Sustainability of Fish Feed in Aquaculture:

Reflections and Recommendations

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How to feed farmed fish has been proved a major challenge for the global sustainable development of aquaculture.

Since the 1980s, global fish farming has developed considerably and farmed fish occupy an ever-more important place in the human diet. The growth of aquaculture has ensured a reliable supply of fish for our increasing needs.

Reducing the environmental footprint of aquaculture has become a high priority as part of the drive for greater sustainability in modern society. In the European Union, particularly in France and Northern European countries, the laws in place have been instrumental in significantly reducing the environmental impacts of fish farms observed in the last ten years. Equally of note is the heightened environmental awareness among aquaculture professionals, who are now concerned about the image their business enjoys with consumers and the general public.

To date, a major concern has been the challenge of feeding farmed fish with products that are nutritious but, at the same time, economically and environmentally sustainable. The use of compounded pelleted feeds formulated with a great variety of ingredients was a major step in the development of the worldwide aquaculture industry in the last century. Scientific work has allowed the identification of major nutritional requirements for the most important farmed aquatic animals, high value species such as salmonids being the most well known and investigated species. Among raw materials, fish meal and fish oil originating from wild pelagic fish (forage fish) have been incorporated in aquafeeds as the main ingredients, and a reference for quality and nutritional standards, creating a dependence on wild fish stocks widely questioned in recent years. Indeed, global aquaculture growth has led to an increasing demand for these raw materials. The limited availability and high prices of these raw materials are also related to the following factors: the fluctuating state of fishery resources in the fishing zones, overexploitation or exploitation of fish stocks, phenomena

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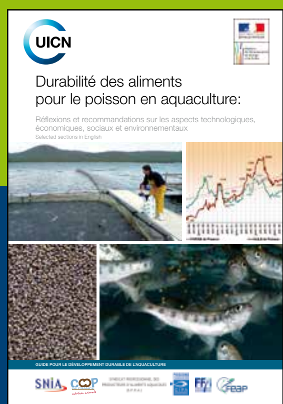

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like El Niño, the introduction of fishing quotas and increasing pressure to use fish oils and fishmeal in other markets such as health, food supplements and cosmetics. Consequently, the scientific research has been focusing on the substitution of these ingredients with other sources of raw materials with significant progress. Further improvements are expected.

Fish feed is a vital element in the sustainability ambitions of the fish farm industry. Industry professionals need to assess the sustainability of the raw materials that make up fish farm feed. But, the sustainability of aquafeeds and their ingredients has to be assessed on the firm bases of the Ecosystem Approach and on Precautionary and Good Governance principles. Produced in collaboration with many industry players, these reflections and recommendations shed light on the different sources of feed ingredients provided to fish during their life cycle. It should prove to be a very useful tool for anyone — researchers, professionals, and governments alike — who aims to reduce the impact of the aquaculture industry on marine and freshwater resources.

While acknowledging the complexity of assessing the sustainability of raw materials, this work substantiates these conclusions and encourages the industry to continue its search for solutions in partnership with other stakeholders, hoping that the challenging and complex issue of feeds and feeding contributes to the sustainable development of the sector, in harmony with the local actors, while maintaining ecosystem functions and services.

The above-mentioned efforts, much like those carried out collectively for this work, will allow the fish farming industry to assert itself more confidently as a sustainable food source that can meet the needs of a growing human population. The publication will also serve to meet the development objectives related to aquaculture at EU level, which France has also incorporated as part of its Multiannual National Strategic Aquaculture Development Plan for 2014-2020.

In the framework of its current programme, centered on the concept of «Nature Based Solutions», IUCN has begun to focus on aquaculture issues in recent years. Its work has been developed in partnership with the aquaculture sector, in particular through a collaboration agreement with the Federation of European Producers (FEAP) since 2004. Similarly, the development of this guide was considered in close collaboration with the aquaculture and food manufacturing sector in France, represented by the Interprofessional Committee for Aquaculture Products (CIPA), the Technical Institute of Poultry and Small Farm Animals (ITAVI), the Union of Professional Aquaculture Feed Producers (SPPA) and the National Union of the Animal Nutrition Industry (SNIA). This work has been done in the framework of the activities of the Ecosystem-based Aquaculture Group (EbAG) of IUCN Commission on Ecosystem Management, with the support of IUCN French Committee. This work has been also supported by the Prince Albert II of Monaco Foundation.

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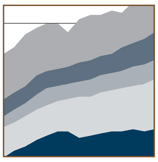
The English translation has been made by Raphaëlle Flint, James Oliver (IUCN), and Alistair Lane (European Aquaculture Society).

Sustainability of raw animal material of aquatic origin



Raw animal material of aquatic origin is mainly fish oil and fishmeal from industrial fisheries and co-products of fishing and aquaculture.

General context and Issues

Fishmeal and fish oils from forage fisheries are still the benchmark in terms of nutritional quality for farmed species. If these fisheries are responsibly managed and traceability is ensured, their use in aquaculture feed can be maintained. But given the continued global growth of aquaculture, it would be necessary to use these valuable raw materials in the most economical way possible, reserving their use for particular stages of farming such as spawning, larval and juvenile stages or as finishing feed.

As for fishmeal and fish oil, some environmental NGOs and scientists have expressed concerns over the use of krill meal - considered to be essential to all trophic marine food webs.

It should also be noted that some fishmeal and fish oils are made from wild fish containing high levels of heavy metals, dioxins and PCBs, which are considered unsuitable for processing. It is technically possible to decontaminate fish oil, but this of course increases its price.

The situation is quite different for the co-products resulting from fishing and aquaculture, which are increasingly used for the production of fishmeal, fish oil, protein hydrolysates and other extracts. The Marine Ingredients Organisation (IFFO) estimates that co-products represent 10-15% of total fish meal and fish oil raw material. There is a clear potential for further increase in their quality and use. Moreover, these co-products could benefit from positive consumer perception linked to avoiding valuable waste. The application of the new Common Fisheries Policy is an opportunity to further develop complementarities and synergies between fisheries and aquaculture and between aquaculture products.

In order to compare the sustainability of fish meal and fish oil from forage fisheries with those form fisheries and aquaculture by-products, there are several criteria to consider. For example, small pelagic fisheries provide a good catch/energy yield (kg fish per litre of diesel) compared to other fisheries. The products of these fisheries are transported on intercontinental maritime networks where the carbon footprint is lower compared to road transport. Nonetheless, from a perspective of local development and the environment, keeping transport distances to a minimum and the sourcing locally are important sustainability indicators. In addition, the evaluation of environmental impacts such as greenhouse emissions, does not necessarily take into account the indirect costs on the environment. For example, shipping over long distances uses container ships with an increasing capacity, requiring deeper and more advanced port infrastructures that have direct impact on the local coastal waters and adjacent sea beds.

Regarding the use of co-products from fishing and aquaculture, the energy cost of transforming wet weight to a dry product probably remains less effective for fish meal than for the production of other, high value raw materials (such as hydrolysates). This criterion would therefore favour the production of hydrolysates over fishmeal for this type of raw material. So if the use of fisheries and aquaculture co-products seems an attractive option, it may prove to be limited for fish meal production, but in contrast appears promising for hydrolysate-type products.

Special case of marine worms

The production of marine worms, targeting the recreational fishing market as live bait, is a potentially interesting source of ingredients for fish feed. It is of strong environmental interest due to the possibility of its integration into existing organic waste disposal systems. Worms can also be produced with the recovery of faeces/solid substrates from marine aquaculture or fish farms. Their «naturalness» (as feed items for fish) is also a major asset.

This said, the nutritional potential and the industrial feasibility of marine worm farms to produce raw materials for fish feed still needs to be properly evaluated.

PRINCIPLE

Sustainable use of fishmeal and fish oil based on responsible, restricted and controlled exploitation of resources, and recognising that these raw materials are necessary to ensure quality aquaculture production.

RECOMMENDATIONS

Depending on the origin of these raw materials, their sustainability assessment varies and therefore requires specific recommendations for each product type:

For fishmeal and fish oil from small pelagic industrial fisheries (forage fisheries):

1) Sourcing only from countries with management quotas for fish stocks to ensure that the raw materials used are sustainable.

For example, Peru, South Africa and Namibia have implemented a responsible forage fishery.

2) Focusing as much as possible on raw materials that come from certified fisheries and are processed in certified facilities.

If MSC type certifications are available for industrial fisheries, they should take priority. As for the industrial process, traceability and quality assurance of the finished products are essential. The quality assurances and certifications offered by the Marine Ingredients Organization (IFFO RS) are therefore a prerequisite.

3) Encourage the development of economically viable decontamination technologies for certain raw materials and their official validation to reduce the current limitations and prohibition of their use.

For fishmeal and fish oils, and other products derived from fishery by-products:

4) Explore, characterise and identify potential sources of raw materials for aquaculture.

The European industry, in particular, is ready to participate in discussion on the use and development of the incompressible discards, after implementation of the reform of the CFP. However, noting that their source is not yet localised precisely, they are not yet available and their use must be within the following recommendation.

5) Ensure that by-products come from responsibly managed fisheries that conform to the European CFP.

Better use (and added value) of fishery by-products should not induce further pressure on stocks.

The emergence of a new industry, or helping develop a new start-up sector, should be encouraged, which implies the following recommendations:

6) Improve the collection and processing of raw materials.

Processing facilities for by-products should be further developed, and be close to landing sites. Processing units should be consolidated whenever possible, so that the by-products are, and remain, fresh and of optimal quality. Any additional costs and energy expenditure should be balanced to provide the best solutions that comply with regulations and optimise energy use.

7) Improve process technology to optimise the use of by-products and maximise quality, while reducing the size of the processing units.

This will lower the critical threshold of profitability and encourage further development of medium-sized units in areas with low tonnage (artisanal). Similarly, the production of hydrolysates could be more suitable.

8) In general, prioritise the use of these by-products in the sectors where they are of the highest value.

This would imply preferential use of these by-products in aquaculture (for food security), rather than in the pet food industry, for which this type of raw material is not a vital necessity.

For fishmeal and fish oils derived from aquaculture by-products:

Current regulations prohibit the use of by-products from an aquaculture species providing feed proteins for the same species. However, this allows the use for example, of by-products of farmed prawns as feed for farmed salmon.

9) Explore and identify potential new sources of recoverable aquaculture by-products for fish feed.

Just as by-products from fisheries, the by-products from aquaculture face the same problem of sources being geographically widespread.

10) Promote the synergies of integrated aquaculture products and other integrated production systems.

11) Add value to all aquaculture by-products, while respecting good practices in aquaculture farms from which these by-products originate.

This means setting up a traceability system and implies a focus on quality.

12) Characterise and use these raw materials in fish feed. That is to say, continue to improve the products made from fish meal and fish oil, to ensure a balanced feed formulation that satisfies nutritional requirements and overcomes potential gaps.

For example, if the lipids obtained from certain aquaculture by-products are imbalanced in terms of unsaturated fatty acids, they may be compensated by adding the appropriate essential fatty acids from another raw material such as algae.

For marine worms:

13) Explore further this potential source of raw material.

There is a need to better describe this source, including nutritional value tests (nutritional performance tests, digestibility) and feasibility studies, and to foster farms (good practice in integrated farming) to allow production of the required quantity.

For krill:

14) Promote the use of certified krill (such as MSC) and limit its use to very specific (larval or brood stock conditioning) feeds.

For the whole category:

15) Focus on short production lines and the circular approach of supply chains when the local situation permits.

If local conditions are favourable for putting in place a quality control program for fisheries and aquaculture by-products for producing local fish feed within a region. This solution would be considered more sustainable by the authors of the Guide. Moreover, in view of climate change and given the current economic environment, energy and ecological resilience found in such local systems seem to be higher than those that are procuring raw materials on a global scale.

Sustainability of vegetable materials of terrestrial origin

Raw vegetable matter of terrestrial origin consists of agricultural products and by-products, for human food, animal feed and non-food products like biofuels.

General context and Issues

On a technical and economic level, many vegetable materials are sustainable alternatives to the marine proteins and lipids needed to feed farmed fish and this is now the 'norm' in fish feed manufacture.

Of the plant materials rich in proteins, there are protein-rich seeds and meals. Soybean meal is a basic raw material, due to its high protein and essential amino acid content. It is commonly used for species such as tilapia. In Europe, however, the use of soybean meal as fish feed is faced with the «non-GMO» problem. Indeed, certified non-GM soybean meal is more expensive due to its reduced availability and some logistical constraints. In order to incorporate more soybean meal in aquaculture feed formulas, the «non-GMO» constraints currently in place must be confronted or lifted.

Other raw materials such as rapeseed and sunflower meal, protein-rich crops or fodder/forage crops, could be better used, provided that the non- or anti-nutritional factors are eliminated. However, for these raw materials to be used by feed manufacturers, they must be available at a competitive price and with a regular supply of sufficient quality. Research and development, accompanied by an incentive-based policy from aquaculture producers, are essential for the development of protein crops.

Many by-products (from biofuel, beer production, rubber production, starch, substitution of hydrocarbons ...) have potentially high nutritional value, competitive prices and are easily available. This is the case, for example, for DDGS (dried distillers grain with soluble) proteins and wheat gluten. In fact, for «bio-fuels / bio-ethanol» etc., the essential element is plant carbohydrate. This leaves nitrogen in the plants which retains all its value for fish feed.

Another example of a potentially useful by-product is guar. This product is highly dependent on the production of gum and is used in the process of extracting shale gas: a process that itself could be subject to change as it is controversial in some countries.

Vegetable oils can also replace fish oils, provided that essential fatty acids (EFA) and fish oil supplements are added to the formulated feeds for some fish species, or at certain stages. Among these, vegetable oils, rapeseed, soybean, palm and sunflower oil are the most interesting and most readily available.

The oil obtained from camelina crops (Camelina sp.) is less easily available on the market, but has a clear nutritional benefit due to its richness in Omega 3. A genetically modified camelina containing more Omega 3 has been developed and its oil tested in salmon feed trials. If marketed, it has great potential for global aquaculture feeds but it also has its issues. The question of the acceptability of GMOs in France and in the European market is, in fact, crucial to maintaining the competitiveness of EU aquaculture and European feed producers. Other continents will without a doubt allow GMO oil and protein crops like camelina and canola to produce more EFAs.

There are still a lot of raw vegetable materials under-utilised in fish feeds at present. It is possible to stimulate and promote the exploration of new sources, including co-products from the pharmaceutical and cosmetic industries, agro-food, agro fuels.

Social sustainability

On a social level, there are two key questions relating to the sustainability of raw vegetable matter:

— What is the impact of cultivating the raw material on the local socio-ecosystems?

In the case of soy and palm oil, the impacts on local forest ecosystems and on small producers have been denounced in several countries by public opinion in countries where farmed fish and shrimp are consumed. However, for some countries or concerned parties involved in production, it is recognised that these crops also represent an opportunity for socio-economic development. Labels of responsible production of Soy and Palm oil can contribute to improving acceptability to western consumers of farmed fish or shrimp. However, due to the lack of real demand from end-users, producers involved in these initiatives are still few, although their numbers have increased significantly in recent years. In addition, nearly half of the certified palm oil on the market cannot find a buyer. Work is still on going in the European, and especially French animal feed industry to expand the use of this type of approach. In August 2015, the FEFAC (European Feed Manufacturers' Federation) published guidelines for soybean suppliers, to encourage the development of the "responsible" supply and purchase of soybeans in Europe.

In general, agricultural commodities have good consumer acceptability. This is particularly the case of pulses such as alfalfa, peas and fava beans.

— Are GMOs the plants from which these raw materials originate, or is there a risk of this?

When the plants from which raw materials originate are GMOs, there is a potential rejection in certain regions such as France. But the situation is actually more nuanced. In France, it is more the consuming end of the aquaculture industry that rejects GM plant raw materials included in aquaculture feed.

It is worth noting the different consumer reactions to raw materials compared to fish: people can reject a GM fish, but accept the use of GM plant materials that have fed this fish because it does not render the fish GM.

Outside France, points of view are even more diverse. For some commodities, it is very difficult to purchase a «non-GMO guarantee». This has led some NGOs like WWF to give preference to soybean crops being sustainable (no deforestation), even if the crop is derived from GM seed.

The animal feed industry (SNIA and Coop de France Nutrition Animale) emphasizes this point in the context of the DURALIM approach: the notion of sustainable sourcing of the raw materials. Cultivation from a GMO or non-GMO seed must meet the same requirements to qualify as sustainable. One should therefore dissociate the GMO debate from that of sustainability.

— Other elements of sustainability for consideration

The use of various agricultural by-products for aquaculture is well perceived. These are materials that do not compete with human food and which contribute to the fight against waste. This positive perception can be qualified for an informed public if the production of the original plant matter does not involve a process or a destination challenged by a section of society. This is the case for example in the production of bioethanol or biofuel of the first generation.

In terms of food health and safety, plant raw materials have a positive acceptance.

Finally, a major question remains in terms of acceptability:

— Is it acceptable to feed carnivorous fish with proteins and fats of plant origin? Can we make a salmon vegetarian for example?

The answers to this very complex issue vary among individuals. For the scientific community, feeding a farmed fish means meeting its nutritional needs and choosing the best scientifically-proven ingredients whatever their origin. A fish must eat a certain amount of proteins, among which are some essential amino acids that it finds in plants. But several surveys among European consumers showed that the perception of food and feed "natureness" may vary from one country to another. Some consumers may therefore consider that feeding salmon with proteins of a terrestrial origin is in fact "against nature" whereas others will not accep a carnivorous fish such as salmon become vegetarian, fed with vegetable proteins and oil.

Environmental sustainability

In terms of biodiversity, part of the sustainability assessment of the plant raw materials refers to the two main questions raised earlier: does the cultivation of the original plant respect the biodiversity of the place of origin? and, is this a GM product?

For example, if producing countries can supply soy or palm oil with environmental or ethical certification as explained in this document, it can then be considered that sustainability at an environmental level is achieved. For WWF, soy certification scheme or RTRS (Round Table on Responsible Soy) is a priority and leads to the acceptability of GM soy, with certain reservations. Moreover, energy and water use for soybean cultivation is rather good considering its yields and the low amounts of fertilizer required.

Maritime transport cost is not a significant contributor to the carbon footprint. However, as with other major commodity imports, there are also reservations relating to the complete environmental assessment. The environmental cost of port infrastructures capable of supporting large shipments of soy should also be taken into account, as they are not without impact on coastal ecosystems.

In general, oil seeds are considered able to bring a real environmental benefit at their cultivation site, especially if agro-ecological practices are implemented. Diversification of crop rotations by integrating protein crops valorises their use, enriches the soil with nutrients and reduces the need for additional fertilisation, thus reducing nitrates and phosphates from agricultural sources that can contaminate water bodies. Regarding the evaluation criteria of greenhouse gas emissions, high-yielding crops like soy have less impact per ton produced. This, therefore, penalises production of lower returns, like protein crops of peas or fava bean.

When the digestibility of plant ingredients is very high, as is the case of wheat gluten, pollution at the site of aquaculture production is decreased in terms of solid waste, suspended solids. However, could an excessive substitution of plant proteins lead to a reverse negative effect on the environment? This needs to be further explored.

PRINCIPLE

The use of plant raw materials from sustainable sources.

RECOMMENDATIONS

1) Expand our knowledge base to substitute more of the protein and fat from current fish feed in aquaculture by proteins and lipids from plants.

2) Continue to explore potential plant materials not yet used in aquaculture, by putting in place sufficient resources for research and development.

3) Develop more efficient methodology/technology to extract proteins and oils from various seeds to make these materials more digestible and eliminate non-nutritional factors.

On the two issues raised with regard to the production of plants in their country of origin, two major recommendations emerge:

4) Source vegetable matter from production made in accordance with principles respectful to socio-ecosystems: sustainable soy and palm oil, incorporation of locally produced plant raw material using principles of agro-ecology...

5) Further biotechnology development that may be of interest in the aquaculture feed.

We must consider that new GMOs under consideration like GM camelina may be perceived differently from GMOs developed for resistance to a pesticide.

6) Develop global protein crop production: peas, fava beans and lupin.

Sustainability of land-based animal by-products

In terms of regulations, the by-products of animal origin are derived from both aquatic and land animals. Fishmeal and fish oils are therefore by-products and have been considered in an earlier guide of this book, given their importance in aquaculture feeds.

The focus is on land–based animal by-products originating from livestock farming and in particular: ruminants, pigs, poultry, and also insects. Animal fat and Processed Animal Proteins (PAPs) are made from various slaughter by-products from healthy animals: meat, fats, blood, feathers and other authorised parts of the carcass.

General context and issues

PAPs are a topical subject, although they had been used since the early days of aquaculture feed. Since the mad cow disease crisis in 1990 in Europe, animal meals were generally removed from animal feed formulations. However, in 2013, non-ruminant PAPs were re-authorised in livestock feeds under very specific regulations.

It has to be noted that blood products derived from pigs, poultry and blood PAPs were re-authorised in the European Union in 2005 and in France in 2006, however, uses of all animal fats was never prohibited.

Despite the re-authorisation for non-ruminant PAPs in the EU, feed manufacturers remain reluctant to incorporate them due to negative perceptions higher in the value chain and incorporation varies widely between European countries. The fish feed profession via their inter-professional body CIPA is officially committed to not incorporating PAPs in feeds for French fish farms producing fish under the «Quality Charter - Aquaculture in our Régions®» as long as a social consensus on the issue is not reached. However, French aquaculture producers targeting export markets can use these raw materials. This is also the case of other European players. Outside Europe, PAPs are commonly used in fish feeds. This means that farmed fish and shrimp produced outside Europe and imported to French and European markets may well have been fed with feed containing PAPs.

With the authorisation to use PAPs, their sustainability assessment arises again.

Economically

For the aquaculture feed manufacturer, the use of PAPs is an opportunity both because of its availability from close geographical areas, and their good quality/price ratio. Their non-use in France is therefore an economic disadvantage for the aquaculture profession.

For raw materials derived from insect farms, the lack of information on economic performance affects their potential use in aquafeeds. Many studies to date have not provided clarification of the potential of this new class of raw material. It is likely that, as in other sectors, it is through the use of by-products processed as high-value products for human consumption that will lead to the achievement of economic sustainability for the aquaculture industry. Integrating insect farming into other agricultural products is also an interesting path to explore.

Social acceptability

France has been marked by the mad cow disease crisis. Cultural criteria can also influence the positions and opinions of other stakeholders or communities. The use of by-products of porcine origin is clearly banned in some countries for religious reasons.

For other criteria linked to health risks, the current regulations strictly ban the use of ruminant PAPs products in aquaculture feed. This should contribute to improving the perception of aquaculture feed among consumers.

The position of the French aquaculture industry is to meet social expectations and maintain PAPs exclusion in feeds for fish destined for supermarket shelves. Some fish farmers are different and are likely to use PAPs, because of their perceived benefits. Tests are being conducted among fish farmers to quantify the perceived benefits of PAPs in terms of sustainability. The issue of PAPs in France is clearly a social acceptability problem, which is still unresolved.

In terms of «naturalness», it seems easier to persuade consumers of the need, for example, to produce salmon fed on plant proteins, than to make it «jump» out of its normal conditions and pass from aquatic proteins to terrestrial proteins, a practice considered «against nature».

Environmental Assessment

The assessment of the environmental sustainability of PAPs is the subject of a debate based on the following criteria.

PAPs provide digestible protein and good nutritional quality. These two values enhance the absorption of ingested proteins and therefore reduce the effluent impacts from aquaculture production sites.

For other evaluation criteria of environmental sustainability, a consensus seems difficult to reach.

For some, these raw materials are recoverable in fish feed via a circular economy approach.

The environmental impacts associated with pig or poultry farming should be shared between human consumption and the use of by-products from their production in other industries, including aquafeeds. Work is ongoing in this respect at a European level to define a methodology of referencing, and allocating the impacts between products and agricultural by-products. FEFAC is also working on an international database of environmental impacts of raw materials for animal feed. This will more accurately assess the impacts of various raw materials of animal origin that are used in aquaculture, including land-based animal PAPs vs. fishmeal.

Another thought is emerging and recurring throughout this document on the evaluation of fish feed by-products. The use of PAPs must be part of a) a sustainable production approach, b) the whole production chain, and c) respectful of European legislation.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PRINCIPLE

A well-managed and well controlled use of PAPs to add value to the by-products of land animal production.

RECOMMENDATIONS

1) Communicate with full transparency the origin and the advantages of using PAPs in aquaculture feed in Europe and clarify the strict framework that regulates their usage and traceability from origin.

2) Enforce the same regulatory and traceability requirements on the use of PAPs in third country imports of aquaculture products for European consumers.

Importing PAPs from third countries into Europe does not seem a necessity for European feed manufacturers given their availability in Europe. The most likely scenario is that of farmed fish or shrimp imported into Europe from third countries, where PAPs use does not have the same regulatory constraints as those required here.

3) Explore and support the use of PAPs from a regional/area-based approach, following circular economy principles.

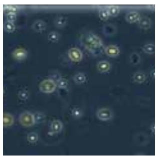
4) Develop communication strategies that support 'local' PAPs production as an example of the circular economy principle.

For insect feed

5) Continue to develop a supply chain of insect-based feed raw materials.

6) Promote farms having an integrated farming and/or good practice approach to ensure supply in sufficient quantity and at a competitive price compared with other protein sources.

Sustainability of raw materials produced from algae



Macro and microalgae derive from cultivation or harvesting. In aquaculture feeds, they can be used after processing, or as a by-product from other sectors.

Background and issues

The latest information on macro- and micro-algae clearly shows significant potential for these new raw materials, whose nutritional qualities are particularly promising.

Economically, the absence of an industrial European sector supplying raw materials from macro and microalgae dedicated to feed production, does not yet allow for a judgement of their sustainability. At present, the prices of these algal raw materials remain high and incompatible with the economic constraints of aquaculture, unless these materials are incorporated in very small amounts, as ingredients to complete requirements in essential fatty acids, trace elements or active components for health.

However, many other uses are being continually developed for algae including food and human health, cosmetics and biofuels. For example, current methods for extracting alginate or alginic acid from macro algae for cosmetics make their by-products unsuitable for animal feed. Dialogue is therefore needed between feed manufacturers and algal processors to look into changes in seaweed processing methods that could lead to using their important nutritional products in aquaculture feeds.

The integration of micro and macro algae production into other industries in a more comprehensive way, as recommended in the circular economy, is a very interesting way to optimize their exploitation and potentially make them available for aquaculture feed.

In addition, experts concur that the margins for progress are such that it would be possible to have large amounts of these raw materials in future. The use of algal extracts as major raw materials in aquaculture feed could then become economically feasible.

The technical and nutritional potential of algae is reinforced by advantages on a social level. Given that many algal species are marine and generally enjoy a good «image», their acceptability as aquaculture feed is rather good. Macro algae are perceived as being a natural ingredient, as they are cultivated / harvested in the same environment where farmed fish live.

These positive perceptions are also linked to the progressive introduction of algae in human food that have an excellent image in the eyes of consumers in urban environments. A recent study, however, highlights some reservations that consumers express as they want reassurance about the quality of the algae/seaweed, referring to the quality of the environment in which it was grown or been harvested. This is because seaweed can also be associated with images of pollution and toxicity in the minds of coastal populations.

It was also noted that some current macro algae culture projects off the French coast were the subject to strong local opposition, for environmental reasons or conflicting uses of space. If the social acceptability of seaweed looks excellent as a food/feed product, territorial acceptability of seaweed cultivation projects could face the same problem as a fish farm project or any other new offshore activity.

Regarding environmental impact, we should differentiate between macro algae and micro algae production.

Macro algae

It is essential that all macroalgae production systems are sustainable. Guides to good practices for cultivation and harvesting are currently being issued and disseminated. Consideration and recommendations are also to be made for algal cultures.

In terms of biodiversity, there are two restrictions:

— The first concerns the introduction of non-native species of macro algae for cultivation in an open environment. This practice is not authorised in France.

— Secondly, harvesting must be conducted according to good management practices while respecting the natural biodiversity of sites. This concern is especially relevant for the harvesting of Ulva in Brittany.

At the ecosystem level, the services provided by natural seaweed beds, fields or open sea farms require further study.

Macro algae can assimilate nutrients from natural or anthropogenic sources. They contribute to balancing the environment, playing a purifying role, and help to reduce eutrophication of coastal areas. However, efforts to improve the ecological status of inland and coastal waters bodies should be pursued in accordance with the objectives and action plans of the Water Framework Directive.

The current – often critical – state of eutrophication of many coasts indicates that it will take decades of intensive efforts and drastic reductions of nitrates and phosphates of anthropic origin to improve coastal environments, downstream of watersheds. The state of nitrogen balance indicates that the harvesting of ‘stranded’ seaweed does not help address the current surplus of nitrogen runoff from upstream watersheds. In the medium and long term, it will be more sustainable to consider the cultivation of Ulva crops in a closed, integrated system, using effluents containing nitrates and phosphates of another origin, such as a fish farm.

In terms of carbon footprint, the role of carbon sequestration by natural seaweed beds or algal farms is also worth studying more precisely. Some researchs indicate that it is important. Other goods and products provided by macroalgae should be explored more thoroughly, such as oxygen production, nutrient recycling, purifying environments/biotopes, nursery areas for fish and invertebrates…

All of these ecosystem service concepts require robust scientific data to support the beneficial role of algal cultures in climate and marine biodiversity issues and consequently bring them into IUCN's «Nature based solutions».

Micro algae

The two major modes of micro-algal production lead to a contrasting assessment of their environmental impact. For photo-bioreactors, the energy cost is significant but water consumption is reduced. Other progressive options are possible (connection to solar energy, integration to other industries, etc.), to improve the energy balance.

In open system ponds, the environmental impacts are more related to the surface area occupied as it represents an additional pressure on land use, whereas the energy cost is much reduced. The cost of water use, its transportation and treatment should also be considered.

For micro algae productions that are integrated into other systems, their environmental cost should be evaluated downwards, taking into account other products derived from these systems. There may be positive impacts linked to services provided by micro algae cultures, including depollution, CO_2 capture, utilization of factory smoke, discharges of water treatment or depuration plants, or from fish ponds.

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PRINCIPLE

Sustainable algae production, allowing the production of high quality raw materials in sufficient quantity for the production of high quality aquaculture feeds.

RECOMMENDATIONS

1) Actively support the development of macro and micro algae production sectors, and promote and frame all initiatives aimed at their sustainable development.

Given the potential and the positives identified in the sustainability assessment, this effectively means promoting research and development, facilitating industry scale pilots, integrated production projects and re-assessing regulatory constraints for their use in aquaculture feed.

2) For each sub-sector, support the development and compliance of good production practices as a framework for their development.

Certifications of algae production should be considered for third country production where EU regulations do not apply.

3) Prioritise research in two major directions: nutrition of aquaculture species using algal feed ingredients and sustainability of culture techniques, including analyses of ecosystem services provided by micro and macro algae.

4) Continue to identify algal-derived molecules or macro molecules that can be incorporated into aqua feed and which may improve economic performance of the production sector.

5) Develop integrated approaches to improve environmental performance and profitability.

On macro algae

6) Prioritise research on algae processing methods to extract the target ingredients and improve their digestibility.

7) Develop a concerted approach with other industries using macro algae, to better integrate the needs of aquaculture feed in algal processing.

On microalgae

8) Optimise production costs by improving energy performance and water use in industrial fermentation production systems.

An integrated 'glocal' vision and approach towards sustainability of raw materials in aquaculture

In conclusion, it seemed important to bring out some general thoughts, as well as broader and cross-cutting recommendations.

General trends

There are the opposing profiles between the "past" reference materials (fishmeal, soybean and PAPs) and those of the «future», represented by micro algae. The first three show good technical and economic sustainability, lower societal and environmental rates, whereas the last, micro algae displays the opposite, and in particular very good perception and acceptability. Fishmeal is controversial by society standards - and soybeans and PAPs are even more so.

In general, the long-used raw materials such as fishmeal and fish oil have been increasingly called into question, given their decreasing availability, resulting cost, and impacts on marine food webs. It is not yet possible to conclude that fishmeal and fish oils derived from by-products of fisheries and aquaculture are an interesting alternative.

Substitutions using vegetable materials are already a solid alternative to fishmeal and fish oils. In addition, their replacement with terrestrial animal meal would be a relevant solution, perhaps, and an intermediary measure.

At present time, it is unreasonable to rely on new products derived from micro algae, macro algae, insects and marine worms on an industrial scale to cover the needs of fish feed. But these products and others already used such as yeast, amino acids, haemoglobin synthesis products... are very useful for rationed supplements, additives, and for specific stages in farmed fish life.

On acceptability:

The notion of acceptability is a complex one that requires research in cultural and social factors. In France, there is clearly a negative perception of the main raw materials for substitution, such as soy and processed animal proteins (PAPs), which is the opposite to what is perceived in the real economy. However, numerous dimensions alter the views depending on the countries using aquaculture products. This must be taken into account and reflect the local geographical, cultural, social, religious, and political situations.

For some products, it is likely that the limited knowledge available to the public gives rise to a neutral or positive perception as seems to be the case for amino acids, synthetic products, or microalgae.

The «naturalness» of aquaculture feed or what it could mean is an important element to consider in its acceptability.

Considering all these factors, we can conclude that future plant materials such as macro and micro algae represent a way forward, particularly with how fish feed is «perceived».

On environmental aspects:

The environmental impacts are perceived differently depending on the profile of stakeholders. For example, regarding «greenhouse gases» and «biodiversity of the production site,» it may seem curious that soy is better placed than wild fishmeal in a comparative evaluation of sustainability. But these results should be nuanced by the fact that soy is considered as certified soy produced according to specifications respectful of local socio-ecosystems. There are several soy origins, it is therefore important to refine the analysis with more precise and objective criteria. Measuring environmental impacts using Life Cycle Analysis (LCA) can be a good method, provided that the approach is complete and takes into account other criteria such as impacts on biodiversity, as well as ethical and societal criteria. It must also ensure that the LCA tool is sufficiently fine-tuned to differentiate the modes of production of the same raw material.

Also noteworthy in assessing the sustainability of aquaculture feeds

An important conclusion is clear: «There are no bad raw materials, just misused raw materials, or poorly prepared ones ...everything lies within the process of preparation of the raw materials and their formulation». The whole issue becomes a question of respect of a regulatory threshold, process of preparation and detoxifying a given raw material, which will enable its incorporation in the diet, while remaining within a range of acceptable prices. The equation is complex because it has a multitude of variables. Specific recommendations are thus required.

In addition, feed formulations are constantly evolving with a diversification of sources and products that allows for both improved digestibility and intake, and cost optimisation through various sources. Consequently, we moved from formulas containing 10 lines 30 years ago, to formulas containing 20 lines today for a product identical in appearance.

It must be added that feeds have different effects depending on the target species but also at the feeding sites. The same formulated feed, given in different environments, will not lead to the same result each time. The responsibility and professionalism of the producer is important with relation to the results of production performance, particularly in the use of the feed. The feed conversion ratio is also as much a reflection of the quality of the feed as the feed management of the producer, which guarantees good farming conditions and healthy fish.

The European aquaculture sector is an industry that has high quality requirements. Economic viability is an important sustainability element and should be systematically taken into account. Farmers must integrate environmental issues, fish health, product quality and profitability. Feed affects all of these issues.

On the other hand, the relatively small size of aquaculture production in Europe poses a real handicap regarding certain issues, including the availability and sustainability of raw material in fish feed. Similarly, the global industry of aquaculture products is also relatively low compared to other terrestrial animal production, which results in the same issue, even though in the major aquaculture countries like Norway and Chile, the situation is reversed.

Finally, we can point out that if the issues raised by this work on the sustainability of aquaculture feed are shared at a global level, it is important to ask whether the right answers should not be primarily built locally, using local resources and needs. The appropriate scale of the territory would need to be explored. Sustainability is then addressed in a global manner, although the proposed response is local - a «glo-cal» approach according to the famous R. Dubos words: «think globally, act locally» in a 1972 report already stressing global environmental issues and proposing the principles of sustainable development. Within this framework, all the elements proposed in this publication towards a new path take on a real significance, but one that also requires political will and involvement at the local or territorial level.

General recommendations

1) Promote a wide range of aquaculture feed raw materials that satisfy nutritional requirements of the species in production.

This diversity will provide an economically accessible feed while maintaining product quality, and being in accordance with regulations. To have good feed, producers must have a broad and flexible access to ingredients.

It is important to avoid being too sceptical of raw materials, especially when they are not derived from the aquatic environment. For the feed production sector, the diversity of raw materials is an asset, and encourages responsiveness, dynamism, and improved resilience.

But it is also important to:

2) Develop local production and integrated approaches to the supply of raw materials for fish feed, whilst ensuring the sustainability of these raw materials on all criteria.

A 'glo-cal' approach to the sustainability of aquaculture feeds is suggested, while keeping in mind global issues.

According to local conditions and possibilities, it could also be recommended to change the model, and move towards a transition of targeting a «strong sustainability» according to C. Abel Coindoz, where all integrated and virtuous production systems should be investigated and developed – and in particular those that encompass circular economy principles and industrial symbiosis– as components of aquaculture feeds.

In some regions territories, the relocation of land-based vegetable material production which has been neglected could be relocated and associated with agro-ecology principles. Cultivation of algae and the use of fish by-products could also be investigated as well as the use of locally produced and high quality PAPs.

3) Support research programmes that demonstrate the potential and sustainable use of various raw materials in fish feed.

In this process, there should not be negative a priori against a particular raw material. An objective view is required that provides evidence based evaluation on sensitive issues or sustainability criteria that can subsequently be communicated to consumers.

4) Adapt the regulations when required, so as to align them with technical progress on new materials.

Some raw materials show strong possibilities and regulations should facilitate their use. There is clearly a need to work between professionals and administration officials to better adapt the rules, even if a national or European context does not always facilitate procedures.

5) Measure the environmental impacts of feed ingredients using Life Cycle Assessment (LCA)

To encourage the use of raw materials with a lower environmental impact, information on the environmental impacts of different raw materials should be included in feed formulation tools. The analyses given by the LCA and other tools should be detailed enough to differentiate a particular raw material according to, for example, the mode of production and its country of origin, and its eventual compliance with a certification scheme. But more parameters need to be added to consider the impacts on biodiversity, in a socio-ecosystem approach. In this context, local and social LCAs can become valuable future tools for a more integrated sustainability assessment.

6) Encourage a sustainability certification of raw materials and ingredients in aquaculture where regulatory safeguards are not sufficient, and ensure that sustainability certifications remain consistent.

This is an important point and applies to all raw materials. When a sustainability certification exists relating to the method of production of raw material, it should be encouraged.

There are several sustainability certification systems applied in the aquaculture industry, including feed. These certifications take into account various aspects of the sustainability of aquaculture feed, and are aimed at different links in the chain. They need to be strengthened and harmonized so that consumers can identify sustainable aquaculture products. Furthermore, the complexity of the sourcing of raw materials in fish feed is such that the proposed certifications encounter limitations because they should address elements beyond the boundaries of aquaculture.

7) Strengthen solidarity throughout the value chain, from upstream to downstream, from manufacturers of raw materials, aquaculture feed manufacturers, aquaculture producers and to consumers.

This point is particularly important, as aquaculture sustainability is a complex matter that justifies the involvement of all, but which is not always the case.

The sustainability of aquaculture feed must be based on the most complete chain of custody possible, from the production of raw materials to the final aquaculture product.

8) Strengthen communication, to make it more relevant and adaptable.

On this topic, ideas are numerous and sometimes divergent on what constitutes «good» communication about how farmed fish are fed. It is not certain that «good communication» is enough to solve all the issues raised in this book regarding the acceptability of certain raw materials. Furthermore, the frequently-voiced expectations for "ideal communication" often occurs through better communication from the aquaculture industry and all professional actors. Communication lines should be shared by producers of raw materials, fish feed, fish, processors, marketers and retailers at the point of sale.