal framework

Which components of the algae approved in the European Union (EU) up to now may be used and in which foodstuffs they may be incorporated is regulated, depending on the date of their approval, by the novel food catalogue and the Regulation on novel foods (Regulation (EU) 2015/2283) [8, 21, 35]. Independently of this, all algal products are subject to the same general legal provisions as other food, for instance Regulation (EC) No 178/2002, Regulation (EC) No 852/2004 on the hygiene of foodstuffs and Regulation (EU) 2017/625 on official controls on all foods, the Regulation (EU) No 1169/2011 on the provision of food information to consumers and Regulation (EC) No 1881/2006 setting maximum levels for inanimate contamination [8, 36–41]. Where health-related claims are made for the sale of algal products, these must be in conformity with the Regulation (EC) No 1924/2006 [42]. Since, unlike for other food groups, there are no specific microbiological maximum levels for algae, the criteria set out in Regulation (EC) No 2073/2005 are applied [43]. Additionally, when microalgae are marketed as nutritional supplements they are also subject to the provisions of the German Ordinance on Nutritional Supplements (*Verordnung über Nahrungsergänzungsmittel*, NemV) [44, 45].

Microalgae approved in the EU

Probably the best-known microalgae available on the market are the spirulina and *Chlorella* algae described above [46]. In all legislation it must be borne in mind that the introduction of molecular biological methods has resulted in ongoing changes to the taxonomy of microalgae, whereas previously their classification was done on the basis of morphological and cytological characteristics [47]. This means that the names of the algae used in the legislation and catalogues are often no longer the ones by which they are known in line with the latest scientific research [48, 49]. Thus, the species approved as a food under the designation *Chlorella pyrenoidosa* is now regarded as outdated [50]. In new studies it has been shown that the algae classified in collections under this name belonged to other species and phyla, such as *Chlorella vulgaris*, *Chlorella sorokiniana*, *Coelastrella vacuolata*, *Graesiella emersonii*, or *Auxenochlorella protothecoides* and that there is in fact no actual *Chlorella pyrenoidosa* [50]. The species *Chlorella luteoviridis* has also undergone several taxonomic revisions since its classification in the novel food catalogue. The scientific consensus here is that the algae do not belong to the genus *Chlorella*, but rather to the genus *Heterochlorella* and thus must be designated *Heterochlorella luteoviridis* [50]. Of the three *Chlorella* species listed in the novel food catalogue, only *Chlorella vulgaris* is a currently valid taxonomic name of a species of microalgae. The other two species do not exist according to scientific consensus. However, microalgae are still sold under the names *Chlorella pyrenoidosa* and *Chlorella luteoviridis*, whilst the species actually referred to by this designation is not listed in the novel food catalogue [21]. In order to find solutions to these problems a group of experts from the European Committee for Standardization (CEN, *Comité Européen de Normalisation*) is currently developing criteria by which the nomenclature of algae in Europe could be homogenised and establishing standardised examination processes to classify the species of algae used [51]. Over the course of this five-year project examination methods for the various components of algae and microbiological reference values for algae products are to be established and standardised [51].

Novel food catalogue

Some algae, such as *Chlorella*, have long been used in human nutrition. This means that even before 15 May 1997 they were consumed in significant quantities in at least one Member State of the EU [8, 21]. Foods that were already consumed before this date are treated as not novel and are fundamentally approved for use in products [35]. They are listed in the novel food catalogue as soon as information is available to the European Commission on consumption to a significant degree [21, 35].

The novel food catalogue is administered by the European Commission, which enters information obtained from the EU Member States obtained in turn from firms and companies [21, 35]. The companies have to provide corresponding proof that the foods were already consumed before 1997 [21, 35]. This means that the catalogue is not a definitive list and only serves as a guide as to whether a food is classified as novel [21]. The cyanobacteria *Aphanizomenon flosaquae* var. Flosaquae and *Arthospira platensis* and the green algae *Chlorella luteoviridis*, *Chlorella pyrenoidosa* and *Chlorella vulgaris* are listed as microalgae in the novel food catalogue [21].

The Regulation on novel foods (EU) 2015/2283

The Regulation on novel foods governs the use and approval of foods which were not yet consumed to a significant degree before 1997 [35]. The first Regulation on novel foods came into force in 1997 as Regulation (EC) No 258/97 [52]. It was replaced in 2018 by Regulation (EU) 2015/2283 and the associated implementing regulations [35]. Since 1997 five microalgae species have been approved as novel foods [35, 53]. Only in the case of the microalgae *Odontella aurita* and *Tetraselmis chuii* may the whole biomass be used in certain foodstuffs with defined maximum levels in each case [53]. For *Ulkenia* sp. and *Schizochytrium* sp. only the extracted algae oils are approved [53]. For the microalgae *Haematococcus pluvialis* on the other hand only the astaxanthin-rich oleoresin is approved for use in food supplements, but not as a food [53]. Unlike the microalgae not considered novel foods, the approval for these five algae is very precisely restricted [53]. They are only approved in specific foodstuffs and with defined maximum levels [53]. As at the publication date of this paper, fucoxanthin from *Phaeodactylum tricornutum* is under investigation [54]. ◆ Table 1 gives an overview of the algae species newly approved under Commission Implementing Regulation (EU) 2017/2470 and their approved components.

Approval procedure in line with the Regulation on novel foods

Novel foods are only approved to be placed on the market once they are included by way of an implementing act in the Union list of authorised novel foods included in Council Implementing Regulation (EU) 2017/2470 which is part of Council Regulation (EU) 2015/2283 [35]. In the Regulation on novel foods it is stipulated in this respect that the food must not represent a risk for human

health. In addition, consumers may not be misled about the novel foods and there must be no disadvantage for the consumer when an already approved food is replaced [35].
The final decision as to whether and under what conditions an application can be made is a matter for the European Commission [35]. This body also decides whether a food is considered a novel food and on the final labelling [35]. In addition, the Commission forwards the application to the other Member States and to the public before a decision is made [35]. If the result is positive the food is added to the Union list of authorised novel foods by an implementing act [35, 53].

Algae species approved under Commission Implementing Regulation (EU) 2017/2470	Components approved under (EU) 2017/2470
Odontella aurita	whole alga
Tetraselmis chuii	whole alga
Ulkenia sp.	oil (rich in DHA and EPA) (phylum not precisely defined in Commission Implementing Regulation [EU] 2017/2470)
Schizochytrium sp.	→ oil (rich in DHA and EPA) (phylum not precisely defined in Commission Implementing Regulation [EU] 2017/2470)
	→ oil from the phylum ATCC PTA-9695
	→ oil (phylum not precisely defined in Commission Implementing Regulation [EU] 2017/2470)
	→ oil from phylum T18
Haematococcus pluvialis	oleoresin rich in astaxanthin

Tab. 1: **Algae species approved under Commission Implementing Regulation (EU) 2017/2470** (adapted in line with [53])

There is a simplified procedure for traditional foods from third countries which have been consumed there for over 25 years. In this case the applicant must only send the Commission notification which is passed on to the Member States and the authorities [35, 55]. If no justified objection is raised by these bodies as regards the safety of the traditional food, the Commission approves introduction to the market and the Union list of authorised novel foods is updated immediately [35, 55].

Role of the EFSA

A novel food must be safe and in order to test this precondition the European Commission can request a scientific opinion from the EFSA [35, 41, 56]. The EFSA is then in direct contact with the food producer, evaluates the application submitted and can also request further investigations of the novel food in order to evaluate the risk [35, 56]. However, the final decision is made by the European Commission on the basis of the expert report from the EFSA [35].

Microalgae in third countries

Regulation (EU) 2015/2283 only applies in the Member States of the EU [35]. In third countries corresponding national provisions apply. A large proportion of the microalgae produced originates in East Asia, Australia and the USA and is therefore not subject to European legislation [57]. Such microalgae are interesting for the European market because the approval of traditional foods from third countries is simplified [55]. Approval of these microalgae thus represents an alternative to the more complex approval of microalgae not yet approved as foods.

In Asia it is predominantly *Chlorella* and spirulina that are cultivated as traditional foods [57, 58]. But in China, for instance, the microalgae *Dunaliella salina*, *Haematococcus pluvialis*, *Chlorella pyrenoidosa*, *Euglena gracilis* and *Nostoc sphaeroides* are also approved as novel foods [59, 60].

The biomass from spirulina and *Chlorella*, β-carotene from *Dunaliella salina* and oil from *Cypthecodinium cohnii* are considered traditional foods in Australia [58, 61, 62]. However, only *Schizochytrium* sp. (oil and biomass) and *Ulkenia* sp. (oil) are approved as novel foods in Australia [63].

In the USA the precondition for use of a substance as a food or a food ingredient is inclusion on the GRAS (generally recognised as safe) list of the US Food and Drug Administration (FDA) [64]. GRAS status has been granted to *Chlorella protothecoides* (biomass and extract), spirulina (biomass and phycocyanin extract), *Dunaliella bardawil* (biomass), *Haematococcus pluvialis* (astaxanthin-rich extract), *Prototheca moriformis* (oil and fat), *Ulkenia* sp. (oil), *Crypthecodinium cohnii* (oil) and *Schizochytrium* sp. (oil) [65] (◆ Table 2). The oil of the dinoflagellates *Crypthecodinium cohnii* is used in baby food in the USA, since this oil consists almost exclusively of docosahexaenoic acid [66].

Possible sources of risk for consumers

The goal of Regulation (EU) 2015/2283 is to protect consumers from unsafe foods and food fraud. In the case of microalgae such risks can occur as a result of impurities during their cultivation or due to intrinsic components of the microalgae.
Impurities from outside can be minimised, as in the case of other foods too, by cultivation conditions or later further processing. Con-

Microalgae	Component	GRN No.
Chlorella protothecoides	biomass	469, 519
	oil	384
Arthrospira platensis (spirulina)	biomass	127, 417
	phycocyanin extract	424
Dunaliella bardawil	biomass	351
Haematococcus pluvialis	astaxanthin-rich extract	294, 580
Ulkenia sp. SAM2179	oil	319
Crypthecodinium cohnii	oil	41
Schizochytrium sp.	oil	137, 553, 677, 731, 732, 776, 777
Prototheca moriformis	oil	527, 754
	fat	673

Tab. 2: **Microalgae with GRAS status** [own diagram]
GRAS = generally recognised as safe; GRN No. = GRAS notice

tamination with heavy metals can occur, e.g. by the algae absorbing and accumulating matter from their environment [67]. In closed systems with water free from heavy metals this is therefore not a problem. The maximum levels for such inanimate contamination are stipulated in Regulation (EC) No 1881/2006. Animate contaminants, like bacteria or fungi, also get into the culture from outside and should be reduced by suitable management and treatment of the algae before their use as a food. Thus, for instance, through drying and disrupting *Scenedesmus* biomass, it has been possible to achieve a reduction of microbiological flora from 4 x 10^7 CFU[1] /ml algae culture to 1 x 10^5 CFU/g algae powder at a concentration of 0.48 g/l dry biomass per litre of algae culture [68]. However, the lack of microbiological reference values does present a problem, i.e. there are no unified rules for the microbiological structure of microalgal products. When commercial traders give their own specifications these vary considerably.

Another risk is contamination with undesirable species of microalgae. For instance, when harvesting *Aphanizomenon flosaquae* var. Flosaquae (AFA algae) from the Klamath Lake – the only place from which these microalgae are harvested – there may be contamination with microalgae of the species *Microcystis aeruginosa*, which can produce microcystin LR [69, 70]. In animal models and human cell lines this substance has shown genotoxic and hepatotoxic properties [71, 72]. As a result, the Oregon Department of Agriculture (ODA) has established a maximum level of 1 µg microcystin LR/g AFA algae product [73]. There is no other limitation for microcystin in algae products anywhere in the world, so this is also applicable for exports to the EU [73, 74]. Nevertheless, an anonymous online survey by Rzymski et al. indicated that consumers who were taking AFA algae products showed significantly higher damaging side-effects than consumers of *Chlorella* or spirulina products [75].
Not due to conditions in the system are hazards represented by the microalgae themselves. Species from the groups of cyanobacteria and dinoflagellates in particular can produce a wide range of toxins which can also get into the food chain via fish and mussels that absorb these algae. However, no species of microalgae with the capacity to produce toxins is approved as a food and when new microalgae are approved for use by way of the Regulation on novel foods the EFSA requires a subchronic cytotoxicity test over 90 days [56, 76]. Another risk in single-celled microorganisms is the relatively high content of purines, which are a component of nucleic acids [77]. In the human body these are broken down into uric acid and can increase the risk of gout if high levels are absorbed [78]. Compared to yeasts (11% of dry matter) and bacteria (up to 18% of dry matter) the content of nucleic acids in algae is fairly low at 4–6% of dry matter [77, 78]. This also applies to cyanobacteria like spirulina [79]. Since the safe dose of nucleic acids from single-celled protein has been established at 2 g per day, this would mean a daily intake of approx. 40 g of algae [80].

Conclusion

Even the few microalgae known and investigated up to now produce a wide range of nutrients (fatty acids, pigments, proteins, vitamins, precursors to vitamins) and thus have potential for various fields of use. They grow considerably faster than land plants and it is also relatively easy to influence the quantity of their constituents by cultivation method [9]. As a result of these properties they are becoming ever more popular, particularly in the field of functional foods and nutraceuticals, as demonstrated by the steadily increasing number of microalgal products in supermarkets. At present only a few different species of algae are used since their use must be authorised. The strict legal provisions are intended to protect consumers from insufficiently researched and potentially unsafe foodstuffs. In order to enable innovation in the algal product sector despite this fact, the homogenisation of standards within Europe by the European Committee for Standardisation (CEN) is a first step to making the approval of new algal products more transparent and thus simpler. Another option would be the approval of algae such as *Microchloropsis* sp., which are already used in aquaculture. Experience acquired from long years of their use as a feedstuff could be used instead of toxicity studies for these microalgae [33]. The easier approval of microalgae from third countries could enable new algae species

[1] CFU = colony forming unit

to expand the limited range available on the European market [55]. More intense cooperation between industry and the scientific community is also desirable and could accelerate discoveries on the potential of microalgae and their approval. Overall, the approval of additional species of algae with their specific nutrient profiles would open up new opportunities for use and ensure that the high potential of these microorganisms was fully exploited.

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Tomke F. Prüser[1]
Prof. Dr. Peggy G. Braun
Dr. Claudia Wiacek
Institut für Lebensmittelhygiene
Veterinärmedizinische Fakultät, Universität Leipzig
[1] tomke_friederike.prueser@vetmed.uni-leipzig.de

Conflict of Interest
The authors declare no conflict of interest.

References

1. *van den Hoek C, Mann D, Jahns HM: Algae: Introduction to phycology. Cambridge: Cambridge Univ. Press 1998.*
2. *Borowitzka MA: Systematics, taxonomy and species names: Do they matter? In: Borowitzka MA, Beardall J, Raven JA (eds.): The physiology of microalgae. Cham: Springer International Publishing 2016, 655–681.*
3. *Macreadie PI, Jarvis J, Trevathan-Tackett SM, Bellgrove A: Seagrasses and macroalgae: importance, vulnerability and impact. In: Phillips BF, Pérez-Ramírez M (eds.): Climate change impacts on fisheries and aquaculture: a global analysis. Hoboken, NJ: John Wiley & Sons 2018, 729–770.*
4. *Metting FB: Biodiversity and application of microalgae. J Ind Microbiol Biotechno 1996; 17(5–6): 477–89.*
5. *Neumann U, Bischoff S: Mikroalgen in der Humanernährung – eine sinnvolle Zukunftsperspektive? Aktuel Ernahrungsmed 2018; 43(2): 102–10.*
6. *Carmichael WW: Cyanobacteria secondary metabolites-the cyanotoxins. J Appl Bacteriol 1992; 72(6): 445–59.*
7. *Borowitzka MA: Algal physiology and large-scale outdoor cultures of microalgae. In: Borowitzka MA, Beardall J, Raven JA (eds.): The physiology of microalgae. Cham: Springer International Publishing 2016, 601–652.*
8. *Enzing C, Ploeg M, Barbosa M, et al.: Microalgae-based products for the food and feed sector: an outlook for Europe. Luxembourg: Publications Office 2014.*
9. *Dragone G, Fernandes BD, Abreu AP, Vicente AA, Teixeira JA: Nutrient limitation as a strategy for increasing starch accumulation in microalgae. Appl Energy 2011; 88(10): 3331–5.*
10. *Sakarika M, Kornaros M: Kinetics of growth and lipids accumulation in Chlorella vulgaris during batch heterotrophic cultivation: effect of different nutrient limitation strategies. Bioresour Technol 2017; 243: 356–65.*
11. *Spolaore P, Joannis-Cassan C, Duran E, Isambert A: Commercial applications of microalgae. J Biosci Bioeng 2006; 101(2): 87–96.*
12. *Nova P, Martins AP, Teixeira C, et al.: Foods with microalgae and seaweeds fostering consumers health: a review on scientific and market innovations. J Appl Phycol 2020; 32(3): 1789–802.*
13. *Lafarga T: Cultured microalgae and compounds derived thereof for food applications: strain selection and cultivation, drying, and processing strategies. Food Rev Int 2020; 36(6): 559–83.*
14. *TechSci Research: Global algae products market by source (macroalgae and microalgae), by application (pharmaceuticals and nutraceuticals, food & beverages, cosmetics and others), by region, competition, forecast & opportunities, 2024. ID: 4790320. www.researchandmarkets.com/reports/4790320/global-algae-products-market-by-source#rela1-4521311 (last accessed on 21 April 2020).*
15. *Europäische Kommission: Joint Research Centre – Algae Database. Knowledge Centre for Bioeconomy. https://ec.europa.eu/knowledge4policy/visualisation/bioeconomy-different-countries_en#algae_prod_plants (last accessed on 19 October 2020).*
16. *Tomaselli L: Morphology, ultrastructure and taxonomy of Arthrospira (Spirulina) maxima and Arthrospira (Spirulina) platensis. In: Vonshak A (ed.): Spirulina platensis (Arthrospira): Physiology, cell-biology, and biotechnology. London, Bristol, PA: Taylor & Francis 1997, 1–17.*
17. *Watanabe F, Katsura H, Takenaka S, et al.: Pseudovitamin B(12) is the predominant cobamide of an algal health food, spirulina tablets. J Agric Food Chem 1999; 47(11): 4736–41.*
18. *Becker EW: Microalgae as a source of protein. Biotechnol Adv 2007; 25(2): 207–10.*
19. *Clément G, Giddey C, Menzi R: Amino acid composition and nutritive valve of the alga Spirulina maxima. J Sci Food Agric 1967; 18(11): 497–501.*
20. *Nethravathy MU, Jitendra MG, Sandeep MN, Ajam SY: Recent advances in microalgal bioactives for food, feed, and healthcare products: commercial potential, market space, and sustainability. Compr Rev Food Sci Food Saf 2019; 18(6):*

1882–97.
21. Europäische Kommission: Novel Food Catalogue. https://ec.europa.eu/food/safety/novel_food/catalogue_en (last accessed on 11 September 2020).
22. Beijerinck MW: Kulturversuche mit Zoochlorellen, Lichenogonidien und anderen niederen Algen. Bot Ztg 1890; 48: 726–40.
23. Krienitz L, Huss VAR, Bock C: Chlorella: 125 years of the green survivalist. Trends Plant Sci 2015; 20(2): 67–9.
24. Grossman A: Nutrient acquisition: The generation of bioactive vitamin B12 by microalgae. Curr Biol 2016; 26(8): R319–21.
25. Kittaka-Katsura H, Fujita T, Watanabe F, Nakano Y: Purification and characterization of a corrinoid compound from Chlorella tablets as an algal health food. J Agric Food Chem 2002; 50(17): 4994–7.
26. Watanabe F, Abe K, Takenaka S, Tamura Y, Maruyama I, Nakano Y: Occurrence of cobalamin coenzymes in the photosynthetic green alga, Chlorella vulgaris. Biosci Biotechnol Biochem 1997; 61(5): 896–7.
27. Sijtsma L, Swaaf ME de: Biotechnological production and applications of the omega-3 polyunsaturated fatty acid docosahexaenoic acid. Appl Microbiol Biotechnol 2004; 64(2): 146–53.
28. Calder PC: Docosahexaenoic acid. Ann Nutr Metab 2016; 69(Suppl 1): 7–21.
29. Meiser A, Schmid-Staiger U, Trösch W: Optimization of eicosapentaenoic acid production by Phaeodactylum tricornutum in the flat panel airlift (FPA) reactor. J Appl Phycol 2004; 16(3): 215–25.
30. Rebollosos-Fuentes MM, Navarro-Pérez A, Ramos-Miras JJ, Guil-Guerro JL: Bimoass nutrient profiles of the microalga Phaedactylum tricornutum. J Food Biochemistry 2001; 25(1): 57–76.
31. Neumann U, Louis S, Gille A, et al.: Anti-inflammatory effects of Phaeodactylum tricornutum extracts on human blood mononuclear cells and murine macrophages. J Appl Phycol 2018; 30(5): 2837–46.
32. Safafar H, Hass M, Møller P, Holdt S, Jacobsen C: High-EPA biomass from Nannochloropsis salina cultivated in a flat-panel photo-bioreactor on a process water-enriched growth medium. Mar Drugs 2016; 14(8): 144.
33. Zanella L, Vianello F: Microalgae of the genus Nannochloropsis: chemical composition and functional implications for human nutrition. J Funct Foods 2020; 68: 103919.
34. Norton TA, Melkonian M, Andersen RA: Algal biodiversity. Phycologia 1996; 35(4): 308–26.
35. Europäisches Parlament und Rat: Verordnung (EU) 2015/2283 des Europäischen Parlaments und des Rates – vom 25. November 2015 – über neuartige Lebensmittel, zur Änderung der Verordnung (EU) Nr. 1169/2011 des Europäischen Parlaments und des Rates und zur Aufhebung der Verordnung (EG) Nr. 258/97 des Europäischen Parlaments und des Rates und der Verordnung (EG) Nr. 1852/2001 der Kommission 2015.
36. Europäisches Parlament und Rat: Verordnung (EG) Nr. 852/2004 des Europäischen Parlaments und des Rates vom 29. April 2004 über Lebensmittelhygiene 2004.
37. Europäisches Parlament und Rat: Verordnung (EU) 2017/625 des europäischen Parlaments und des Rates vom 15. März 2017 über amtliche Kontrollen und andere amtliche Tätigkeiten zur Gewährleistung der Anwendung des Lebens- und Futtermittelrechts und der Vorschriften über Tiergesundheit und Tierschutz, Pflanzengesundheit und Pflanzenschutzmittel, zur Änderung der Verordnungen (EG) Nr. 999/2001, (EG) Nr. 396/2005, (EG) Nr. 1069/2009, (EG) Nr. 1107/2009, (EU) Nr. 1151/2012, (EU) Nr. 652/2014, (EU) 2016/429 und (EU) 2016/2031 des Europäischen Parlaments und des Rates, der Verordnungen (EG) Nr. 1/2005 und (EG) Nr. 1099/2009 des Rates sowie der Richtlinien 98/58/EG, 1999/74/EG, 2007/43/EG, 2008/119/EG und 2008/120/EG des Rates und zur Aufhebung der Verordnungen (EG) Nr. 854/2004 und (EG) Nr. 882/2004 des Europäischen Parlaments und des Rates, der Richtlinien 89/608/EWG, 89/662/EWG, 90/425/EWG, 91/496/EEG, 96/23/EG, 96/93/EG und 97/78/EG des Rates und des Beschlusses 92/438/EWG des Rates (Verordnung über amtliche Kontrollen) 2017.
38. Europäisches Parlament und Rat: Verordnung (EU) Nr. 1169/2011 des Europäischen Parlaments und des Rates vom 25. Oktober 2011 betreffend die Information der Verbraucher über Lebensmittel und zur Änderung der Verordnungen (EG) Nr. 1924/2006 und (EG) Nr. 1925/2006 des Europäischen Parlaments und des Rates und zur Aufhebung der Richtlinie 87/250/EWG der Kommission, der Richtlinie 90/496/EWG des Rates, der Richtlinie 1999/10/EG der Kommission, der Richtlinie 2000/13/EG des Europäischen Parlaments und des Rates, der Richtlinien 2002/67/EG und 2008/5/EG der Kommission und der Verordnung (EG) Nr. 608/2004 der Kommission 2011.
39. Europäische Kommission: Verordnung (EG) Nr. 1881/2006 der Kommission vom 19. Dezember 2006 zur Festsetzung der Höchstgehalte für bestimmte Kontaminanten in Lebensmitteln 2006.
40. Europäisches Parlament und Rat: Verordnung (EG) Nr. 178/2002 des Europäischen Parlaments und des Rates vom 28. Januar 2002 zur Festlegung der allgemeinen Grundsätze und Anforderungen des Lebensmittelrechts, zur Errichtung der Europäischen Behörde für Lebensmittelsicherheit und zur Festlegung von Verfahren zur Lebensmittelsicherheit 2002.
41. Volkhardt I, Christen O, Stangl GI, Braun PG, Lorkowski S, Meier T: Legal aspects regarding product innovations in the food sector. Ernahrungs Umschau 2017; 64(11): 158–65.
42. Europäisches Parlament und Rat: Verordnung (EG) Nr. 1924/2006 des Europäischen Parlaments und des Rates vom 20. Dezember 2006 über nährwert- und gesundheitsbezogene Angaben über Lebensmittel 2006.
43. Europäische Kommission: Verordnung (EG) Nr. 2073/2005 der Kommission vom 15. November 2005 über mikrobiologische Kriterien für Lebensmittel 2005.
44. Bundesministerium für Verbraucherschutz, Ernährung und Landwirtschaft: „Nahrungsergänzungsmittelverordnung vom 24. Mai 2004 (BGBl. I S. 1011), die zuletzt durch Artikel 11 der Verordnung vom 5. Juli 2017 (BGBl. I S. 2272) geändert worden ist" 2004.
45. Noble P: Nahrungsergänzungsmittel: Rechtliche Grundlagen, Abgrenzung zu Arzneimitteln, sonstige Fragestellungen. Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz 2017; 60(3): 260–7.
46. Camia A, Robert N, Jonsson R, et al.: Biomass production, supply, uses and flows in the European Union: first results from an integrated assessment. Luxembourg: Publications Office 2018.
47. Neustupa J, Němcová Y, Eliáš M, Škaloud P: Kalinella bambusicola gen. et sp. nov. (Trebouxiophyceae, Chlorophyta), a novel coccoid Chlorella-like subaerial alga from Southeast Asia. Phycological Res 2009; 57(3): 159–69.
48. Temraleeva AD, Moslalenko SV: Application of morphological and molecular systematics for identification of green microalgae of the genus Chlorococcum and some closely related taxa. Microbiology 2019; 88(1): 27–38.
49. Darienko T, Gustavs L, Eggert A, Wolf W, Pröschold T: Evaluating the species boundaries of green microalgae

(Coccomyxa, Trebouxiophyceae, Chlorophyta) using integrative taxonomy and DNA barcoding with further implications for the species identification in environmental samples. PLoS ONE 2015; 10(6): e0127838.

50. Champenois J, Marfaing H, Pierre R: Review of the taxonomic revision of Chlorella and consequences for its food uses in Europe. J Appl Phycol 2015; 27(5): 1845–51.
51. European Committee for Standardization: CEN – Technical Bodies – CEN/TC 454. https://standards.cen.eu/dyn/www/f?p=204:7:0::FSP_ORG_ID:2278882&cs=1F20FCBCD6123B309AAB0F52C8CDEF169 (last accessed on 10 September 2020).
52. Europäisches Parlament und Rat: Verordnung (EG) Nr. 258/97 des Europäischen Parlaments und des Rates vom 27. Januar 1997 über neuartige Lebensmittel und neuartige Lebensmittelzutaten 1997.
53. Europäische Kommission: Durchführungsverordnung (EU) 2017/2470 der Kommission – vom 20. Dezember 2017 – zur Erstellung der Unionsliste der neuartigen Lebensmittel gemäß der Verordnung (EU) 2015/2283 des Europäischen Parlaments und des Rates über neuartige Lebensmittel 2017.
54. Europäische Kommission: Summary of applications and notifications: Summary of the applications submitted within the meaning of Article 10(1) of Regulation (EU) 2015/2283. https://ec.europa.eu/food/safety/novel_food/authorisations/summary-applications-and-notifications_en (last accessed on 11 September 2020).
55. Europäische Kommission: Durchführungsverordnung (EU) 2017/2468 der Kommission – vom 20. Dezember 2017 – zur Festlegung administrativer und wissenschaftlicher Anforderungen an traditionelle Lebensmittel aus Drittländern gemäß der Verordnung (EU) 2015/2283 des Europäischen Parlaments und des Rates über neuartige Lebensmittel 2017.
56. EFSA Panel on Dietetic Products, Nutrition and Allergies (NDA): Guidance on the preparation and presentation of an application for authorisation of a novel food in the context of Regulation (EU) 2015/2283. EFSA J 2016; 14(11): 54.
57. Algen-Parks Aktiengesellschaft: Marktanalyse Mikroalgenproduktion 2013.
58. Chen J, Wang Y, Benemann JR, Zhang X, Hu H, Qin S: Microalgal industry in China: challenges and prospects. J Appl Phycol 2016; 28(2): 715–25.
59. Organisation?: Zusammenfassung der Liste der neuen Lebensmittelzutaten und allgemeinen Lebensmittel. www.nhc.gov.cn/sps/pztq/201612/712553a5f7554e0e9ec1dfdbcc91e99a.shtml (last accessed on 16 October 2020).
60. Chemical Inspection and Regulation Service: NHC approved two new food raw materials in China – news and articles. www.cirs-reach.com/news-and-articles/NHC-Approved-Two-New-Food-Raw-Materials-in-China.html (last accessed on 16 October 2020).
61. Food Standards Australia New Zealand: Record of views formed in response to inquiries. www.foodstandards.gov.au/industry/novel/novelrecs/Documents/record-of-views-september-2020.pdf (last accessed on 16 October 2020).
62. Sánchez M, Bernal-Castillo J, Rozo C, Rodríguez I: Spirulina (Arthrospira): an edible microorganism: a review. Univ Sci 2003; 8(1): 7–24.
63. Food Standards Australia New Zealand: Australia New Zealand Food Standards Code – Schedule 25 – Permitted novel foods. In: Food Standards Australia New Zealand 2017.
64. U.S. Food & Drug Administration: Generally recognized as safe (GRAS). www.fda.gov/food/food-ingredients-packaging/generally-recognized-safe-gras (last accessed on 16 October 2020).
65. U.S. Food & Drug Administration: GRAS Notices. www.cfsanappsexternal.fda.gov/scripts/fdcc/?set=GRASNotices (last accessed on 11 September 2020).
66. van Pelt CK, Huang MC, Tschanz CL, Brenna JT: An octaene fatty acid, 4,7,10,13,16,19,22,25-octacosaoctaenoic acid (28:8n-3), found in marine oils. J Lipid Res 1999; 40(8): 1501–5.
67. Wong MH, Tam FY: Sewage sludge for cultivating freshwater algae and the fate of heavy metal at higher trophic organisms. IV. Heavy metal contents in different trophic levels. Fundam Appl Limnol 1984; 100(4): 423–30.
68. Mahadevaswamy M, Venkataraman LV: Microbial load in mass cultures of green algae Scenedesmus acutus and its processed powder. J Biosci 1981; 3(4): 439–47.
69. Carmichael WW: Harvesting of Aphanizomenon flos-aquae ralfs ex born. & flah. var. flos-aquae (Cyanobacteria) from Klamath lake for human dietary use. J Appl Phycol 2000; 12(6): 585–95.
70. Saker ML, Jungblut A-D, Neilan BA, Rawn DFK, Vasconcelos VM: Detection of microcystin synthetase genes in health food supplements containing the freshwater cyanobacterium Aphanizomenon flos-aquae. Toxicon 2005; 46(5): 555–62.
71. Fawell JK, Mitchell RE, Everett DJ, Hill RE: The toxicity of cyanobacterial toxins in the mouse: I microcystin-LR. Hum Exp Toxicol 1999; 18(3): 162–7.
72. Zhan L, Sakamoto H, Sakuraba M, et al.: Genotoxicity of microcystin-LR in human lymphoblastoid TK6 cells. Mutat Res 2004; 557(1): 1–6.
73. Gilroy DJ, Kauffman KW, Hall RA, Huang X, Chu FS: Assessing potential health risks from microcystin toxins in blue-green algae dietary supplements. Environ Health Perspect 2000; 108(5): 435–9.
74. Eisenbrand G: Microcystine in Algenprodukten zur Nahrungsergänzung 2005.
75. Rzymski P, Jaśkiewicz M: Microalgal food supplements from the perspective of polish consumers: patterns of use, adverse events, and beneficial effects. J Appl Phycol 2017; 29(4): 1841–50.
76. EFSA Panel on Food Additives and Nutrient Sources added to food (EFSA ANS Panel): Guidance for submission for food additive evaluations. EFSA J 2012; 10(7): 367.
77. Richmond A (ed.): Handbook of microalgal culture: Biotechnology and applied phycology. 4th ed., Oxford: Blackwell Science 2007.
78. Soeder CJ: Zur Verwendung von Mikroalgen für Ernährungszwecke. Naturwissenschaften 1976; 63(3): 131–8.
79. Ciferri O: Spirulina, the edible microorganism. Microbiol Rev 1983; 47(4): 551–78.
80. Sarwar G, Shah B, Mongeau R, Hoppner K: Nucleic acid, fiber and nutrient composition of inactive dried food yeast products. J Food Sci 1985; 50(2): 353–7.