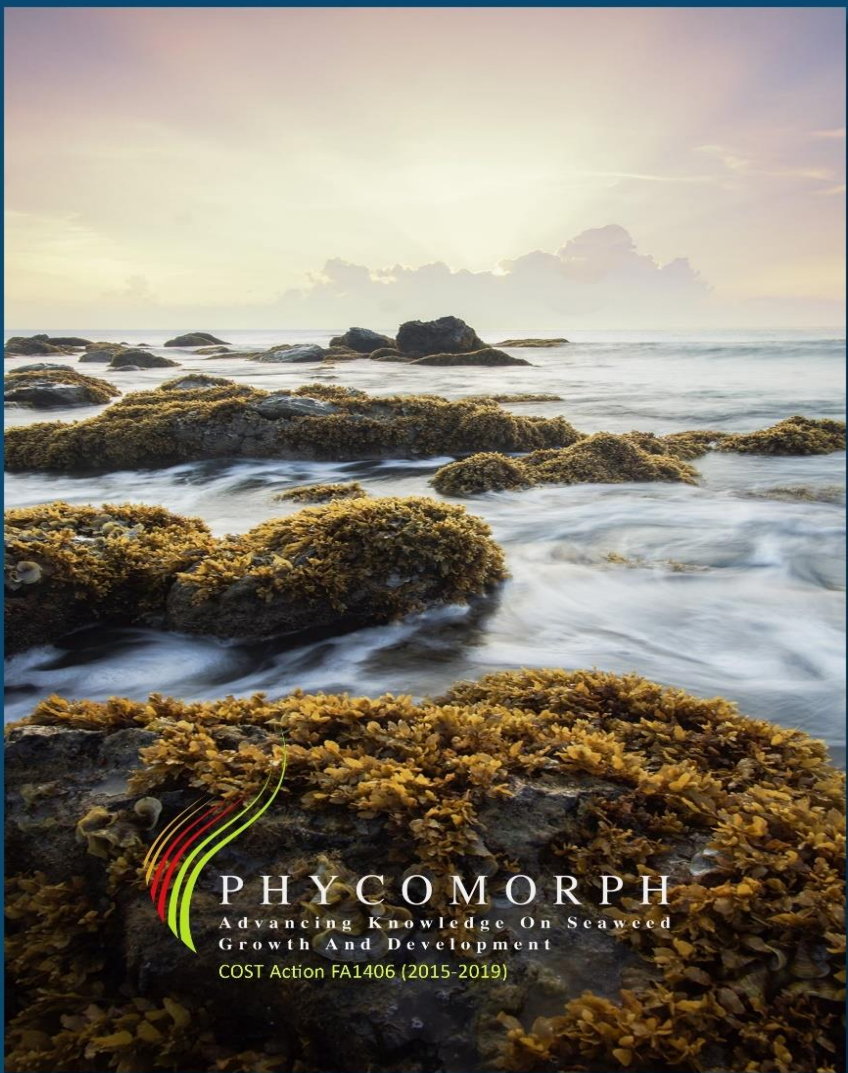
CONCLUDING

RECOMMENDATIONS

PEGASUS

PHYCOMORPH EUROPEAN GUIDELINES FOR A SUSTAINABLE AQUACULTURE OF SEAWEEDS



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PHYCOMORPH EUROPEAN GUIDELINES
FOR A SUSTAINABLE AQUACULTURE OF SEAWEEDS

COST Action FA 1406

CONCLUDING RECOMMENDATIONS

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RECOMMENDATIONS FOR A SUSTAINABLE DEVELOPMENT OF SEAWEED AQUACULTURE IN EUROPE

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Seaweed plays a key ecological role in coastal ecosystems and can be used for various applications. The development of the seaweed aquaculture sector can help to address global challenges related to human health, human consumption and sustainable circular bioeconomy. The applications are various from medical, cosmetics, food, animal feed sectors to agriculture (as a biofertiliser) and aquaculture development.

The global seaweed industry has a total estimated value of €8.1 billion per year and is continuing to expand (Bixler and Porse 2011; FAO 2016). Yet the rapid expansion of this industry can have unforeseen ecological and societal consequences. The lack of biosecurity measures and global legislation governing the cultivation and movement of seaweeds between regions and continents has been identified as one of the main challenges to tackle in order to safeguard a sustainable seaweed industry (Cottier-Cook et al. 2016).

Although European marine flora displays one of the highest species-diversity levels in the world, its seaweed production in Europe is still in its infancy. Meanwhile, interest in seaweed's many industrial applications is on the rise. There is, therefore, a need to support industries in the development of European seaweed aquaculture sustainably.

Markets show increasing interest in seaweed resources and their potential role in European Blue Growth and Bioeconomy. The development of seaweed aquaculture thus involves, in the medium and long term, the expansion of cultivation at sea due to the unlimited space offered by the latter. However, offshore cultivation may bring meaningful impacts on the environment and on biodiversity owing to the risk of escape of propagules with the potential to affect local genetic biodiversity.

The need to establish a framework for the sustainable and profitable development of European aquaculture is the impetus for these recommendations, which are based on scientific expertise and identification of the challenges and bottlenecks currently preventing this sector's development.

To support the sustainable development of seaweed aquaculture, all stakeholders – industry, farmers, researchers and policy-makers – must collaborate to establish European strategic-development plans.

The sector is multidimensional, with economic, environmental, scientific, legal, technological, and marketing dimensions.

Several European laws, regulations and recommendations already consider seaweed-related activities in general, but updates may be necessary at various levels (e.g. for environmental protection and food safety). In addition, an emphasis needs to be placed on the correlations and links between the different regulations and legislation related to seaweed and food safety. The visibility of clear-cut, transparent, coherent governance across Europe will help foster the development of the industry.

Finally, even if the market for food is often trend-based, Western consumers must be educated and incited to consider seaweed as food. Sensory-evaluation panels have been successfully implemented at the national/regional level and merit further development. It is recommended that a vocabulary be created to describe the flavour of seaweeds, so helping consumers identify what they are buying, and what seaweeds add to their food, in terms of taste or nutrients.

Figure 1 highlights some of the bottlenecks identified in these guidelines.

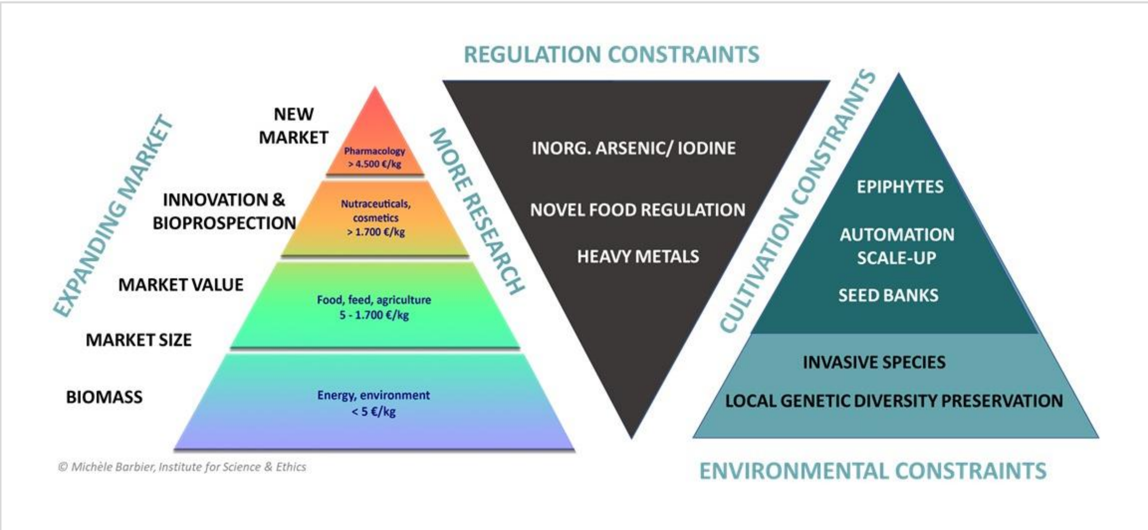

***Fig. 1**: The development of sustainable seaweed aquaculture in Europe comes across various challenges: market size, environmental constraints and the preservation of local genetic diversity, the need for more research – both fundamental and applied –, regulations on food quality, heavy metals or alien species, and cultivation constraints ranging from automation to epiphytism problem.*

ROLE IN REMEDIATION

Seaweeds hold potential for flood control, because they are a means of coastal protection. Furthermore, by their capacity in absorbing N, P and C, their potential role in ocean acidification and bioremediation at sea should be further investigated.

Photo credit: Enrapture Captivating Media from Unsplash

The main recommendations detailed in the various chapters of these guidelines are summarised below.

MARKET ASPECTS

To support the development of the seaweed industry, a market analysis is necessary at the European level to gain better knowledge of the market demand and structure in order to clearly identify the different uses of seaweed in various sectors. For existing farms, the innovative use of seaweed biomass can maximise its value, via the extraction of as many compounds as possible for different markets. The market for food and feed needs to be expanded and consumer education would accordingly help encourage the consumption of more and better quality seaweed products.

EUROPEAN PRODUCTION

A better knowledge of current production yields at the European level is necessary and requires reference to homogenised measurements in biomass production, for measurement outcomes are variable, being for example directly dependent on the season, species, age, organs, drying methods used.

At the national levels, seaweed-aquaculture licensing procedures need to be simplified for greater transparency and efficiency while the social acceptability of seaweed concessions should be promoted. Moreover, it is important for all stakeholders and the whole industry (from policy makers, local authorities, researchers to the production sectors) to have trained personnel, thus requiring the development of training programmes in regional and/or national centres.

Figure 2 sums up some needs.

Fig. 2: *To improve the market, many aspects must be taken into consideration.*

Photo credit: Shane Stagner from Unplash

CULTIVATION AT SEA

The choice of the cultivated species depends on the trait of interest (characteristics) it presents to a pre-identified market, and on the cultivation site which has been selected for its environmental conditions.

The geographic sites, the trait of interest and the cultivated species must all be congruent - a requirement that suggests local native species are the best suited, being well adapted to the given local environment. Regarding use of non-native species chosen for a specific trait of interest, studies should first be carried out to assess the potential impact of its introduction into the environment and its respective economic importance.

CHOICE OF SPECIES

To help farmers, maps of the seaweeds available along the European coasts can provide tools to characterise the resources in the vicinity of each potential farm.

For at-sea cultivation, the identification of local seaweed species will be useful for sourcing. To this end, a better knowledge of the populations and their connections (i.e. level of gene flow) is needed to identify the optimal sourcing areas from which farmers can harvest fertile individuals and produce “local strains”. In parallel, the domestication process requires more understanding of the biology of seaweeds as well as the diversity of associated organisms (symbionts, pests, diseases, etc.), the structure of the marine ecosystem, and the evolution of human needs.

Aquaculture activities not only have the potential to affect surrounding communities but also to improve the quality of the water. These aspects should be adequately documented and considered when planning the locations of aquaculture facilities. The potential impact of the cultivated species on the local community should also be assessed. It is essential to preserve local genetic diversity; therefore, any reproduction events and/or dispersal from farms to the wild populations should be carefully monitored and prevented.

The definition of local geographic areas/limits for these local strains will be helpful for authorising or prohibiting the transfer of strains from one area to another.

As recommended, only native species should be cultivated at sea until the population dynamics and population genetics are better understood for each cultivated species. The use of non-indigenous species (specifically those imported from outside Europe) should be prohibited in the open sea unless control over the dispersion of these non-native species is implemented.

These non-indigenous species are potentially invasive and can also act as vectors of introduction for new pathogens or pest organisms.

Identifying the nature of pest and disease propagation must be performed to develop better management of resources. Toxic elements can affect human health either directly or indirectly by their accumulation in other organisms used for human consumption. Additionally, the fact that, under the Marine Strategy Framework Directive (MFSD) only newly introduced non-indigenous species are a primary criteria, potentially controls less the impacts of established non-native species (secondary criteria in MSFD). The dynamics of these species needs also to be assessed.

Figure 3 summarises the actions needed for preserving European marine biodiversity.

IMTA

IMTA for integrated multi-trophic aquaculture is a promising co-cultivation system, but its development requires further research to optimise the technique. A framework should be established for guiding the spatial organisation of open-sea aquaculture to maximise production (e.g. through the selection of optimal sites) while minimising impacts on the environment; this framework could be an integral part of local Maritime Spatial Planning.

In IMTA as in land-based aquaculture, non-native species should be considered only if its impact on the environment has been shown to be negligible.

Fig. 3: *Actions promoting the preservation of European marine biodiversity*

SELECTION PROGRAMMES

When strains are chosen for their traits of interest, increasing their yield as well as their robustness is important. Well-planned and -designed breeding and selection programmes will help to achieve the goal of long-term sustainability but require further research to determine the appropriate conditions for cultivation given the high risk of new genetic materials escaping into the wild.

CULTIVATION ON LAND

In land-based systems, non-native species can be cultivated within a well-defined framework whereby the cultivation system ensures optimal treatment of discharged water to avoid any dispersal into the wild marine ecosystem.
This system is likely to require the implementation of monitoring tools (methodology, applications and devices) and quality-control supervision of inlet and outlet water (e.g. sterilisation of outlet waters to neutralise spores). The use of alien species needs to be considered carefully.

PRESERVATION TECHNIQUES

Once a strain with the specific traits of interest is successfully cultivated at one site, its maintenance and preservation are necessary. For example, climate changes, diseases and pests can decimate a population (as well as affect the local surrounding environment), as it has already occurred in Asia. Preservation methods such as cryopreservation must be further supported to ensure the maintenance of strains bearing the specific traits of interest.

Alien species

In view of the recommendations regarding alien seaweed species management in aquaculture and in light of the regulations in force, **a list of alien species of economic interest in Europe needs to be established.** The risk of such species for the environment should be assessed to decide to either protect the environment in case of high risk by including these species in the list of species of EU concern or facilitate aquaculture cultivation by including them in Annex 4 of Regulation EU 708/2007 (which currently does not include any seaweed species). To do so, risk assessments are necessary to understand in which risk category to place introduced species currently established in Europe.

BIOBANKS AT REGIONAL TECHNICAL CENTRES

In parallel, the concept of biobanks, i.e. collections of strains from wild and cultivated populations, can provide a solution for ensuring access to an efficient strain. It is advisable that each country develop infrastructures to breed and produce seedlings in nurseries for producers, but in a coordinated way. Each European country should therefore set up agencies that collect and maintain stocks at the regional level, if this is in line with national strategies. These agencies could also contribute to state sovereignty over natural resources (Nagoya Protocol). These centres should also nuture links with local elected officials, as well as professional representatives from the legal, financial (banking) and insurance sectors. This industrial-relations service would support the development of this sector by creating jobs at a regional level – although the sector still requires investment and social acceptability. These centres should be co-designed by professional experts.

A transparent database listing these regional/national agencies can ensure access to technical information for producers and decision-makers alike for each country/region.

Best practices of the cultivation of seaweed are needed at the European level.

NATIONAL INTEGRATED GOVERNANCE

Taking the governance process further, an integrated system at the national level should include experts from technical centres, research institutions and producers to foster collaborations. This national-level system would provide support for producers to obtain funding for investment purposes or to cover damages in the event of vandalism, accidents or natural disasters.

TRACEABILITY AND CONTROL OF ORIGIN

The notion of local strains for a specific market - also usable as a marketing argument - requires appellations of geographic origin. The implementation of tools to ensure the traceability of all culture strains (indicators and procedures) is necessary. In particular, the indicators need to be homogenised across EU Member States. Certification procedures need to be implemented or transferred to existing certification centres for aquaculture, such as the Aquaculture Stewardship Council.

CULTIVATION TECHNIQUES

In Europe, seaweed cultivation is still in its infancy, but scientific knowledge on seaweed genetics is already available.

To support the cultivation process, a better understanding of species' life cycles is also necessary. This knowledge will help to identify the technical factors that can control the reproduction and growth of seaweeds.

To protect local genetic diversity, assessment of the impact on local biodiversity should be carried out before any launch of installation in the open sea.

For the improvement of cultivated species, controlled breeding and selection programmes are needed.

The mechanisation of infrastructures or the automated harvesting of seaweeds cultivated offshore can help producers to scale up and reach the targeted production yields.

In general, more research is required to meet some of the challenges identified in seaweed production (Table 1 and Table 2).

In at-sea systems, non-intensive strategies are recommended but require preliminary definition of the "limits" of intensive cultivation.

Alternative solutions consist in the combination of strains, alternation of species, spatial and/or temporal heterogeneity of cultivation practices. High densities in cultivation systems can prevent the presence of competing species but may increase the spread of pathogens in the farmed seaweed. Optimal densities must be adapted to each species. Strains and techniques can be improved at the local scale.

Figure 4 and Table 1 summarise the challenges and needs in terms of scientific knowledge.

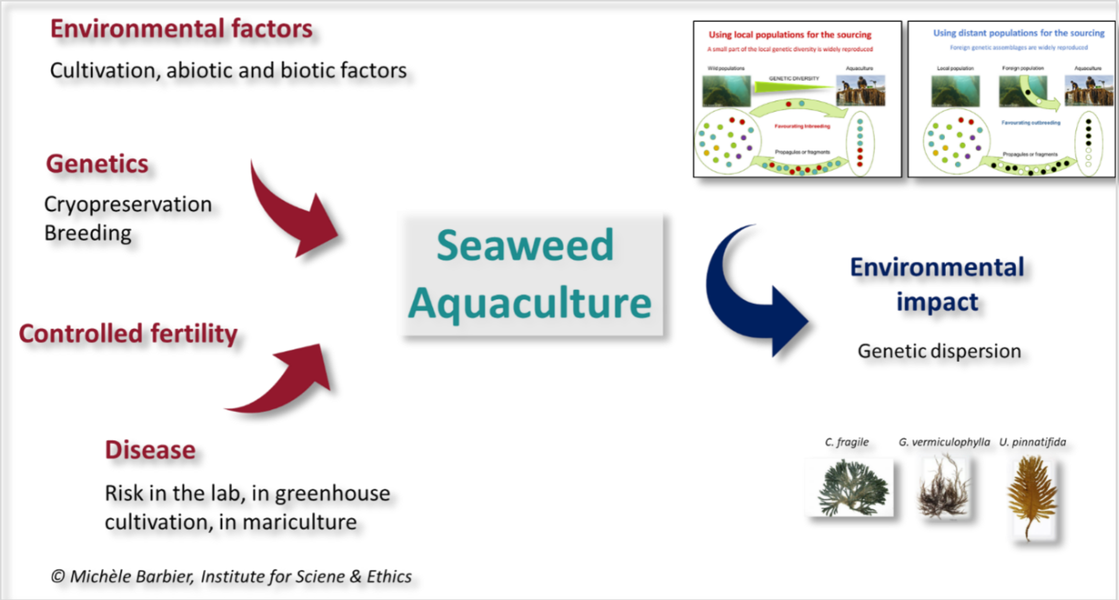

Fig.4: *Many aspects of seaweed aquaculture are challenging and require more scientific knowledge.*

Table 1: Research programmes flagged to provide more understanding on the biology of seaweeds

<table>
<tr><th></th><th>CHALLENGES</th><th>MORE RESEARCH TO</th></tr>
<tr><td rowspan="6">Basic Biology of Seaweeds</td><td>Conservation of species of interest</td><td>Develop cryopreservation methods</td></tr>
<tr><td>Improve strains of interest through breeding and selection programmes</td><td>Understand genetic compatibility and genome interactions</td></tr>
<tr><td>Cultivation of new species under artificial conditions</td><td rowspan="2">Understand the parameters that control fertility & reproduction</td></tr>
<tr><td>Improve production of juvenile seaweeds</td></tr>
<tr><td>Improve the shape, texture and content of seaweeds</td><td rowspan="2">Understand the impact of environmental factors (biotic and abiotic) on phenotypic traits of interest</td></tr>
<tr><td>Prevent epiphytes, diseases and pest blooms</td></tr>
</table>

SEASONAL AND GEOGRAPHIC VARIABILITY

The time (in terms of investment and years of cultivation) necessary to make an operation profitable should be evaluated.

The influence of environmental factors such as temperature, nutrients, salinity and light also needs to be known to identify optimal conditions for growth, biochemical composition or flavour, effort and cost. Since the form and beneficial constituents of one species can vary according to the season and geographic region, attention should be paid to the temporal and geographic distribution of the characteristics of interest (either the extent of this variation, or the means to control and predict it).

PRE-TREATMENTS

Relevant pre-treatment steps associated with efficient production systems are needed to stabilise post-harvest seaweed biomass and ensure high-quality products that can undergo further conversion processes. More studies are required to develop these pre-treatment steps.

Conservation techniques (freezing, drying, fermentation) and alternative techniques require more research, and regardless of the technique used, their impact on the quality of the end-products as well as on the environment must be assessed. Product quality and safety should be quantified and, if possible, optimised, while energy efficiency must be improved.

STABILISATION PROCESS

Efficient stabilisation alternatives and optimal procedures to prepare biomass for production-chain extraction of high-value components will ensure access to seaweed biomass year round and support the growing demand for bioactive substances.

The development of these procedures will create value in the coastal industry and support sustainable development of the European bioeconomy based on the cultivation and processing of seaweed biomass. Table 2 summarises some research needs.

Table 2: Research programmes necessary to improve cultivation

	CHALLENGES	MORE RESEARCH TO
Cultivation process	Impact on the environment	Control genetic dispersal
	Improvement of production	Improve facilities and technical itineraries
	New cultivation systems such as IMTA	Optimize site location, co-cultivation best practices
	New cultivation artificial substrates	Develop understanding of adhesion mechanisms & adaptation
	Biorefineries	Improve technologies & methodologies

SEAWEED AS FOOD IN LEGISLATION

The market for food is promising, even in Western countries, but a number of existing bottlenecks in legislation can hamper market development. An updated and complete list of seaweed species authorised as food in Europe should be compiled. Such a list would facilitate the work of seaweed companies wishing to introduce new products to the market, by determining the adequacy of regulations with the reality of the seaweed sector and by contributing to food safety control.

The monitoring of heavy metals, iodine, inorganic arsenic, etc. in seaweed - an issue that is highly relevant to the market - can remove market barriers and provide clear updated signals and regulations on the threshold values of different contaminants. EFSA (European Food Safety Authority) is in the process of drawing up this list.

Additionally, the dissemination of this list of species authorised as food will increase public awareness of the use of seaweeds as food, for unfamiliarity currently stands as one of the main hindrances to the commercialisation of seaweeds as a mainstream food product. Scientific studies are needed for risk-benefit analyses that take pros and cons into consideration. To back up claims that seaweed is a nutraceutical bioactive food or a superfood, more research and clinical proof are needed.

NUTRITIONAL VALUE

Although seaweed products are being rapidly developed, knowledge remains limited regarding the effects of preservation on the quality of seaweed biomass. General studies are furthermore needed on red, green and brown seaweeds to evaluate the long-term effects of drying treatment, while alternative solutions of treatment should also be investigated. The methods for determining some of the nutritional properties of algae are to be recommended by CEN/TC 454 Algae. Algae product standardisation should also applied.

Photo credit: Joshua K. Jackson from Unsplash

COMPOUNDS FROM SEAWEEDS

New compounds extracted from seaweed should be checked for their eligibility as food ingredients according to the Commission Implementing Regulation (EU) 2017/2470; if they are unlisted, applications should be made for their acceptance. In parallel, species must be clearly and specifically identified to guarantee the sources of compounds extracted for the market. It is essential that the ongoing work on standardisation of identification methodologies carried out by the CEN/TC 454 be supported and encouraged.

NOVEL FOOD LIST

For the European Commission's (online) Novel Food Catalogue, a clear and rational overview should be developed to include an updated list of novel and non-novel (species already consumed as food before 15 May 1997) food products. To avoid misinterpretation of the online version content, the designation should be changed to Food catalogue since it includes both novel and non-novel food items.

In addition, an official list of all seaweed species accepted as food before 15 May 1997 should be compiled (possibly including notes on specific species accepted in different Member States), so that producers, companies and other stakeholders can consult an updated list, promoting a simplification of procedures.

Some seaweeds used in Europe, and thus already on the market, might not yet be approved as food (novel or non-novel), and are, therefore, not listed anywhere. These seaweeds should go through the authorisation process for novel food.

LEGISLATION ON SEAWEED AS SAFE FOOD

Legislation on contaminants such as heavy metals and the problematic issues of iodine and inorganic arsenic should refer to "seaweed as food"– and not "seaweed as food supplements" as it is the case in the current legislative texts – and should also clearly state if threshold value are given in terms of dry or fresh weight. A monitoring program has been initiated at EFSA to compile analyses in order to evaluate the threshold values for seaweed as food. Ideally, EFSA and the Novel Food Catalogue officer will harmonise the list of seaweed species for food.

Arsenic

The total arsenic threshold value is at present a market barrier. Feed legislation needs to be updated as does legislation on seaweed as food. As it is now possible to distinguish harmful inorganic arsenic from organic arsenic, the focus should be on providing the inorganic arsenic threshold level rather than continuing to follow the outdated approach of giving the total-arsenic (organic and inorganic) level, as required by current feed legislation. Threshold values should also be specified as being on a dried- or wet-weight basis.

Iodine

The high concentrations of iodine accumulated in some of the large brown seaweeds are market barriers. More knowledge is needed on speciation and/or chemical form and bioavailability and/or uptake of seaweed iodine just as the development and dissemination of iodine-reduction methods are required. More generally, new methods for the detection of different chemical forms must be developed.

Health food

Risk-benefit analyses including chemical risk assessments are needed to evaluate the health risks related to seaweed consumption. Research on high iodine content, heavy metals, nutrient or even nutraceutical effects of seaweed must continue for the purposes of ensuring food safety. There is a need for general risk-benefit analyses of seaweed with clear guidelines on which element under which form is beneficial, at what levels (daily or monthly intake?), and which chemical form is present in the seaweed. The current EFSA work on monitoring seaweeds is timely.

Organic certification

Organic certification exists for cultivated and natural populations of seaweeds, but it is overseen by a wide range of bodies while various certification processes apply in the different European countries. It is probably not feasible to set up a single organic certification process with harmonised regulations across Europe.

However, best practices at the European level could guide, advise and homogenise the process across Europe.

Photo credit: Stefan Lorentz from pexels

PRESERVATION OF SEAWEED FOR FOOD

At present no specific legislation relating to quality stability (e.g. is it still safe to eat after two months?) exists. There is a need for increased knowledge about the impacts of post-harvest handling (e.g. preservation treatments) on the quality and quality stability of seaweed (nutrient content, organoleptic properties) destined for food applications (food safety).

Best storage procedures and industrial-classification codes including self-checks must be determined for each species and product along with best practices for the evaluation of product shelf-life.

Further research is needed to:

(i) minimise losses of valuable compounds, *(ii)* ensure product safety and *(iii)* limit energy consumption and associated costs. This is a key to the increased profitability of the industry.

Moreover, for preservation/downstream processing, industrial-classification codes should be drafted by producer companies in collaboration with food authorities. These codes can also be drawn up in collaboration within EU seaweed experts for the purposes of establishing common rules.

The development of the food market for seaweeds is ongoing. However, bottlenecks that hamper market development have been identified in European legislation. Integrated European governance stands to benefit from the recommendations listed above. In parallel, additional research is needed to provide further understanding on how to secure seaweeds as food, as reported in Table 3.

Table 3: Recommendations (for policy makers and researchers) for fostering the market development for seaweed as food.

CHALLENGES AND NEEDS FOR THE INDUSTRY	RECOMMENDATIONS	
	RESEARCH	GOVERNANCE
Secure food security: inorganic arsenic, iodine, heavy metals	Risk-benefit analyses and more knowledge on speciation of iodine/chemical form, bioavailability	Update the threshold value of contaminants and define this for seaweed as food, as well as a common standard on dry-weight or wet-weight basis
Elevated concentrations of iodine in some large brown seaweeds Monitoring of potentially undesirable compounds in edible seaweeds	Standardisation & definition of chemical compound classes, activities, traceability, methods and species identification	
Food preservation to maintain consistent contents and improve organoleptic properties	More knowledge of the effects of preservation methods & treatments on biomass	Set up certification centres
Impacts of post-harvest handling (preservation treatments) on the quality and quality stability of seaweed (nutrient content, organoleptic properties). Stabilisation of seaweed biomass	Definition of best storage procedures & best practices for the evaluation of product shelf-life	Implement best practice / industrial classification codes developed in collaboration with companies and national / European authorities
Various certification processes for organic certification in different EU countries		Harmonize organic certification across EU
Know more on seaweed behaviour in the human body and effects on health	Risk-benefit analyses of seaweeds	
Cultivate additional seaweeds	More knowledge on domestication process	
Attract consumers	Implement sensory evaluation panels	Increase public awareness, create vocabulary to describe the flavour of seaweed

Finally

To boost the sustainable development of seaweed aquaculture in Europe, these guidelines call for the harmonisation of legislation and management frameworks across Europe on exotic species, cultivation rules, environmental protection, evaluation of the risk of loss of wild biodiversity, marine water quality and the cultivation of hybrids.

The scientific community must anticipate needs and develop knowledge on the biology of marine macroalgae: e.g. growth, reproduction, physiology, metabolism, pathology, ecology and the environmental impact of cultivation.

A clear understanding of the current production in Europe is also needed, including standardisation of biomass production and quality assessment.

Photo credit: Joshua K. Jackson from Unsplash

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GLOSSARY

Alien: A species, subspecies or lower taxon, introduced outside its natural past or present distribution; includes any part, gametes, seeds, eggs, or propagules of such species that might survive and subsequently reproduce (CBD 2002). synonymous: introduced species, exotic species, or non-native species.

Breeding/inbreeding/outbreeding: While inbreeding indicates crosses between two related individuals of the same population, which are genetically close, outbreeding defines crosses between members from two distant populations (Lynch 1991).

Cultivar: Plants obtained by targeted selection (breeding). Different cultivars can be obtained from the same species.

Domestication: "Domestication is considered a long and complex process during which domesticators select and modify organisms that can thrive in human eco-environments and express traits of interest for human use" (Valero et al., 2017).

EFSA: European Food Safety Authority.

IMTA: Integrated Multi-Trophic Aquaculture combines aquaculture of fed organisms (e.g. finfish) with that of extractive organisms consuming dissolved inorganic nutrients or particulate organic matter (seaweeds and invertebrates, respectively), so that the environmental processes at work counterbalance each other (Chopin 2006).

Invasive species: An invasive alien species (IAS) is a species that is established outside of its natural past or present distribution, whose introduction and/or spread threaten biological diversity (CBD 2002).

Life cycle: Duration and steps which an organism goes through, from a single- cell stage, to the next generation. It usually involves an alternation of haploid and diploid generations (haplo-diplobiontic) and sexual reproduction.

Local strains: A cultivated strain or variety whose genetic background is similar to that of the natural population geographically close. The degree of similarity taken into account is directly dependent on the observed genetic diversity of the species in the considered area, compared to distant populations of the same species. It is a relative parameter ("more or less similar").

Native vs non-native species: While a native species settled in an area, independently from the human activity, a non-native (alien) species is one which has been introduced, deliberately, or not, in the area as a consequence of human activities (Pyšek 1998).

Offshore: The common notion of "offshore" simply refers to "not on land", meaning the cultivation of fish, shellfish or seaweed in cages, long lines or other structures in the sea. In the context of seaweed farming, it is suggested that the term "offshore" be used for large-scale activities in open-sea waters, unlike the farming in coastal waters as practised at present.

Population: A population is a group of individuals belonging to the same species, reproducing mainly between themselves, occupying a common geographical area and playing a particular role in the ecosystem (Odum 1971).

Selection programme: A process by which artificial selection for individuals with targeted traits is operated through a succession of crosses between selected genitors.

Strain: This term has no official definition or ranking status in botany but can refer to the offspring from a common ancestor with uniform phenotypes (Usher, 1996). In order to avoid any confusion between the terms “strain” and “lineage” in these guidelines, we make the choice to use “strain” as one isolated individual (e.g single isolated genotype) from either a wild or a cultivated population. “Lineage” will refer to the succession of offsprings from artificial crosses between strains.

Sustainable: To ensure that an activity meets the needs of the present without compromising the ability of future generations to meet their own needs. The concept of sustainable development does imply limits imposed by the present state of technology and social organisation on environmental resources and by the ability of the biosphere to absorb the effects of human activities. However, technology and social organisation can be both managed and improved to make way for a new era of economic growth (Brundtland Report, 1987).

Vegetative reproduction: Asexual reproduction (as e.g. “cloning”) through which a mature organism grows from a fragment of the parental plant or its zoid

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AFTERWORDS

PEGASUS was released in May 2019.

It was prepared by 50 contributors from several countries worldwide.

During the previous 18 months, PEGASUS outlines and preliminary versions were presented in different international conferences and to several groups of European stakeholders.

PEGASUS was open to an international public consultation in December 2018.

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