Growing Algae Sustainably in the Baltic Sea (GRASS)
WP 3.4 Unlocking the potential of using macroalgae for food purposes

Macroalgae as food and feed ingredients in the Baltic Sea region – regulation by the European Union

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1. Introduction

Macroalgae are a diverse group of organisms comprising roughly 10 000 different species that vary in size, shape and type of lifecycle. Macroalgae are further divided to brown, red and green algae. Edible species are found across all three groups but are a small fraction of the total number of species. In addition to species that are considered edible sea vegetables, various macroalgae species are used for extraction of additives, like colorants and gelling agents, utilized in the food industry. Macroalgae are nutrient rich ingredients for food and feed and have long history of consumption at coastal areas throughout the world

Macroalgae are intriguing ingredients for food and feed as they typically have high content of fiber, minerals, antioxidants and vitamins. Many edible species are especially rich in vitamins A, K and B12. Moreover, seaweeds have typically low fat content with high relative abundance of polyunsaturated fatty acids (PUFAs) like docosahexaenoic acid (DHA). The protein content varies between genera and is typically higher in green and red macroalgae (approximately 10–47% dry weight) and low in brown algae (Fleurence et al., 2018). Importantly, unlike many plant protein sources, macroalgae contain all essential amino acids for human and animal nutrition. Furthermore, macroalgae can be used to enhance flavor and as a healthier alternative to salt. Finally, seaweeds harbor a variety of delicate and interesting aromas. Kombu (*Saccarina japonica)* has a rich umami flavor and *Palmaria palmata* is called sea bacon due to its smoky aroma.

Seaweed usage in Europe has been minor but interest towards its consumption is increasing. Also the European Commission (EC) has recognized macroalgae as important marine resource with potential as food and feed (European Commission, 2017). The use of macroalgae as food and feed in the European Union (EU) is under regulation by the EU food and feed legislation. This report summarizes the EU policy framework that regulates the use of macroalgae as food and feed in the EU member countries. Moreover, this report gives a

brief overview of the seaweed production in Europe and the use of macroalgae as food in the Baltic Sea region.

2. Seaweed production and consumption in Europe and in the Baltic Sea region

Some 221 macroalgae species are estimated to have commercial value according to Food and Agriculture Organization of the United Nations (FAO) (FAO 2018). Global macroalgae market is 9 billion USD per year and counts for over 30 million tons of macroalgae (FAO, 2019). Although seaweed industry takes place in around 50 countries worldwide, the production is dominated by the aquaculture in the Asian countries of China, Indonesia and Korea (FAO, 2019). Species of the genera *Saccharina, Undaria, Porphyra/Pyropia, Euchema/Kappaphycus* and *Gracilaria* form 98% of world's seaweed production (FAO 2018 and 2019). Over 97% of the yearly seaweed production comes from aquaculture and only around 845 000 tons of seaweed were harvested from wild macroalgae reservoirs in 2017 (FAO, 2019). The biggest producers of wild harvested seaweeds were Chile and Norway (FAO, 2019).

Compared to Asia, the usage of macroalgae in Europe has been minor and relied on harvesting the wild macroalgae populations at the coastal areas either by hand or mechanically by boats. However, the harvesting is often tedious, some macroalgae species are difficult to reach and the sustainable usage of the wild reservoirs only allows harvesting in small scale. Thus both on-shore and off-shore seaweed aquacultures have been established also in Europe. Around 238 000 t of seaweed were produced in Europe in 2017 (Table 1, FAO 2019). Norway, France and Ireland are the biggest seaweed producers in Europe, while smaller production takes place also in Iceland, Russian Federation, Portugal, Spain, Italy, Estonia, Denmark, and Bulgaria (Table 1, FAO, 2019). Most of the production consists of species *Ascophyllum nodosum, Chondrus crispus, Fucus spp., Himanthalia elongata, Laminaria hyperborea, Laminaria digitata, Palmaria palmata, Porphyra umbilicalis, Sachharina latissima and Ulva spp.* (Camia et al., 2018, Barbier et al., 2019). Aquacultures have been established in Norway, Russian Federations, Spain, Ireland, Denmark and Bulgaria. Pilot scale seaweed farms and experimental cultivation sites have been started also in other European countries including Sweden, Poland and Estonia. Most of the seaweed aquaculture relies on kelps *Saccharina latissima* and *Alaria esculenta* but also *Ulva spp*. are grown (Barbier et al., 2019). Experimental cultures have been set up also for other macroalgae species. Notable share of the European macroalgae production goes to other than direct food or feed uses. However, currently there are no reliable estimations of the material flows and destinations of the produced macroalgae biomass (Camia et al., 2018). The macroalgae production rates in 2017 in the European countries with reported macroalgae harvesting or aquaculture are listed in Table 1.

Table 1. Seaweed production in 2017 in Europe and in European countries with recorded commercial seaweed aquaculture and capture (FAO statistics 2017). Production unit 1000 kg.

Area	Total production (t)	Macroalgae	Wild harvest (t)	Aquaculture (t)
Europe	237 824	Brown algae	231 072	1 717
		Red algae	4 189	n/a
		Green algae	840	4
Norway	132 169	Brown algae	131 871	149
France	39 072	Brown algae	39 072	n/a
Ireland	29 541	Brown algae	29 400	41
		Red algae	100	n/a
Iceland	21 313	Brown algae	21 313	n/a
Russian Federation	10 788	Brown algae	9 111	1 517
Portugal	2 857	Red algae	2 857	n/a
Spain	982	Brown algae	305	n/a
		Red algae	636	n/a
		Green algae	40	1
Italy	1 200	Red algae	400	n/a
		Green algae	800	n/a
Estonia	36	Red algae	36	n/a
Denmark	10	Brown algae	n/a	10
Bulgaria	4	Green algae	n/a	4

In Europe, seaweeds have been traditionally used to add minerals and vitamins to food. Seaweed flour has been mixed in bread and *Fucus spp.* among others have been used as animal feed. Traditional European seaweed dishes include the Welsh laverbread and dulse (*Rhodymenia palmata*) which is used as food ingredient in Ireland. There is little tradition of using seaweeds as food in the Baltic Sea region, although they have been used as feed at the coastal regions. However, recent interest towards seaweeds is apparent also at the Baltic Sea region. Currently several small companies are producing seaweed food products in Denmark, Sweden, Germany and Estonia. Seaweeds are used to make wine, beer, cocktails, pesto and sandwich spread, flour, pasta and snacks among other things. Also restaurants have taken seaweeds on their menus and bigger diversity of seaweed species, including some local seaweeds, are used as food ingredients. However, the use of the Baltic Sea seaweeds as food is still rare.

The European macroalgae resources have been mainly utilized for phycocolloid extraction. Macroalgae hydrocolloids agar, alginic acid and carrageenan are used as thickening, gelling and stabilizing agents in food, cosmetics and pharmaceutics. Agar is mostly produced from *Gelidium* and *Gracilaria spp.,* alginate from *Ascophyllum nodosum* and *Laminaria spp.* and carrageenan from *Chondrus crispus*, *Mastocarpus stellatus* and *Gigartina spp*. In 2015, 6% of the world's phycocolloid production came from Europe (Porse & Rudolph 2017). While Europe produces minor shares of world's agar and carrageenan production, it has been a leader in the production of alginate for food and pharmaceutical purposes (Porse & Rudolph 2017).

Also in the Baltic Sea region, seaweed has been mostly used as raw material for gelling agents. *Furecellari lubricalis* from the Baltic Sea has been used in the production of furcellarin (classified as carrageenan, E407), in Estonia, Latvia and Poland. Small scale production of iodine and alginic acid mostly from *Fucus vesiculosus* took place in Poland in the 60's and 70's. Currently, the furcellarin production continues in Estonia by Est-Agar. Moreover, in Denmark, carrageenan is produced from imported seaweeds. In the past, side streams of the macroalgae harvesting and possessing were utilized as animal feed.

3. Regulatory limitations of using macroalgae as food and feed

The seaweed usage as food and feed ingredients is under various regulations. In the EU the food safety is regulated by the General Food Law Regulation (Regulation (EC) No 178/2002), which is implemented in all member countries. It defines the general principles and procedures and sets a foundation to food and feed laws regulating the food and feed safety respectively. The EU food legislation sets rules for the biological and chemical safety, food labeling, usage of food additives and introduction of novel species on the market. Similarly, feed production, composition and hygiene are regulated by the EU feed laws. Seaweed based food and feed products, additives and dietary supplements are subject to these laws.

Consumption of macroalgae has been marginal in Europe and seaweeds as food and feed ingredients have been neglected in many areas of the EU food and feed safety regulation. Moreover, the European legislation has not kept up with the increasing diversity of macroalgae species and products on the market. In 2017, The EC has recognized seaweeds as sustainable raw material for food and feed in Europe and shortcomings in the legislation and standards have been noted and will most likely be issued in the near future (European Commission, 2017). The Board of European Committee for Standardization (TCS) has set a Technical Committee to develop standards for algae and algae based products. CEN/TC 454 Algae and Algae Products deals with product specification, algae processing, terminology and determination of methods for algae species and products and species identification guidelines. Their work has started in 2017 and standards are expected to be set in the coming years. Thus the legislative barriers for seaweeds as food and feed ingredient are under update and change.

The EU regulations are implemented in the member countries in the Baltic Sea region by their national authorities. To our knowledge, there are currently no national guidelines established for seaweed usage as food and feed in any of the member countries of the GRASS program. However, some difference in the implementation of the EU legislation are likely to exist, exemplified by the inclusion of macroalgae species on the list of commercial designations of fishery and aquaculture products (See section 3.5). As macroalgae

production and use in food and feed is a developing area, further adjustments in the related legislation and its national implementation may be expected.

3.1 EU Novel Food regulation

The macroalgae species put on the EU market are regulated by the Novel Food legislation which limits the entry of novel species on the EU market area (Regulation (EC) 2015/2283 and Regulation (EC) No 258/97). According to Regulation (EC) No 258/97, novel foods and novel food ingredients are foods that have not been used in the EU member countries to a significant degree before the regulation came effective on the 15th of May 1997. Seaweed producers or importers have to make sure that the marketed species are allowed to be sold as food in the EU under the Novel Food Law. The EU upholds a so-called Novel Food Catalogue that contains a list of species whose status as a novel food has been inquired from authorities in one or more EU member countries (Novel Food Catalogue v.1.1). The Novel Food Catalogue is available online (https://ec.europa.eu/food/safety/novel_food/catalogue_en) and with ambiguous cases the national authorities can be consulted regarding the Novel Food status of the seaweed species.

If a seaweed species is considered novel or not authorized yet, any material demonstrating the food use of the seaweed species before 1997 may help to get an authorization as a “not novel” species. These materials may include invoices, recipes, cookbooks, and catalogues with data of the species in question. EU provides an online guide of the criteria applied to species whose novelty is evaluated (https://ec.europa.eu/food/sites/food/files/safety/docs/novel-food_leg_guide_humn-consumption.pdf).

In case the macroalgae species is considered a Novel Food, it requires an authorization that can be requested via an online application (https://ec.europa.eu/food/safety/novel_food/e-submission_en). The safety of the food for human consumption is evaluated by the European Food Safety Authority (EFSA), after which the EC will submit a draft of the implementing act to the Standing Committee on Plants, Animals, Food and Feed that makes the decision of the acceptance of the novel food. The workflow and the timeframe of the Novel Food authorization procedure is presented in the Figure 1.

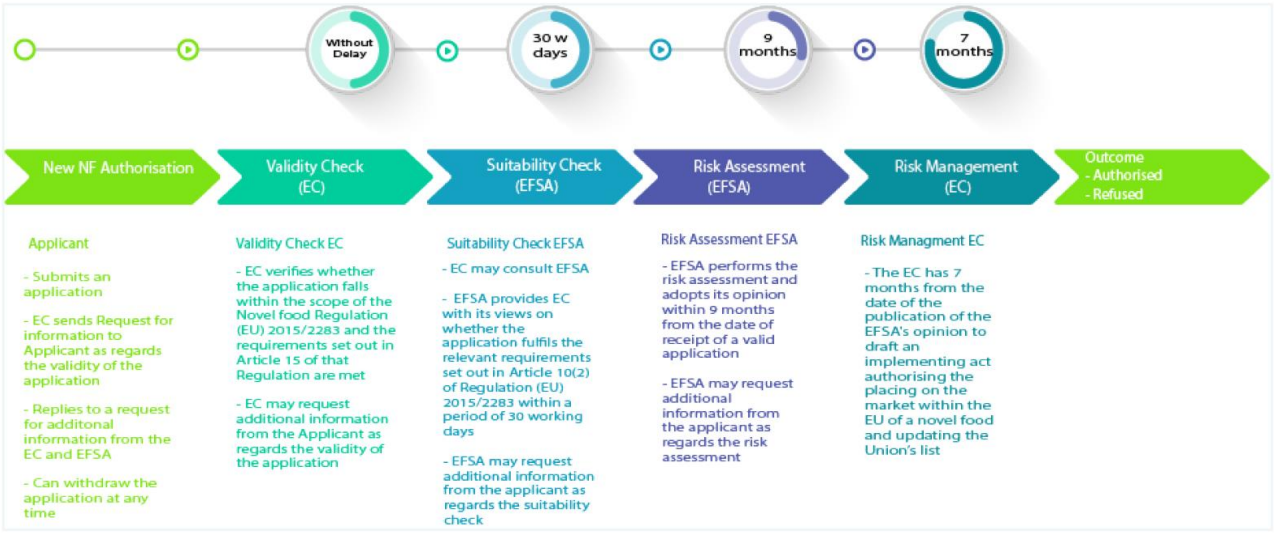

Figure 1. Fork flow and timeframe of the Novel Food authorization procedure Figure from e-Submission system for Novel Foods, User Guide, Version 1.2 (https://ec.europa.eu/food/sites/food/files/safety/docs/fs_novel-food_e-submission-system_user-guide_en.pdf)

An additional fast-track is provided for traditional foods from third countries based on their usage history. These foods are considered new to EU but have long tradition of safe consumption somewhere else. These foods must undergo a notification system and evaluation by EFSA before they can be put on the EU market. Some macroalgae species may fall to this category and their introduction to the EU market may benefit of this simplified notification system (Online application: https://ec.europa.eu/food/safety/novel_food/e-submission_en). Administrative and scientific requirements for the traditional foods from third countries are defined in the Commission Implementing Regulation (EU) 2017/2468. In case the application is rejected by the European Commission for duly reasoned safety objections, the applicant may re-submit the application with additional information and documentation supporting the safety of the food and its traditional use in the third countries. The workflow and timeframe of the notification system and the possible re-submission of the application are presented in the Figure 2.

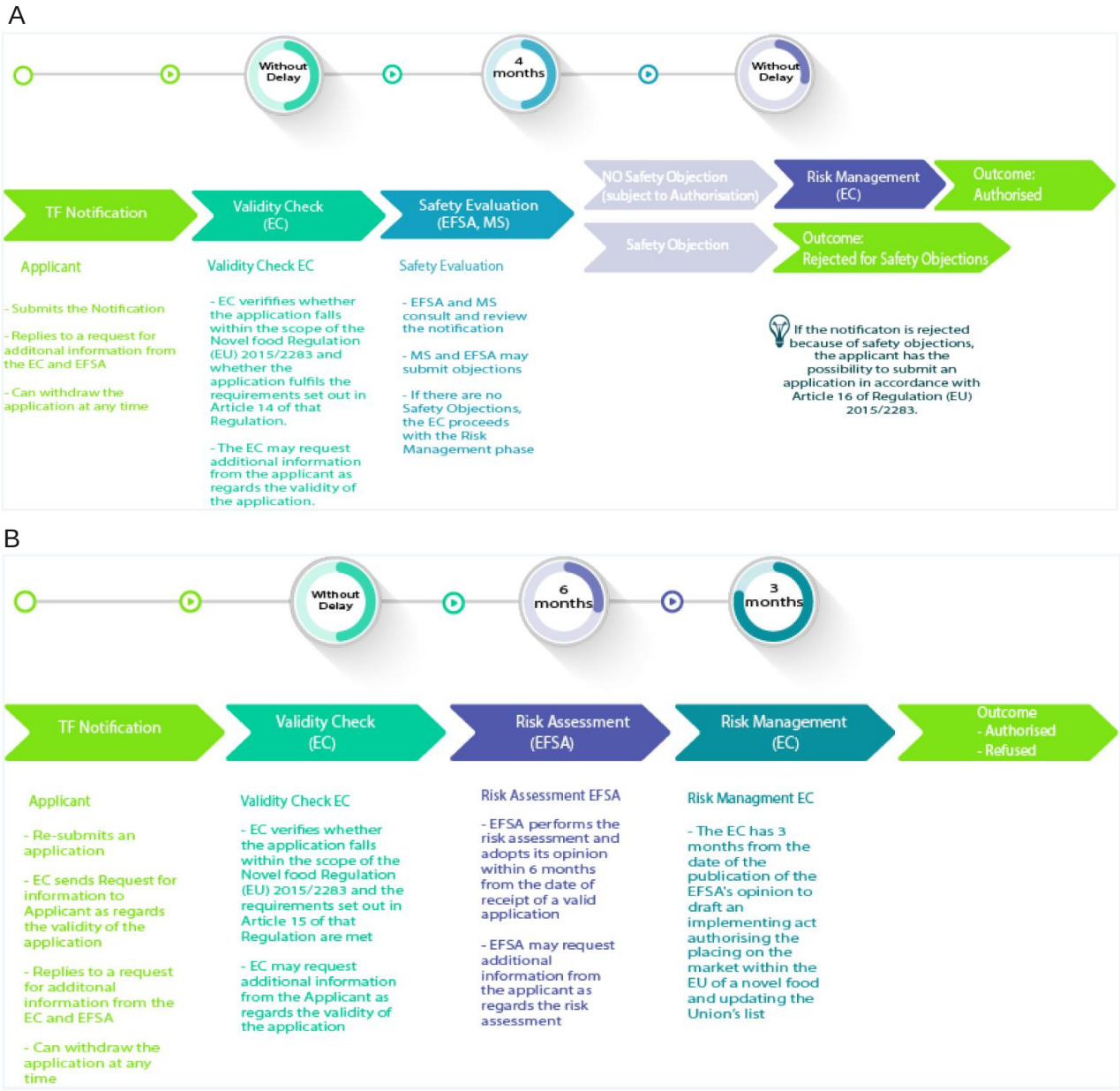

Figure 2. Workflow and timeframe of the Traditional Food notification system (A) and the re-submission procedure of the rejected application (B) Figure from e-Submission system for Novel Foods, User Guide, Version 1.2 (https://ec.europa.eu/food/sites/food/files/safety/docs/fs_novel-food_e-submission-system_user-guide_en.pdf)

The macroalgae species listed in the Novel Food catalogue and accepted for food use are listed in the Table 2 (until June 2019). They are all considered "not novel" and have been used as food before 1997 and are thus accepted on the market in the EU member countries. In addition to the species found in the Novel Food Catalogue, some EU countries have their own lists of accepted macroalgae species that have been used as food. However, these lists may not be automatically accepted by other EU member countries. Center for Study and Promotion of Algae (CEVA) in France has published a synthesis of algal species that have been consumed in France before 1997. Some species listed by CEVA, like several *Porphyra spp.* are not found in the EU Novel Food Catalogue (Table 2.). According to the information in the Novel Food catalogue, the novel

food status of a brown algae *Sphaerotrichia divaricata* has been inquired from authorities, but the species was ruled to be novel and a safety assessment and authorization are required before entry to the market. The Novel Food Catalogue is not an exhaustive list of species on the EU market and it is likely that even more macroalgae species than the ones listed in the Table 2. have been in food use in the EU.

The Baltic Sea inhabits several edible macroalgae species, some of which are listed in the Novel Food Catalogue as "not novel" foods. *Fucus serratus* and *Fucus vesiculosus* are listed as "not novel" foods. *Ulva sp.* is listed on the CEVA synthesis of algae species that have been used as food before 1997 and *Enteromorpha sp*. is included in the Novel Food Catalogue as a "not novel" species. However, neither of the two lists specifies the Ulva or Entermorpha species, and it could be assumed that all of the species in these genera are accepted as "not novel" species.

Table 2. Macroalgae species accepted as food by the EU (EU/Not novel) or by the Center for Study and Promotion of Algae, France (Novel Food Catalogue v.1.1;. CEVA 2014)

Seaweed	Common name	Accepted as food
Brown algae		
Alaria esculenta	Dabberlocks	EU/Not novel
Ascophyllum nodosum/Ascophyllum laevigata/ Fucus nodosus	Rockweed	EU/Not novel
Eisenia bicyclis	Arame	EU/Not novel
Fucus serratus	Saw wrack	EU/Not novel
Fucus spiralis	Spiral wrack	EU/Not novel
Fucus vesiculosus	Badderwrack	EU/Not novel
Himanthalia elognata	Sea spaghetti	EU/Not novel
Laminaria digitata	Oarweed	EU/Not novel
Laminaria longicruris		EU/Not novel
Saccharina japonica/Laminaria japonica		EU/Not novel
Saccharina latissima/Laminaria saccharina	Sugar kelp	EU/Not novel
Sargassum fusiforme	Hijiki/Hizikia	EU/Not novel
Undaria pinnatifida	Wakame	EU/Not novel
Red algae		

Chondrus crispus	Irish moss	EU/Not novel
Gracilaria verrucosa		EU/Not novel
Lithothamnium calcareum	Mäerl	EU/Not novel
Porphyra tenera	Nori	EU/Not novel
Porphyra lacinata	Nori	CEVA/ Used before 1997
Porphyra umbilicalis	Nori	CEVA/ Used before 1997
Pyropia leucostica	Nori	CEVA/ Used before 1997
Porphyra dioica	Nori	CEVA/ Used before 1997
Porphyra purpurea	Nori	CEVA/ Used before 1997
Porphyra yezoensis	Nori	CEVA/ Used before 1997
Palmaria palmata	Dulse	EU/Not novel
Green algae		
Enteromorpha sp.	Anori, Green laver	EU/Not novel
Ulva lactuca	Sea lettuce	EU/Not novel
Ulva sp.	Sea lettuce	CEVA/ Used before 1997
Monostroma nitidum	Green nori	EU/Not novel

3.2 Regulation of seaweed based food additives

Macroalgae hydrocolloids are widely used in food industry as thickening and gelling agents. The use of food additives in EU is controlled by the Regulation (EC) No 1333/2008, which contains a list of authorized additives and the Commission Regulation (EU) No 231/2012 which further specifies the origin, composition and usage of the accepted additives. The macroalgae derived food additives allowed in the EU and their species of origin are listed in the Table 3. Seaweeds are also a source of various pigments including chlorophylls, carotenes and fucoxanthin. However, at the moment, algae derived colorants are not found on the list of accepted food additives with the exception of algal carotenes (E160a) extracted from microalgae *Dunaliella salina.* The accepted maximum levels of toxic contaminants such as arsenic, lead, mercury and cadmium in the macroalgae based food additives have been defined in the Commission Regulation (EU) No 231/2012.

Commission Regulation (EU) No 231/2012

Table 3. Algal based food additives accepted in the EU (Regulation (EC) No 1333/2008, Commission Regulation (EU) No 231/2012).

E number	Food additive	Origin of the Additive in Commission Regulation (EU) No 231/2012
E400	Alginic acid	Brown seaweeds (Phaeophyceae)
E401	Sodium alginate	Not defined
E403	Ammonium alginate	Not defined
E404	Calcium alginate	Not defined
E405	Propane-1,2-diol alginate, Propylene glycol alginate	Not defined
E406	Agar	*Gelidiaceae spp*. and *Gracilariaceae spp*. and relevant red algae (Rhodophyceae)
E407	Carrageenan	*Gigartinaceae spp., Solieriaceae spp., Hypneaceae spp.* and *Furcellariaceae spp.*
E407a	Prosessed Eucheuma seaweed	*Eucheuma cottonii* and *Eucheuma spinosum*

3.3 Regulation of toxic contaminants in food

Macroalgae readily accumulate heavy metals from the surrounding water to their cell walls. This feature has been utilized in the assessment of water quality by measuring pollutants from the seaweeds and in bioremediation of polluted water pools (Arumugam et al., 2018, Chakraborty et al., 2014). However, when seaweeds are grown or harvested for food or feed, their ability to accumulate toxic pollutants poses a threat to human and animal health. As the heavy metals are accumulated from the surrounded water, the aquaculture and harvesting sites should be carefully selected.

The levels of contaminants are regulated by the Commission Regulation (EC) No 1881/2006 setting maximum levels for certain toxic substances like heavy metals. The EU has set maximum levels for arsenic, cadmium, lead (Commission Regulation (EC) No 1881/2006) and mercury (Regulation (EC) No 396/2005). Specific maximum tolerable limits are established for different foodstuffs like cereals, vegetables, dairy products or meat. At the moment such maximum levels of arsenic, cadmium and lead have not been defined for seaweed foodstuffs. For mercury the maximum level in algae and prokaryotic organisms is set in the Regulation (EC) No 396/2005 on maximum residue levels of pesticides in food and feed, and is 0,01 mg/kg. However, it is not specified if the maximum level is calculated of the dry weight or the fresh weight of the product (Table 3).

Special concerns have been raised about the high content of inorganic arsenic in some brown macroalgae species. Seawater typically contains relatively high levels of arsenic, which accumulates to the marine organisms. In macroalgae, part of the inorganic arsenic is incorporated to organic compounds like arsenosugars significantly reducing its toxicity to humans. However, some brown seaweeds like *Hizikia fusiforme* (hiziki) and some *Laminaria* species have been reported to contain high levels of inorganic arsenic rising concerns about their safety as food ingredients (Almela et al., 2006, Ronan et al., 2017). Almela et al. (2006) detected inorganic arsenic between 41-117 mg/kg dry weight in various Japanese hiziki products. In comparison, a maximum level of 3,0 mg/kg dry weigh has been established for inorganic arsenic in seaweed foodstuffs in France (CEVA, 2014). The concentrations measured by Almela et al. (2006) significantly exceed the maximum levels of 3,0 mg/kg and if similar thresholds would be set by the EU, they would most likely avert the marketing of hiziki products. However, the inorganic arsenic levels in other common edible seaweeds were below 1,5 mg/kg dry weight and the limit of 3,0 mg/kg would not restrict the use of most seaweed food products.

Iodine is an essential element for humans and needed for the biosynthesis of thyroid hormones. Brown macroalgae typically contain high levels of iodine and are considered a healthy alternative to iodinated salt, due to the high iodine content and low Na/K ratio. However, Europe is an area of endemic iodine deficiency which may cause higher sensitivity to excess iodine intake. The limit for safe iodine intake set by EFSA (600 µg/day for adults and 200 µg/day for 1-3 year old children, EFSA, 2006) may be exceed with relatively small portions of seaweed. Food iodine content is not regulated in the EU but foods with high iodine content may pose a danger to certain risk groups like pregnant women.

As seaweed food products become increasingly popular and have increasing contribution to the diet of the EU citizens, maximum levels for harmful contaminants may be established also for seaweed products. In March 2018 European commission gave a recommendation to the member countries to monitor the levels of heavy metals and iodine in seaweed foodstuff (Commission Recommendation (EU) 2018/464). The recommendation advocates the member countries to monitor the content of arsenic, cadmium, lead, mercury, and iodine in several seaweed species reflecting the consumption habits of the citizens including *Ecklonia bicyclis, Fucus vesiculosus, Palmaria palmata, Hizikia fusiforme, Chondrus crispus, Laminaria digitate, Laminaria japonica, Saccharina japonica, Porphyra and Pyropia spp., Ascophyllum nodosum, Ulva sp., Himanthalia elongate, Fucus serratus, Codium sp, Sacharina latissimi, Undaria pinnatifida and Alaria esculenta.* Moreover, similar monitoring should be carried out for seaweed feed and seaweed based food additives E400, E401, E403, E404, E405, E406, E407, E407a and E160a (Table 5.). In the future, this monitoring may promote additional regulations concerning the food and feed safety of seaweed products.

Dioxins and dioxin-like polychlorinated biphenyls (PCBs) are anthropogenic toxins accumulating in the marine food webs. Their usage has been prohibited but the levels at certain sea areas remain high and limit the use of the marine resources as food and feed. Dioxins and PCBs are fat soluble and accumulate in certain fish but have not been considered a health threat in the edible seaweeds. The EU commission has set the maximum levels for dioxins and dioxin-like PDBs in various foodstuffs by the Commission Regulation (EC) No 1881/2006. However, these regulations do not specify a maximum level of dioxins or PCBs for seaweeds.

3.4 Regulation of seaweed food supplements

Several macroalgae species are used as nutraceutical extracts and food supplements. In the General Food Law, food supplements are considered as foodstuff and their maximum levels of toxic contaminants are controlled by the Commission Regulation (EC) No 1881/2006. Maximum levels for lead (3,0 mg/kg) and mercury (0,1 mg/kg) are defined for food supplements without specifying their content and apply also to macroalgae food supplements. Maximum levels for cadmium is set to 3,0 mg/kg specifically for seaweed based food supplements. Moreover, the levels of polycyclic aromatic hydrocarbons (PAH) are regulated in food supplements containing botanicals including powdered algae (Table 4). The maximum levels of toxic contaminants set for seaweed food products including food supplements are listed in the Table 4.

In addition, many food supplements are considered novel foods and require an authorization. Commission Regulation (EU) 2017/2470 contains a list of authorized novel foods including authorized food supplements. The list includes fucoidan extracts from *Fucus vesiculosus* or *Undaria pinnatifida*.

Table 4. Established maximum levels of toxic contaminants in macroalgae food products including food supplements.

Contaminant	Level	Food product	Regulation
Cadmium	3,0 mg/kg (weight as sold)	Food supplements consisting exclusively or mainly of dried seaweed or of products derived from seaweed	(EC) No 1881/2006
Lead	3,0 mg/kg (weight as sold)	Food supplements	(EC) No 1881/2006
Polycyclic aromatic hydrocarbons: Benzo(a)pyrene	10 µg/kg (weight as sold)	Food supplements containing botanicals (including comminuted or powdered algae)	(EC) No 1881/2006
Polycyclic aromatic hydrocarbons: Sum of benzo(a)pyrene, benz(a)anthracene, benzo(b)fluoranthene and chrysene	50 µg/kg (weight as sold)	Food supplements containing botanicals (including comminuted or powdered algae)	(EC) No 1881/2006
Mercury	0,01 mg/kg*	Algae and prokaryotic organisms	(EC) No 396/2005
	0,1 mg/kg (weight as sold)	Food supplements	(EC) No 1881/2006

*Regulation (EC) No 396/2005 does not specify if the mercury content is calculated based on the dry weight or the fresh weight of the product.

3.5 Labeling of seaweed food products

In the Regulation (EU) No 1379/2013 on the common organization of the markets in fishery and aquaculture products, seaweeds are considered as fishery and aquaculture products. Thus they are subjected to special rules concerning their marketing and product labeling. Seaweed products sold within the EU, regardless of their origin, must include the scientific and designated market name of the species, production method, area wherein the product was harvested or cultured, whether the product has been defrosted and the date of minimum durability, where appropriate. Member countries may exempt from the labeling requirements any small quantities sold directly from a fishing vessel.

The Regulation (EU) No 1379/2013 also states that member countries must publish a list of the fishery and aquaculture products which are allowed on the market in their territory, including market names and scientific names of the species. There is some variation in the national implementation of the regulation and whether and how the seaweed species are included on these lists. Therefore, the national lists of commercial designations should be consulted when placing seaweed products on the market. If a seaweed species is not listed, its addition can be requested from the national authorities. The lists of commercial designations of the EU member countries are available online (https://ec.europa.eu/fisheries/cfp/market/consumer-information/names_en).

Correct labeling of seaweed products relies on the identification of the different macroalgae species, which is sometimes difficult due to similar appearance of related species and high phenotypic plasticity. Currently, no standards exist for macroalgae species determination at the EU level. The technical committee CEN/TC 454 Algae and Algae Products will give recommendations to the EC regarding the standards for classification of algae genera and products, and guidelines for macroalgae species determination may be established in the future.

3.6 Regulation of seaweed feed materials

Macroalgae are useful feed ingredients due to their high content of minerals and vitamins. Unlike many plant based feed materials, they also contain all essential amino acids. Moreover, the potential of seaweed meals in the reduction of methane emissions of ruminants has been studied with promising results (Maia et al., 2016). The EU has set regulations to control the composition and safety of animal feeds and feed additives. Moreover, all feed producers must obtain an authorization from the national authorities and follow the feed hygiene guidelines set in the Regulation (EC) No 183/2005.

The accepted feed materials in the EU countries are defined in the Commission Regulation (EU) No 68/2013. The authorized seaweed and algae based feed materials therein and the compulsory declarations of their composition are presented in Table 5. Moreover, according to the Regulation (EC) No 1831/2003 on additives for use in animal nutrition, EU upholds a register of authorized feed additives. It includes the macroalgae derived additives E401, E402, E406, E407 (Table 6) and *Fucus vesiculosus* extract (CAS 68917-51-1) that are currently accepted in the EU.

Table 5. Algae based feed materials accepted in the EU Table derived from the Commission Regulation (EU) No 68/2013. The name of the product must be supplemented with the algal species.

Number	Name	Description	Compulsory declarations
7.1.1	Algae	Algae, live or processed, including fresh, chilled or frozen algae. May contain up to 0,1% antifoaming agents.	Crude protein Crude fat Crude ash
7.1.2	Dried algae	Product obtained by drying algae. This product may have been washed to reduce the iodine content and the algae have been inactivated. May contain up to 0,1% antifoaming agents.	Crude protein Crude fat Crude ash
7.1.3	Algae meal	Product of algae oil manufacture, obtained by extraction of algae. The algae have been inactivated. May contain up to 0,1% antifoaming agents.	Crude protein Crude fat Crude ash
7.1.4	Algal oil	Oil obtained by extraction from algae. May contain up to 0,1% antifoaming agents.	Moisture if >1%
7.1.5	Algae extract; [algae fraction]	Watery or alcoholic extract of algae that principally contains carbohydrates. May contain up to 0,1% antifoaming agents.	
7.1.6	Seaweed meal	Product obtained by drying and crushing macroalgae, in particular brown algae. This product may have been washed to reduce the iodine content. May contain up to 0,1% antifoaming agents.	Crude ash

Maximum levels for toxic contaminants in animal feed are defined in the Directive 2002/32/EC. The established limits for arsenic, cadmium, lead and mercury for various feedstuffs are listed in the Table 6, as these contaminants are more likely to limit use of seaweeds as animal feed. Moreover, maximum levels of inorganic contaminants, mycotoxins, inherent plant toxins, organochlorines, dioxins and PCBs and harmful botanical impurities are applicable also to seaweed meals if not otherwise mentioned, even if specific limits for seaweed based feed products have not been defined. Complete lists of acceptable levels of different contaminants in different feedstuffs are listed in the Directive 2002/32/EC.

Table 6. Established maximum levels of toxic contaminants in seaweed feed products.

Contaminant	Maximum content relative to a feed with a moisture content of 12%	Product	Regulation
Arsenic (total)	40 mg/kg*	Seaweed meal and seaweed derived feed material	Directive 2002/32/EC
	10 mg/kg*	Complementary feed for pet animals containing products derived of	

		seaweed meal and feed materials derived from seaweed	
	10 mg/kg*	Complete feed for pet animals containing seaweed meal and feed materials derived from seaweed	
	10 mg/kg*	Calcareous marine algae	
Cadmium	0,5 mg/kg	Complementary feed (exceptions below)	Directive 2002/32/EC
	2,0 mg/kg	Complementary feed for pet animals	
	0,5 mg/kg	Complete feed (exceptions below)	
	1,0 mg/kg	Complete feed for cattle (except calves), sheep (except lambs), goats (except kids) and fish	
	2,0 mg/kg	Complete feed for pet animals.	
Lead	10 mg/kg	Feed materials	Directive 2002/32/EC
	10 mg/kg	Complementary feed	
	5 mg/kg	Complete feed	
	15 mg/kg	Calcareous marine algae	
Mercury	0,1 mg/kg	Feed materials	Directive 2002/32/EC
	0,1 mg/kg	Compound feed (exceptions below)	
	0,2 mg/kg	Compound feed for fish	
	0,3 mg/kg	Compound feed for dogs, cats, ornamental fish and fur animals	

*Upon request, the operator must demonstrate that the content of inorganic arsenic is lower than 2 mg/kg. The analysis of inorganic arsenic is considered to be important especially when the product contains *Hizikia fusiforme.*

3.7 Regulation on nutrition and health claims

The EU regulates the nutrition and health claims associated to the food products and mentioned in the package labels, advertisements or other marketing material. Nutrition claims are defined statements of the nutritional composition of the food products, such as “low fat” or “high protein”. These claims are regulated by the Commission Regulation (EC) No 1924/2006. In addition to nutritional claims, also the use of health claims is harmonized and under EU regulation. Health claims are statement about a relationship between food and health. Lists of the approved health claims are established in the Commission Regulation (EU) No 432/2012 and Commission Regulation (EU) No 957/2010. For the approved health claims, food products must meet certain nutritional requirements and the claim must be based on sufficient scientific evidence.

Currently, there are no authorized health claims for seaweeds or seaweed products. However, especially brown seaweeds have high iodine content and six health claims have been authorized for iodine and listed in the Table 7. According to the Regulation (EC) No 1924/2006 and Regulation (EU) No 1169/2011, these health claims may be used for products that are “source of iodine” i.e. contain at least 15% of the 150 µg daily reference intake for iodine in 100 g of the food product or in a single portion when a package only contains one portion. Thus, the limit is 22,5 µg of iodine per 100 g of the seaweed or per portion. To fill the requirements for the nutritional claim “high in iodine” the food product must contain at least twice the amount required for “source of iodine”. These limits are easily exceeded in many seaweeds that, depending on the species, may have over thousand times higher iodine content (MacArtain et al. 2007).

Table 7. Accepted health claims for iodine. The claims may be used for food which is at least a “source of iodine” defined in the Commission Regulation (EC) No 1924/2006 and Regulation (EU) No 1169/2011.

Health claim	**Regulation**
Iodine contributes to normal cognitive function	(EU) No 432/2012
Iodine contributes to normal energy-yielding metabolism	(EU) No 432/2012
Iodine contributes to normal functioning of the nervous system	(EU) No 432/2012
Iodine contributes to the maintenance of normal skin	(EU) No 432/2012
Iodine contributes to the normal production of thyroid hormones and normal thyroid function	(EU) No 432/2012
Iodine contributes to the normal growth of children	(EU) No 957/2010

4. Conclusions

Macroalgae have newly been recognized as potential food and feed ingredient in Europe and in the Baltic Sea countries, where their consumption has traditionally been less compared to other regions. With the increased consumption of imported seaweed products, also the interest towards local seaweeds is starting to rise. The Novel Food law still limits the use of many European macroalgae species as food, although the

authorization processes have been developed and simplified. Moreover, the food safety regulation setting limits to harmful contaminants in food suffers from shortcomings concerning the seaweed food products. Maximum levels for arsenic in seaweed foodstuffs have not been established even though high levels of inorganic arsenic in certain macroalgae species may result in the intake of harmful quantities of inorganic arsenic even when relatively small amounts of seaweed are consumed. However, these shortcomings in the regulation have been recognized and are likely to be resolved in the future. The classification of seaweeds as fishery and aquaculture products is noteworthy, since it obligates detailed product labeling and authorization of the species by the national authorities. The limitations and requirements for macroalgae based feed materials are established in the EU feed laws where, depending on the regulation, algal feed materials are either considered as their own feed category with specific safety regulations, or covered by common principles applicable to all feed materials.

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