EUROPEAN COMMISSION
DIRECTORATE-GENERAL FOR RESEARCH & INNOVATION

Directorate F - Bioeconomy
F.4 - Marine Resources

Aquatic food products and new marine value chains – reinforcing EU Research and Innovation policy for food & nutrition security.

FULL REPORT

12 October 2016
14:30 - 17:50 – The SQUARE, Brussels

A report summarising the "Aquatic food products and new marine value chains" participatory workshop, organised by the Marine Resources Unit of the Directorate General for Research and Innovation of the European Commission and held just prior to the Commission High-Level Event "FOOD 2030: Research & Innovation for Tomorrow's Nutrition & Food Systems".

SUMMARY 3
Part I. Aim of the workshop 5
Rationale 5
Objective of the Workshop 5
Structure of the Workshop 6
Part II. State of the art 7
Underused fish biomass for food and food ingredients 7
New algae value chains for food 9
Consumer acceptability of aquaculture products 10
Farmed in the EU 11
Part III. Challenges and research to overcome them 13
Key challenges and non-technical barriers 13
Underused fish biomass 13
Micro-algae and macro-algal value chains 14
Aquaculture awareness 15
Research & innovation priorities and actions 17
Underused fish biomass 17
Micro- and macro-algae value chains 17
Aquaculture awareness 19
Part IV. Recommendations 21
Direct financial support actions 21
Communication actions 21

SUMMARY

As part of the European Commission High-Level Event 'FOOD 2030: Research & Innovation for Tomorrow's Nutrition & Food Systems' held in Brussels in October 2016, four parallel workshops were organised to provide ideas and needs towards building the future of EU research and innovation policy for Food and Nutrition Security.

One of these - Aquatic food products and new marine value chains - was organised by the Marine Resources Unit of the Directorate General for Research and Innovation of the European Commission and looked at three thematic areas of aquaculture and fisheries: Underused fish biomass, new algae value chains for food and consumer acceptability of aquaculture products.

The participatory workshop brought together 30 key stakeholders, representing diverse upstream and downstream interest in these high-potential marine value chains and in communicating aquaculture as a high-potential contributor to European consumer health and food security. Guided by initial expert presentations, stakeholders identified the key challenges, barriers, research and innovation needs and short/medium term actions to help expand the sectors.

These presentations provided core messages for consideration:

- Many wild capture seafood value chains are characterised by low utilization factors and high proportion of waste. Only 21% of some EU finfish catches currently end up as human consumption - so how can we make better use of the biomass that is wasted?
- (Micro) algal composition and nutritional value is at least as good as – and in some cases better than soya. So why aren't we using it?
- As Jacques-Yves Cousteau famously quoted "We must plant the sea and herd its animals … using the sea as farmers instead of hunters. That is what civilization is all about — farming replacing hunting". Aquaculture is the most feed-efficient food production sector and can also contribute to ocean conservation. Should we therefore communicate aquaculture as farming?

The three thematic areas discussed in the workshop are very different and thus have different challenges, barriers and needs. In better using fish biomass, we must understand the markets for new food products from fish 'waste' and address regulatory constraints that potentially hinder increased utilisation. The landing obligation is likely to improve utilisation of previously discarded catches and lead to development of new products. New and improved technology, along with changes in consumer behaviour will also lead to increased utilisation and reduction in waste.

Microalgae biomass has enormous potential in both food and non-food products. But we must understand better how to produce it at large scale and how to better embrace biorefinery concepts in its conversion to food products. While people in Asia consume algal food products as part of their tradition and culture, this is not yet the case in Europe, although we are starting!

Consumer awareness and perception of aquaculture is variable across Europe and between different demographic groups. It is therefore important to recognise this and to have more knowledge on the common issues, but also on those that differ between groups or countries, so that the approaches and communication tools can be adapted to the 'audience'.

The workshop resulted in several recommendations to the Commission, national and regional bodies and sectorial representatives to consider as pathways to develop the potential of underused fish biomass, new algae value chains for food and consumer acceptability of aquaculture products. They include direct financial support actions to develop pilot plants and bio-refineries as 'lighthouse'

projects to encourage further investment. They also include communication actions to improve dialogue between actors in the food chains and ensure industry and societal involvement in research strategies to provide solutions.

We have significant opportunities in all three of the workshop themes, but all need upscaling.

Upscaling our research and innovation systems by investing in large demonstration or smaller regional biorefineries is the key for aquatic food chains to contribute better to the Food and Nutrition Security priorities of Nutrition for sustainable and healthy diets. Upscaling our communication activities in aquaculture and novel marine food value chains will also move us closer to obtaining a 'critical mass' of fact-based information that can impact acceptability.

We need to cement the role of aquaculture and new marine food value chains in society as being required and desired.

Part I. Aim of the workshop

Rationale

The European Commission High-Level Event 'FOOD 2030: Research & Innovation for Tomorrow's Nutrition & Food Systems' sought to explore what is needed to transform and future-proof our food systems to be sustainable, resilient, competitive, diverse, responsible and performant in their provision of accessible, healthy and sustainable food and diets for all.

Specifically, it wanted to address how research and innovation systems can be scaled-up to better contribute to the Food and Nutrition Security priorities of Nutrition for sustainable and healthy diets; Climate smart and environmentally sustainable food systems; Circularity and resource efficiency of food systems and Innovation and empowerment of communities.

Just prior to this event, four parallel participatory workshops took place, and one of these, organised by the Marine Resources Unit of the Directorate General for Research and Innovation of the European Commission, focussed on "Aquatic food products and new marine value chains".

Objective of the Workshop

Chaired by Head of Unit Sigi Gruber, **the principal objective of the workshop was to identify the needs and research priorities linked to three key topics for European aquaculture and fisheries sectors: Underused fish biomass, new algae value chains for food and consumer acceptability of aquaculture products.** These outputs would then help to shape EU research and innovation policy for Food and Nutrition Security.

In her introductory comments to participants, she explained the expected outcomes of the workshop, noting the importance of their inputs and experience in the development of research priorities. The broad context of the workshop and the FOOD 2030 high-level conference is one of food security and nutrition that go hand in hand with the United Nations Sustainable Development Goals (SDGs) based on" Food for Pleasure", "Food for Life" and also "Food for Thought"!

With 90% of global food production from terrestrial sources, food from aquatic resources represents an excellent opportunity to meet growing demand and food production needs. Political commitment to COP21 and the clear relevance of marine resources within at least 7 of the UN Sustainable Development Goals, and where the conservation and sustainable use of marine resources is enshrined in Goal 14, it is time now to develop clear priorities and action plans.

These may be to increase production, to focus on production methods or to waste less in food value chains by adding value and finding new markets for co-products. A future strategy may probably be with a combination of all three.

Structure of the Workshop

The workshop was structured to provide the maximum input from participants. The three topics were presented by invited experts – the presentation on consumer acceptability being complemented by a short overview of the Commission aquaculture promotional campaign "Farmed in the EU" – so as to highlight the main issues. This was followed by round table discussion amongst participants, with final summaries being presented back to the whole group.

This report follows the workshop structure and is written in four parts. The first provides background and objectives. The second is a summary of the presentations and hence the 'state of the art' in each of the three workshop themes. The third part lays out the key challenges, non-technical barriers, research needs and short terms actions, resulting from group discussions amongst the workshop participants. The final part is a list of recommendations for the Commission on short term communication and direct financial support to increase the current 10% of global food production from aquatic sources.

Participants discussed key challenges and solutions for each of the workshop thematic areas in focussed break-out groups.

Part II. State of the art

Underused fish biomass for food and food ingredients

Jónas R. Viðarsson, research group leader in the resources & products department of the Icelandic food and biotech company MATIS ltd, opened the workshop with a look at the possibilities and challenges of using currently underutilised fish biomass for producing food and food ingredients.

Of the global 2014 food production of 4.8 billion tonnes[1], total fish production from aquaculture and capture was 167 million tonnes, so just 3.5% of this. The total food production used for human consumption was 3.0 billion tonnes (73% of the total) and the total fish production for human consumption was 147 million tonnes (88% of the total). However, poor utilisation and waste at almost every stage in the fish food supply chain actually means that consumption is much, much lower. Today, fish accounts for 10% of global human protein intake.

Studies[2] suggest that in some cases just 21% of EU finfish catches end up on consumers' plates - so the question is "How can we make better use of the biomass that is wasted through discards at sea, through processing, through retail and distribution and finally by consumers"?

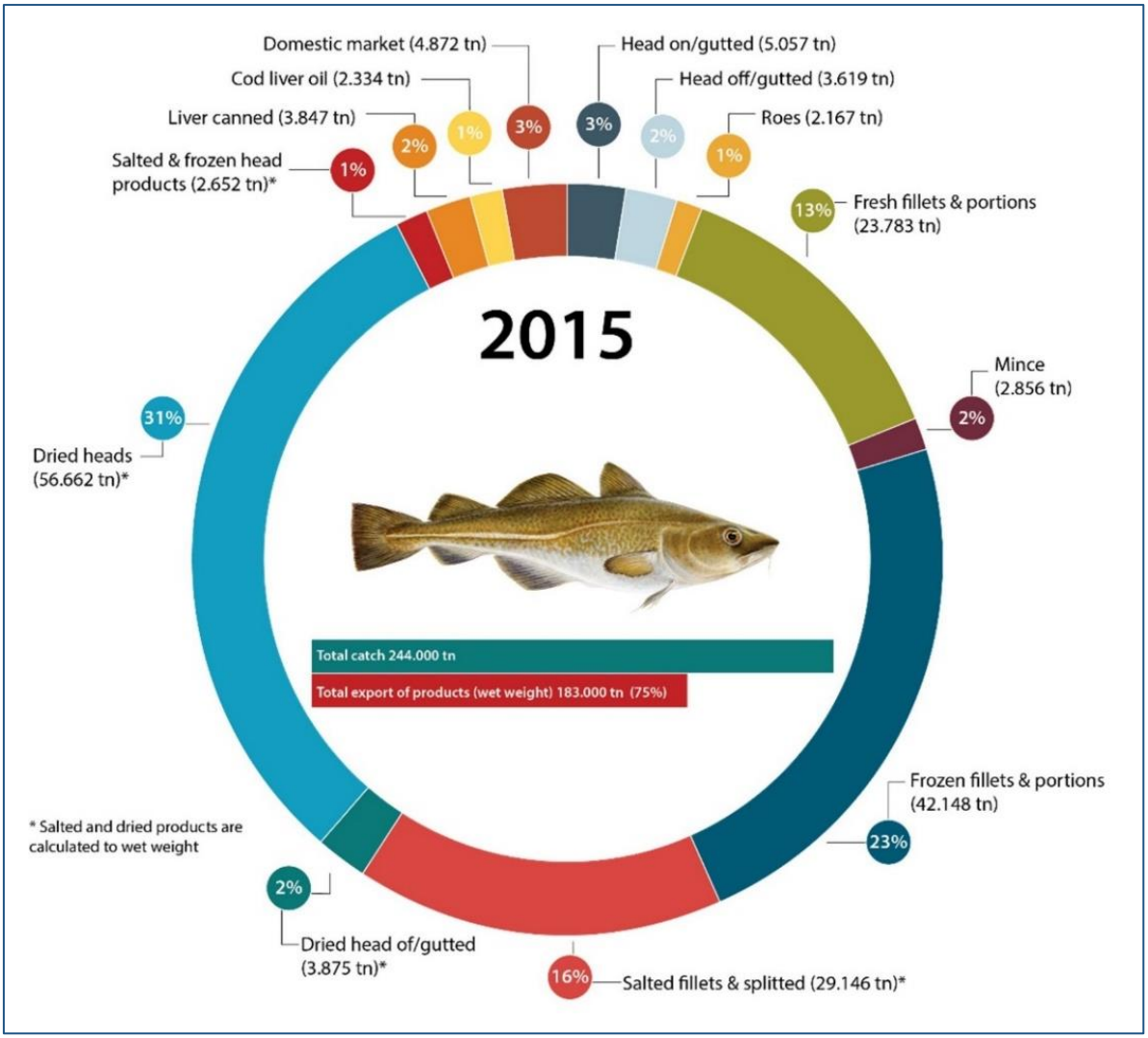
Traditional processing of fish such as Atlantic cod produces only the fillets for human consumption. The remainder of the fish is either used for animal feed or simply wasted. This means that only 35% of the whole fish is used for food. A comparative study into the utilisation of the Rest Raw Materials (RRM) or 'by-products' of whitefish, pelagic fish, farmed salmon and crustaceans in Norway[3] concludes that just 37% of the RRM for whitefish is utilised for human consumption, whereas comparative figures for pelagic fish are 100%, aquaculture (farmed salmon) 90% and shellfish 40%. It should however be noted that the uses are not always for direct food and is mainly used to make fish meal and fish oil.

Of their total 2015 catch of Atlantic cod (244.000 tonnes) Iceland used and exported 183.000 tonnes for food use, representing 75% of the catch. This percentage is higher when the non-food use is added.

[1] Source: FAO Food Outlook 2016. http://www.fao.org/3/a-i5703e.pdf

[2] Kelleher, K., 2005: Discards in the World's Marine Fisheries – An Update. FAO Fish. Tech. Pap. 470, Food and Agriculture Organization of the United Nations, Rome, pp. 154.; Love DC., Jillian F.P., Millia M.C. and Neffa R.A. 2015: Wasted seafood in the United States: Quantifying loss from production to consumption and moving toward solutions. Global Environmental change 35(2015) 116-124.;

[3] Richardsen, R., Nystøyl, R., Strandheim, G., and Andrea, V. (2015). Analyse marint restråstoff, 2014. Technical report, SINTEF Fiskeri og havbruk AS and Kontali Analyse AS. In Norwegian.



2015 utilisation of Atlantic cod in Iceland. Source: Matís ohf. 2016

This is way above the EU average and shows that RRM can be made into value-added food products to a much larger extent than is presently being done within the EU. In addition to this, the viscera and skin are used for animal feed, textiles, pharmaceuticals, cosmetics and others.

The utilisation of RRM can go even further, approaching complete use for human food consumption. For example, the Norwegian demersal bottom trawler "Molnes" that is also a processing plant where 100% of the catch is used, with rest raw materials being used to produce fish protein hydrolysates that are commonly used as food additives, flavouring, and health promotors.

With changing demographics (the age composition of the Japanese population in 2060 was provided as an example), health care systems will need to focus even more on healthy diets – which can partly be supplied by marine biomass. It is therefore predicted that a mass market for consumer healthcare products (linked to growing risk factors) will develop midway between pharmaceutical and consumer goods companies.

New algae value chains for food

The second presentation was made by Patricia Harvey, Faculty Professor of Engineering and Science at the University of Greenwich in the UK, who looked at the potential of algae value chains for food. Her focus was on microalgae, but many of the points raised are also applicable to macro algae.

Of the 80-100 000 algal species, found in many biotopes including high temperature, pH, salinity and CO_2 only about 200 are used globally at present. They are used as the whole alga in food supplements, ingredients and as live feed enrichment for early (hatchery) stages of aquaculture production and as high value molecules, including β-carotene, astaxanthin, phycocyanin and the long chain n3 fatty acids EPA and DHA. *Spirulina*, one of the most popular microalgae, has been described by the World Health Organization as one of the greatest superfoods on earth.

Microalgae compare favourably with the reference and other food proteins in the amino acid content and proportion and availability of amino acids in their protein profile, in the protein efficiency ratio, the apparent biological value, and the true digestibility value of protein content[4].

They are also a fine source of carbohydrates, found in the form of starch, cellulose, sugars, and other polysaccharides. The available carbohydrates have good overall digestibility and, therefore, few limitations on their uses and applications. The average lipid content in microalgae varies between 1% and 40% and, according to growing conditions, can be as high as 85% of dry weight. Algal nutrient contents are typically composed of sugars and lipids like glycerol or bases esterified to fatty acids, with carbon numbers in the range of C12 to C22.

(Micro) algal composition and nutritional value is at least as good as – and in some cases better than soya. So why aren't we using it?

Large scale production of the 'top three' – *Chlorella*, *Spirulina* and *Dunaliella* is 'only' about 20 000 tonnes dry weight per annum. In comparison, macro-algae (seaweed) production is 100 times greater and wheat, 70 000 times greater! So the potential is vast.

Our knowledge of production requirements (CO_2 supply, nutrients, temperature, water, irradiance, mixing rate and O_2 accumulation) still needs further development, as the current productivity of less than 10 g $m^{-2}d^{-1}$ should be about 25 g $m^{-2}d^{-1}$. Site-specific biological 'surprises' and the fragility of algal species are other factors that require knowledge development.

Images left to right: supercritical fluid extraction (NATECO2, Germany); membrane cartridges; high performance countercurrent chromatography (Dynamic Extractions, UK); Dunaliella powder, residue after supercritical fluid extraction and extract (Monzon Biotech, Spain; NATECO2, Germany;).

[4] T.L. Chac´on-Lee and G.E. Gonz´alez-Mari˜no (2010) Microalgae for "Healthy" Foods—Possibilities and Challenges Comprehensive Reviews in Food Science and Food Safety 9: 655-675

We also need to better understand biorefinery processes and markets, applying sustainability assessments to improve algae pathways including LCA, carbon and water footprints.

New food applications are needed and examples were given of initial tests made to incorporate Dunaliella-derived biomass fractions in fish sausages and bread products highlighting some of the challenges (performance in blends, texture, taste, smell, shelf life…) that are linked to these.

Consumer acceptability of aquaculture products

As the basis of her presentation, Ana Noronha, the Executive Director of "Ciência Viva", the Portuguese National Agency for Scientific and Technological Culture, informed participants of the outcomes of a workshop organised during the 4th Annual Conference of the European Marine Science Educators Association (EMSEA), organized by the Horizon 2020 projects AORA – CSA[5] and Sea Change[6]. The purpose was to understand challenges and solutions to the acceptance of aquaculture, in order to propose recommendations and proposals for action.

Three proposed facets of aquaculture for raising consumer acceptability of the activity:

- Aquaculture is the most feed-efficient food production sector
- Aquaculture is ocean conservation
- Aquaculture is farming

The third of which is linked to the timeless quote of the pioneer of the seas….

> *"We must plant the sea and herd its animals … using the sea as farmers instead of hunters. That is what civilization is all about — farming replacing hunting". Jacques-Yves Cousteau*

Ana presented some of the negative perceptions that consumers have with elements of aquaculture production, including the question of contaminants and environmental impact, noting that many of the communication needs could be fulfilled by educators, and that there are many examples of good practice that need to be shared.

A particular example was the development and availability of 'kits' for educators that would be used in the classroom as well as in science festivals or ocean literacy events. One of these is a modular kit to demonstrate Integrated Multi Trophic Aquaculture (IMTA) developed by CIIMAR[7] in Portugal within the Sea Change initiative.

[5] http://www.atlanticresource.org/aora/
[6] http://www.seachangeproject.eu/
[7] Interdisciplinary Centre of Marine and Environmental Research - a research and advanced training institution of the University of Porto http://www.ciimar.up.pt/

An educational kit to show the principle of Integrated Multi Trophic Aquaculture – SeaChange Project – funded by the European Union's Horizon 2020 Framework Programme for Research and Innovation (grant agreement 652644).

Other examples from various European countries were also presented as good models.

Suggested actions and initiatives for educators include:

- Continuous Professional Development Courses (CPDs) or Massive Open Online Courses (MOOCs).
- Connect with core curriculum subjects where **Nutrition** is addressed.
- Go beyond the food supply question and present aquaculture in the context of **Economy and job creation.**
- Organise visits to aquaculture industry sites: the direct contact of **educators and students with producers** will contribute to develop trust.

Farmed in the EU

As a complement to the previous presentation, Gilles Doignon (European Commission DG MARE) informed participants of the ongoing promotional campaign "Farmed in the EU[8] " and its key outputs to date.

Farmed in the EU is part of the European Commission "Inseparable" initiative, containing information on EU

[8] https://ec.europa.eu/fisheries/inseparable/en/farmed-eu
https://www.facebook.com/EUmaritimefish/https://twitter.com/EU_MARE
#FARMEDintheEU and #CRIADOenlaUE

aquaculture products as a healthy, fresh and local alternative. The site contains facts and figures, infographics, video testimonials and Q&A about EU aquaculture.

Compared to the production of meat, vegetable or fruit, aquaculture is generally not known. As children, we most probably played with toys or read books that taught us about life on the farm, or fishermen's tales. We had this connect to our food sources. But this is not the case with aquaculture and hence we don't really understand what it means and what its place in society is, even if the sector exists for centuries in Europe and provides since last year more seafood globally than the fisheries sector. The campaign focuses on the "Farmers in the water"[9]: citizens should consider aquaculture as any other animal production sector, with its challenges and advantages.

Part of the Farmed in the EU initiative is a school project - designed to raise awareness of the aquaculture sector among Europe's teenagers (12-18 years old) and find out how it affects their local community. A project kit has been designed for all teachers (biology, but also history, language, informatics, etc) to give them all they need to plan and run the project, from the first lesson, through the visit, to the follow up activities which can focus on anything from Nutrition & Cooking, Science & Technology, or Communication and Arts.

The project was piloted in 2015 in 20 schools across 10 EU countries (Czech Republic, France, Germany, Greece, Hungary, Ireland, Italy, Poland, Spain, and the United Kingdom[10]) and a key component is an on-site visit by a local aquaculture professional (producer or scientist), providing students with the opportunity to talk to an expert, to build on their own research, and to take part in a fun and interactive visitor session. The #FARMEDintheEU / #CRIADOenlaUE project is now being implemented by Spain, with dozens of schools involved.

It was also pointed out that Article 68 (point g) of the European Maritime and Fisheries Fund provides clear measures for "regional, national or transnational communication and promotional campaigns, to raise public awareness of sustainable fishery and aquaculture products."

[9] As presented by the campaign video: https://www.youtube.com/watch?v=o6Ouoj36vJc
[10] Projects summarized on https://www.youtube.com/watch?v=h-BQ0S0VV4I

Part III. Challenges and research to overcome them

Participants were given the choice to participate in one of three groups to discuss and further elaborate the key challenges, non-technical barriers, research needs and actions for the three workshop themes. These discussions were moderated by the presenters of the themes and were then reported back to the whole group.

While the three themes represent very different elements of aquatic food value chains and communication of aquaculture practices, there are some commonalities. The sections below are the main outputs of the workshop and also try to bring together some common issues.

Key challenges and non-technical barriers

The table at the end of this sub-section summarises the key challenges and non-technical barriers for each of the workshop themes. These are categorised within the key value chain elements.

Underused fish biomass

From a purely production point of view, one of the main challenges is the handling of 'low value' materials. They have historically been treated as 'waste' and they are often fragile (in terms of their structure) and hence easily spoiled.

The key challenge for processing is having sufficient material of sufficient quality at the right time. This is a function of the disconnect between catch and processing, but also of seasonality in species availability and hence the 'minimum' volume required to make processing lines economically viable.

Clear market feasibility needs to be demonstrated for new products (food and non-food) going into new or existing markets. Some good examples (e.g. in Iceland and Norway) exist as potential models for new products, but there is enormous potential, and a need, to expand marketing for other products coming from other species and in other countries.

Two regulatory issues were also presented as challenges within this sector, meriting further explanation.

The first is the Common Fishery Policy landing obligation. Paragraph 11 states "For the species subject to the landing obligation as specified in paragraph 1, the use of catches of species below the minimum conservation reference size shall be restricted to purposes other than direct human consumption, including fish meal, fish oil, pet food, food additives, pharmaceuticals and cosmetics".

The EU decided that there is a need to have an economic disincentive to targeting juvenile undersize fish species, even if it is noted that this constraint does not exist in other (non-EU) countries. Non-EU participants consider that it adds a significant reduction to the potential biomass that can be used for (direct) food.

EC Regulation 1774/2002[11] of the European Parliament and of the Council of 3 October 2002 lays down health rules concerning animal by-products not intended for human consumption.

Of particular interest in seafood processing are the Category 2 materials – especially digestive tract content – but also including waste from slaughterhouses (including aquaculture), products containing drug or contaminant residues or products imported from third countries that fail to comply with the Community veterinary requirements. Several promising food/feed products are present in fish that come under this category, although these cannot be used for human

[11] http://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=URISERV:f81001&from=EN

consumption. Products made from viscera fall under this category. Food safety is however the top priority which ultimately is the justification for having these regulations.

Micro-algae and macro-algal value chains

The basic question for producing (micro) algal biomass, is what to grow, and where and how to grow it. For microalgae, intensive cultivation is carried out either in open pond raceways requiring innovative solutions to deliver high all-year-round productivity at low cost, or in more controllable but at the same time more expensive contained photobioreactors. Micro algae also have complex genomes and a somewhat confused taxonomy. Genome sequence information is generally lacking and there is also the question of possible horizontal gene transfer. For macroalgae 'farming' costs are also a major consideration in relation to food value, as is preventing the introduction of disease and non-indigenous pests and pathogens[12]. Several production technologies for both macro-and micro-algae have been piloted, and some are in commercial production, but the management of the production process and the 'consistency' of the harvested algal pastes or dried product remain issues, especially noting that algae are not produced in sterile conditions, hence bacterial or other species 'contamination' needs to be managed.

Spatial planning is lacking in some EU countries for algae production and in many cases there is no clear regulatory framework to govern the process.

Downstream processing 'know how' is new – and related the handling of large volumes of algal material (pastes and powders), feedstock variability, the development of new technologies that use acceptable solvents from a regulatory perspective, product/process analysis and control and the shelf life of final products.

From a marketing perspective, the Novel Foods Regulation (EU) 2015/2283 may also need to be taken into account. This applies to any food that has been not consumed to a significant degree in the EU before May 15, 1997 and includes food consisting of, isolated from or produced from algae, unless these are traditional foods from third countries with a demonstrated safe history of use of at least 25 years. The responsibility of verifying whether a food falls within the scope of the Novel Foods Regulation lies with the food business operators and requires authorisation from the European Commission and is based on safety assessment from the European Food Safety Authority. In the US, there is no legal distinction between "novel" and other foods, however a "Generally Recognized as Safe" (GRAS) Notification for an algal food obtained in the US does not obviate the requirement to meet the Regulation in the EU.

Value chain integration is therefore not optimal and is probably a key issue that inhibits investment at present.

[12] http://www.sams.ac.uk/news-room/global-seaweed-policy-brief-launch/experts-issue-warning-to-booming-seaweed-industry

Aquaculture awareness

Key challenges for aquaculture can be broadly split into two areas. The first is the challenges and constraints faced by producers so that they can increase production volume in the EU market. The second regards consumer awareness and knowledge - of aquaculture production, the access to communication tools for educators (the example used in the presentation) or other 'trusted sources' of information to bridge this communication gap and the promotion actions that are being done in different European countries. It is the second area that is the focus of this report.

One of the key challenges is that consumers do not always know if seafood is sourced from aquaculture or capture. While retailers and the actors at other points of sale have made significant progress in clear labelling of farmed and geographical origin, there are other points of sale/consumption where the farming status of a seafood product is less clear. This might happen in some 'traditional' fish markets, restaurants, or catering facilities. This lack of clear communication is often coupled with consumer perceptions based on outdated information or (more importantly, maybe) on traditional or cultural myths. Many young children grow up playing with farming and fishing toys, and often see this is a 'romantic' or 'adventurous' activity – which is often a long way away from the realities of an intense industrial sector.

The plethora of aquaculture quality marks and 'sustainability' labels may also be a two-edged sword. On one hand, they provide recognition and assurance and on the other they may often create confusion as to which may be relied upon.

Summary table of key challenges and non-technical barriers

	Underused Fish Biomass	Microalgae Value chains	Aquaculture Awareness
Production	Proper handling of 'low value' materials.	What to grow? Complex genomes and confused taxonomy.	Addressing aquaculture within core curriculum subjects.
		Spatial planning and clear regulatory framework lacking.	Educators lack knowledge of aquaculture production and need tools to present it.
Process	Fragmentation/lack of connection between catch and processing.	Processing 'know how' is new.	Clear provision to consumers of farmed status and geographical origin.
	Consistent supply (volume and seasonality).	Value chain integration.	Complementarity between European, national and regional promotional actions
	Current wastage of biomass in all links of the value chain.		
Market	Market access, new markets (food and non-food), economic applicability.	New food applications and products needed.	Assurance or confusion created by labels and quality marks.
	Category 2 materials (inc. digestive tract)	Aquaculture feed market is established, but algal supply	Promote the nutritional value of algae.

	cannot be used for human consumption.	(volume, consistent nutritional quality and price) is not.	
	CFP Landing obligation does not allow fish below the conservation reference size to be used for human consumption.	Novel Foods regulation EU 2015/2283 with potential generic authorisations	
		Investor confidence in production and consumer acceptance.	
Consumers	Lack of knowledge and/or low perception of fish by-products in our food	Tradition and culture-related behaviour towards direct consumption of algae	Consumers do not always know if seafood is sourced from aquaculture or capture
	Lack of knowledge about regulations regarding antibiotics and contaminants	Lack of knowledge about regulations regarding environment and natural resources use.	Perceptions based on outdated information or traditional or cultural myths
	Proof of sustainability is lacking: (carbon and water footprints, nature conservation, social implications).	Proof of sustainability is lacking: (carbon and water footprints, nature conservation, social implications).	Promote awareness of the high efficiency of aquaculture when compared with terrestrial farming.

Research & innovation priorities and actions

The table at the end of this sub-section summarises the research needs and short/medium term actions for each of the workshop themes categorised within production, process and market.

Underused fish biomass

We have several important knowledge gaps that can be addressed by research and innovation and that need to be filled to increase utilisation and reduce waste in Fish Rest Raw Materials (RRM).

We need to fully identify what options are available and assess their applicability. This includes the scalability of extraction from laboratory examples and knowledge of regional or seasonal properties of potential products.

In the processing area, we need to identify the most important actors that can affect quality throughout the value chain and identify risk management and safety challenges. This would include rapid (in-line) methods for measuring or characterisation of product properties, as well as technologies to improve palatability. This would be facilitated by knowledge transfer from other food production systems.

We need to understand better the business opportunities and demonstrate the quality properties of food made from RRM. We might also address common terminology needed for RRM/by-products/co-products.

The key actions required to achieve these research needs are to foster dialogue between marine scientists and food technologists, develop a feasibility study with infrastructure needs and roadmap for the best use of RRM and to invest in competences, infrastructure and interdisciplinary research.

Micro- and macro-algae value chains

Upstream research needs to focus on upscaling production systems that provide sustainable economic, year-round production. This includes increasing (photo autotrophic) growth rate by a better knowledge of the resources used, guarding against (non-indigenous) pests and pathogens, developing low-cost, continuous harvesting and for microalgal systems, managing process water.

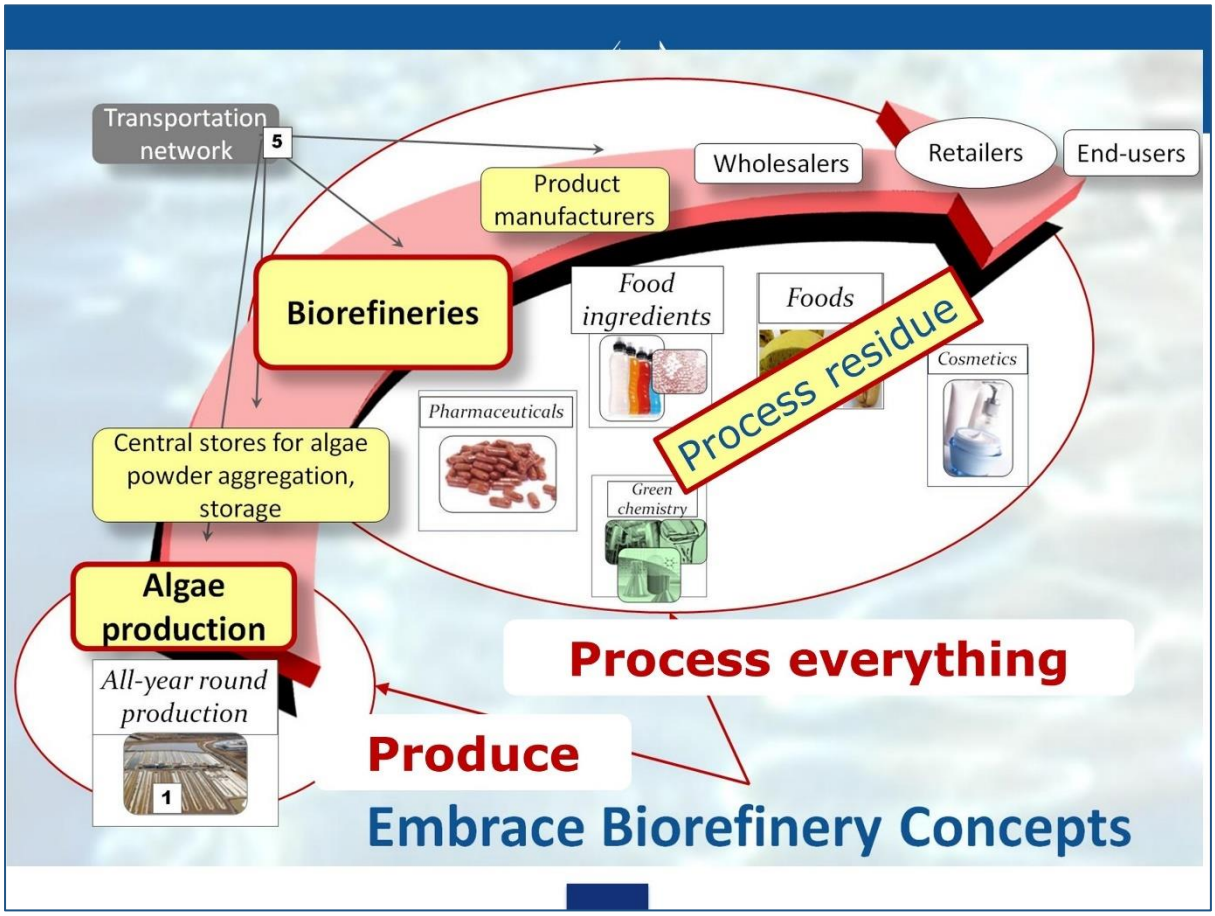
Production systems must also solve potential contamination issues (bioaccumulation in algae or from bacteria in the non-sterile cultures) and engage with the issues of spatial planning.

A key requirement to meet these needs is cooperation between operators in northern and southern Europe, where system technologies are different.

Regarding algal strains, we must also increase our knowledge of algal metabolism and regulation to design, especially with techniques such as CRISPR/Cas9 technology for genome editing. The conventional application of this new technology has become routine because of its ease of use across many species. The potential of CRISPR/Cas system, unlike the traditional methods used in GMO and Synthetic Biology experimentation, is the real possibility of targeting metabolic pathways with the resultant transformant bearing no legacy of the tools used to create it, thereby overcoming public fears of being exposed to genes (and their products) that are not naturally found in their choice of meat, plant, vegetable, fruit or algae.

Downstream needs include developing large-scale high volume processing with decreased inputs and the use of (non-fossil) safe processing solvents.

One of the principal needs for the (micro) algae sector is to embrace biorefinery concepts and understand better, the full range of markets and opportunities possible, in order to offset the costs of algae production for food.



A clear driver for the upscaling of biorefineries is the return on investment on biomolecules for medical or health markets. This leaves the 'residues' for potential food products, but these residues can actually account for <90% of the biomass!

Consumer acceptability of algal food products for direct consumption is increasing in many European countries and many initiatives are teaching people how to select, harvest and prepare macro algae (seaweeds) for the table. We should therefore capitalise on the trend for natural products and healthy sustainable eating, while meeting EU (health and safety) regulations.

Incorporation of micro-algae into foods will also develop in time, but the indirect route of incorporation into aquaculture feed can fill that time gap. Inclusion of a low % of algae with a suitable fatty acid profile that matches the needs of the fish and provides the long chain PUFAs that we need can only happen once algal oils are available on the market at a competitive price to fish oil.

While aquaculture feed manufacturers - frequently in joint projects with academic research - are documenting the 'performance' of algae oil to (partially) replace fish oil, a boost is needed to upscale production in Europe.

Aquaculture awareness

Consumer awareness and perception of aquaculture is variable across Europe and between different demographic groups. It is therefore important to recognise this and to have more knowledge on the common issues, but also those that differ between group or countries, so that the approaches and communication tools can be adapted to the 'audience'.

This includes identifying clearly our interlocutors, developing a range of communication tools and bringing together case studies and examples of successful communication actions. These are developed further in the next section.

Summary of Research needs and short/medium term actions for each of the three areas

	Underused Fish Biomass	Microalgae Value chains	Aquaculture Awareness
Production	Identify options and assess applicability.	Upscale and year-round production systems.	Produce simple communication tools (position papers, videos, testimonials…)
	Scalability of extraction.	Low-cost, continuous harvesting.	Showcase aquaculture production systems, including 'local' or 'artisanal' production.
	Regional or seasonal properties of potential products.	Increase growth rate and knowledge of algal metabolism.	
Process	Identify actors that can affect quality throughout the value chain and identify risk management and safety challenges.	Develop large-scale high volume processing with decreased inputs.	Identify key end-user communicators that are 'trusted sources' for the public
	Measure or characterise product properties.	Use non-fossil solvents and manage process water.	Explore systems that increase predictability of production
	Technologies to improve palatability.	Solve contamination issues.	
	Explore systems that increase predictability of production		
Market	Better understand business opportunities		Further refine EU labels for aquaculture production and products.
	Demonstrate quality properties of food made from RRM		
	Common terminology for RRM/by-products/co-products.		

The 'consumer' element of the above table is missing as it represents a core requirement across all three of the workshop themes. Most, if not all actions are therefore cross cutting and can be equally applied to each. They can be categorised into three main task groups.

Communication needs

1. Who should we be talking to?
    - Health and nutritionist authorities – to reinforce the benefits of food products from aquatic value chains.
    - Local authorities – that provide licences to operate. We need to transform NIMBY into local communities wanting to have the activity in their area.
    - Politicians and policy makers – to move aquatic food even higher up the agenda.
    - NGOs – that can partner with us towards sustainability, noting that aquaculture is crucial for ocean conservation.
    - Public aquariums and science centres – that help to educate young and old.
    - Journalists – that are also looking for good-news stories.

2. What communication tools should we use?
    - Champions or ambassadors - that we can develop food initiatives with and who are recognised in society.
    - Audio-visual material that shows the faces of farmers, their jobs and responsibilities and their pride in showing their facilities and their products.
    - Media kits that provide fact-based information on key consumer issues.
    - Storybooks, toys, games and apps that stimulate our imagination and provide new ways to discover and learn.
    - Product information such are quality labels and (QR codes) that demonstrate origin, production and traceability of our food.

3. How do we bring together existing communications and develop new ones?
    - Use and expand the model of a levy on production to pay for market campaigns.
    - Provide repositories for European and national initiatives to collect and share communication tools and products; liaise with ocean literacy and ocean conservation EU projects.
    - Work with charities (e.g. Aquaculture Without Frontiers) to promote the activity as a tool for poverty alleviation or mitigation of malnutrition.
    - Linking aquaculture to farming, but emphasising the diversity of aquaculture (fish, shellfish, algae…) and its importance in history, culture and tradition.

It is also important to understand how perceptions are changing over time. For example, some of the consumer perception studies for aquaculture products and practices published ten or more years ago showed various issues that were 'top of mind'. We need to regularly re-visit these studies so that we can see national or regional evolution in changing perceptions towards aquaculture.

Part IV. Recommendations

The recommendations listed below are for the Commission, national and regional bodies and sectorial representatives to consider as pathways to develop the potential of underused fish biomass, new algae value chains for food and consumer acceptability of aquaculture products.

Direct financial support actions

- Develop a roadmap (including a feasibility study) on best (food) use of underused fish biomass, including infrastructure needs.
- Use research funds to develop regional pilot plants for proof of concept for fish and for algae food products at semi-industrial scale.
- Identify and use the most appropriate investment tools including public-private partnerships to develop *and take ownership* of large demonstration or smaller regional bio-refineries for underutilised fish biomass and for microalgae as 'lighthouse' projects to encourage further investment.

Communication actions

- Foster and facilitate dialogue between marine (fisheries) scientists, food technologists, health officials and representatives of end-users.
- Promote the involvement of the industry and scientists in societal debate to raise awareness and promote trust.
- Ensure industry and societal involvement in research strategies to provide solutions. This may be achieved by better use of existing networks (e.g. FARNET Fisheries Local Action Groups).

Governance actions

- While maintaining food safety requirements, monitor the impact on availability of marine biomass for human consumption under the Category 2 and CFP landing obligation regulations.
- Ensure long-term stable regulatory framework that provides a stable operating environment and predictability to facilitate investment in technology and know-how.
- Ensure that Member States promote aquaculture communication actions that have a clear place in structural funds (EMFF Article 68) and may also include the production, processing and marketing activities along the supply chain.

We have significant opportunities in all three of the workshop themes.

Upscaling our research and innovation systems by investing in large demonstration or smaller regional biorefineries for fish and for algae food products is the key for aquatic food chains to contribute better to the Food and Nutrition Security priorities of Nutrition for sustainable and healthy diets; Climate smart and environmentally sustainable food systems; Circularity and resource efficiency of food systems and Innovation and empowerment of communities.

Upscaling our communication activities in aquaculture and novel marine food value chains will also move us closer to obtaining a 'critical mass' of fact-based information that can be used in societal dialogue and impact acceptability.

Finally, we need to **cement the role of aquaculture and new marine food value chains in society as being required and desired**.