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By-products from Fish Processing: Focus on French Industry

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Abstract:

Beyond the technical and technological advances in the conversion of marine by-products into useful products, the economic, social, political and environmental parameters, are to be taken into account to understand why and how bioconversion technologies of fish by-products are applicable. The fish sector is facing several issues such as wild fish stocks reduction while in the same time the cultivate one rises, augmentation of the importations on a global market, consumers behaviors. All those influent parameters affect and complicate the definition of an upgrading strategy for the by-products as they directly depend to the raw material processed.

Thanks to some projects addressed this thematic in recent years, several quantitative and qualitative data about by-products availabilities are available. It is time now to propose upgrading strategies and to study their technical and economical feasibilities on different territories. In France, nowadays only two treatment plants are still active for fish by-products processing and they are both located in the northern part of the territory. The comparison of their operation mode allows to identify factors of success or sticking points such as volumes treated, number and proximity of fish processors, qualitative parameters or management. It appears that the optimisation of fish by-products upgrading may depends of many of these factors it is so essential to identify and to study them.

1. Introduction

Biotechnology advances for marine by-products conversion into products of interest are numerous. In order to give maximum elements of understanding, it is essential to define the framework of this research to understand why and how bioconversion technologies are applicable. It is essential to look beyond the technical and technological advances on the subject and so to take into account the economic, social, political and environmental parameters, which govern all forms of approaches for fish by-products upgrading.

All concerns given to marine resources are relatively new. It began in the mid 90s with the publication of two major reports of the FAO in 1994 and 1995, both dealing with the need for responsible fisheries and minimize wastage, particularly in relation to by-catches. Those ones are still a concern for scientist regarding to environmental issues. The European commission works on this thematic and the legislation is still not well defined. These last years, it was proposed to land all bycatches on-shore to encourage fishermen to minimize them but this law is still in discussion[1]. To ensure the feasibility of such a regulation, Raul Perez Galvez worked on a prototype of compaction so

[1] Proposed reform of the Common Fisheries Policy, European Commission, 13th July 2011.

that these by-catches take minimal space in the fishermen's vessels (Perez-Galvez, 2010). As detailed studies on by-catch and discards have already been carried out (FAO, 2004), this problematic will not be considered in this paper. Here, we will highlight the various issues concerning the by-products generated by fish processing companies on-land, focusing on the French territory.

Problem targeted

Management and processing of by-products and waste is an environmental, social and political priority for many countries and is more problematic because of rising production volumes. In France, the food industry annually generates more than 48 million tons of byproducts and waste from two main types of transformation: the animal industry and the plant sector. By-products from fish processing are part of those ones and account for at least 215 000 tons (0.4% of the entire deposit) according to latest estimates for the period 2004-2005 (Perez-Galvez, 2009). The volumes concerned may seem low but as it will be described in the following chapters, fish by-products contain many compounds of interest in various sectors, providing them a great value which is certainly under-utilized at present. Although many efforts have been made by the food industry to manage its waste, improvements are needed for an effective and specific treatment.

Indeed, the fish industry is made up of many small businesses scattered in space which creates logistical problems and difficulties in sitting of new waste recovery units. Moreover, a significant amount of waste is generated by supermarkets and hypermarkets. This major sector in France generates large volumes of food by-products resulting from unsold, obsolete or defective products including fish by-products which represent 6% of the deposit (ADEME, 2010). Nowadays, by-products from supermarkets are currently directed to incineration causing significant impacts on the environment and this could certainly be optimized.

Fish Sector difficulties

Fishing industry is facing major environmental, economic and social issues. The volume of landings have been declining for several years due to depletion of fish stocks. Production costs are high and rising price of diesel is part of a trend in the long run even if efforts are made to support the

occupations most affected (OECD, 2012). To address the overexploitation of fisheries resources, management tools have been developed as part of the Common Fisheries Policy for the European Union, but the level of degraded stocks remains higher than the level of regenerated. FAO estimated that in 2005, 23% of global stocks were moderately exploited or underexploited, 52% experience a level close to the maximum sustainable exploitation and 25% are overexploited, depleted or renewal (17% , 7% and 1%) (FAO, 2006). Additional measures, including incentives to improve the selectivity of fishing gear, the obligation to change fishing location, the reduction of by-catch and the gradual reduction of discards in European fisheries are gradually put in place by the European Commission (Communication from the European Parliament Commission, 2007).

The problems encountered by capture activity involve a consideration to the improvements that can be made for processing activities in order to limit impacts on professionals. Management of by-products represents a cost that may be important, it is therefore necessary to study the feasibility of by-products upgrading, in an environmental but also in an economic perspective.

Factors of change

In addition to the depletion of fish stocks and thus landing volumes at auction which gives rise to regular changes in legislation, the seafood sector has evolved in recent years due to several factors that have an impact on raw material processing and so on the volume of by-products:

- The development and changes of distribution and market
- The changing environment regarding to imports and aquaculture

These changes particularly affect those who catches (fishing) and the first market (fishmongers) (FranceAgriMer, 2009).

Distribution and market

The fish and shellfish level of consumption in France is about 36 kg live weight equivalent annually per person, (24 kg of fish and 12 kg of shellfish, crustaceans and molluscs), all types of presentation combined (fresh, frozen, canned or prepared foods) (OFIMER, 2010). The main species consumed are: tuna, salmon, hake, cod, sardines, trout, mussels, oysters, scallops, shrimp and Jacques. They now

occupy 65% of the seafood French market. Many farmed fish are among the 10 most valuable species: salmon (France is the largest consumer of Norwegian salmon), cod, trout and tropical fish. But farmed fish accounts for only 11.6% of fish consumed in France, against 77% in China (FAO 2006).

The consumption of seafood is encouraged by the decrease in meat products consumption declined steadily since the 90s. The various crises in the meat industry, including the largest one: Bovine Spongiform Encephalopathy (BSE), the dietary and nutritional concerns, which are increasing over the years, have encouraged the consumption of seafood (COGEPECHE, 2009).

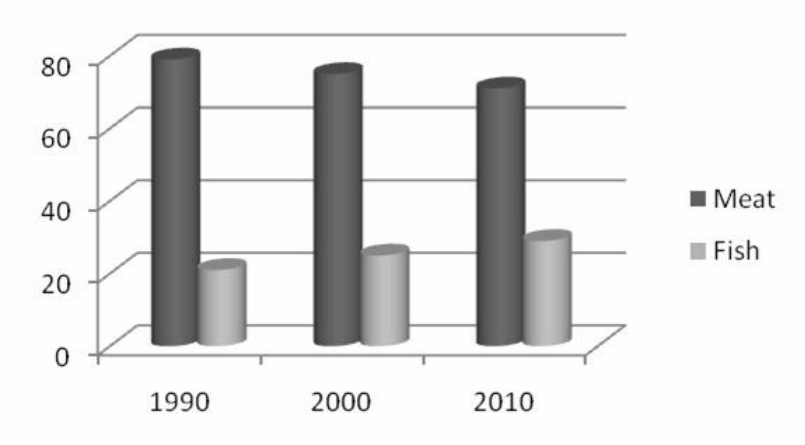

Fig. 1: French households consumption of meat and seafood products in %, FranceAgriMer (2012).

However, it should be noted that today culinary practices are evolving. Indeed, fresh, frozen, canned or chilled deli products are no longer equal in front of consumer's behavior. Customers tend to favor the purchase of frozen foods and to a greater extent, chilled deli products (Cayeux, 2007). There are many reasons: simplicity, speed, convenience. 52% of fresh seafood is sold as fillets, steaks, and cobbles (FranceAgriMer, 2012). Distribution must adapt to these new market demands.

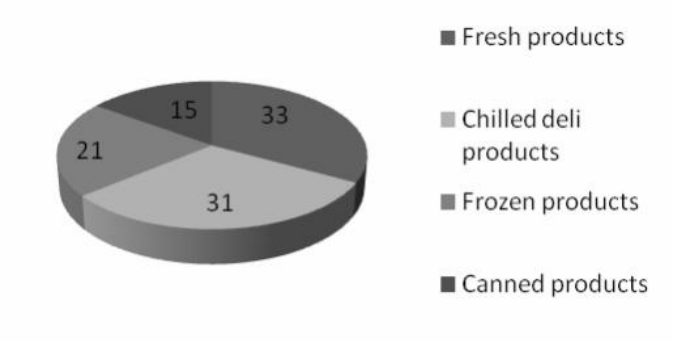

Fig. 2: Households seafood spending in 2011, in %, FranceAgriMer (2012).

These effects are particularly visible in the supermarkets and hypermarkets. The departments are increasingly managed in fresh self service (FLS) in the form of modified atmosphere individual packaging. This induces a decrease in the range of species available for sale (FranceAgriMer, 2009).

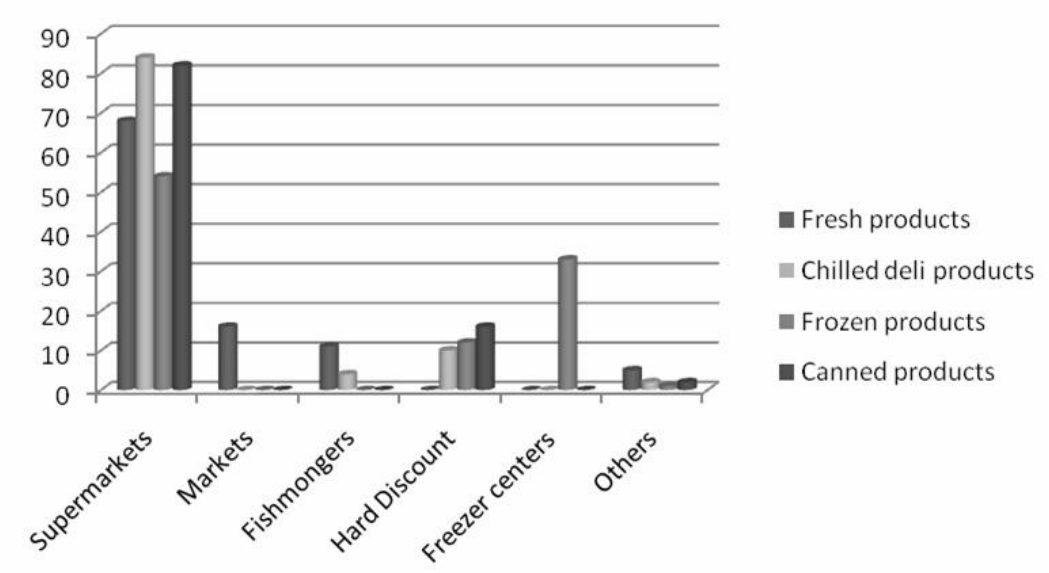

Fig. 3: Purchases of seafood products by French households for home consumption in 2011 (%), FranceAgriMer (2012).

These factors show that the management of by-products is a growing issue because if the fish is bought increasingly transformed, the volumes of by-products will be more and more consequents. In addition, consumer preferences tend to transform the very nature of these byproducts by limiting species processed.

Increase of aquaculture production

Experts have mixed views on the future of fishing, but no significant increase is expected due to the current status of wild fish stocks. The future supply of aquatic products in world market rests on the development of aquaculture (FAO, 2010).

According to FAO, the aquaculture production must double by 2030 (given the increasing population of the planet) to meet the consumption of aquatic products increasing from 12 kg to 17 kg / year per capita between 2006 and 2008. Already, breeding aquatic products represent almost 46% of

the current world fish market against only 9% in 1980. The increase in production is largely due to Asia, China covering more than 70% of global aquaculture production.

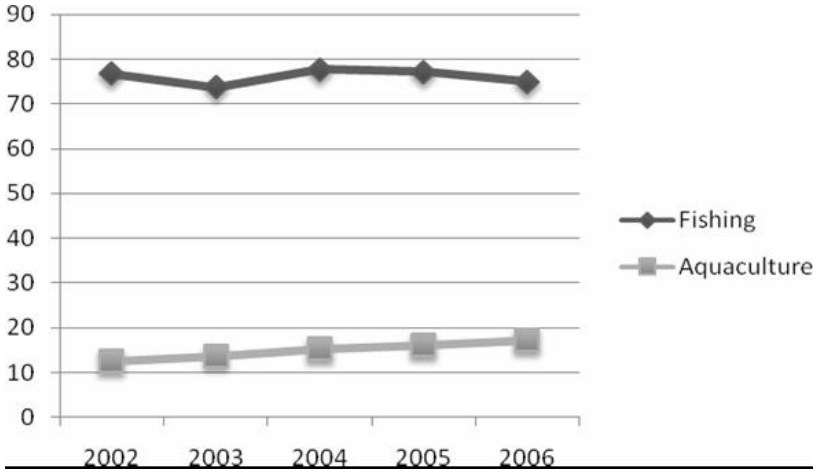

Fig. 4 : Fishing and aquaculture evolution in million tons, FAO, 2007.

The growth of aquaculture largely depends on freshwater fish raised in ponds and shellfish grown in coastal areas. On-land farms concerns species with short food chain (carp, tilapia) whose initially extensive production tends to increase. The other most spectacular developments are shrimp in brackish water in the tropics, Ecuador to Thailand, catfish in cages or ponds (pangasius in Vietnam), salmons (Atlantic salmon and rainbow trout in seawater (Norway, Chile) and marine species in the Mediterranean Sea (bass, sea bream). Although very diverse, aquaculture production is ensured at 90% by about thirty species.

In France, aquaculture consists mainly in trout farming in freshwater with an annual production of 36,611 tons produced by 500 farms, each producing less than 200 tons/year. The sector of marine fish farms in France is mainly constituted of bass and sea bream with 4817 tons produced annually (of which 60 million fingerlings are sold mainly for export). It does not develop due to competition with other countries including Greece and more recently Turkey.

Intensive production is based on the use of blended food, mainly from fish meal and fish oil from industrial fisheries. The growth of aquaculture creates tremendous pressure on the fishing market whose supply is limited and fluctuates as it depends on weather events. Production of fish meal from by-products is therefore an alternative that makes sense. Nowadays, by-products represent only 25%

of raw materials used to make fish meal and fish oil, but this proportion is increasing for several years (IFFO, 2009).

The role of importations in French fish market

In a context of stagnating contribution of fishing and national aquaculture, recourse to imports to supply the French market has continued to grow. French importation of seafood has represented 1.1 million tons in 2011 (Ofimer, 2012). Domestic production covers only 45% of consumption. Imports amounted to 3.6 billion euros in 2005 and 4.8 billion in 2011 and came from Europeans countries (including Norway) and of the rest of the world at equivalent parts.

The importation of fish fillets, which are mostly raw materials for processing industry, accounts for 44% of the deficit value. The remaining deficit is distributed almost equally between whole fresh fish and processed fish. In terms of species, the primary deficit is attributed to the salmon. Also note the very rapid growth of imports of fillets of freshwater fish: Nile perch from Uganda and Tanzania and pangasius from Vietnam.

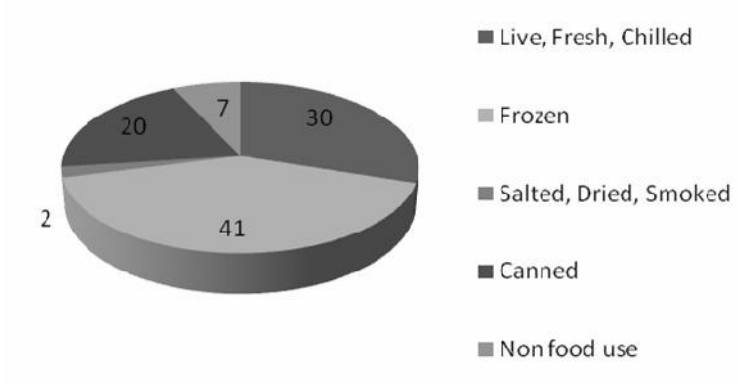

Fig. 5 : Imports by presentation in million tons, FranceAgriMer, 2012.

REPORT ON FISH BY-PRODUCTS FROM FRENCH PROCESSORS

By-products from French processors on-shore

Terminology, definition of waste, by-product and co-product

It seems essential to identify clearly the biomass concerned. The distinction between a waste, a by-product, and a co-product is sometimes thin and definitions are many.

The simplest is to remove the concept of waste, as a waste by definition cannot be upgraded. Since the international Convention of Bâle, in UE a waste is considered as “any substance or object the holder discards, intends to discard or is required to discard” (European Directive (WFD) 2006/12/EC). This definition is negative and does not imply adding any value to products resulting from the processing of raw materials. Although “waste” is still widely used in common language to define by- or “co-product”.

The difference is not always made between a by-product and co-product, although in some countries the law provides two distinct meanings.

The term "co-product" means products derived from fish, produced along with the final product, ultimately intended for human consumption. We can cite for example monkfish cheeks or some livers; they can be consumed with or without subsequent processing. Note that these co-products are then considered as food and therefore are subject to the same regulation.

Fish by-products represent the remainder of the products resulting from the processing of the raw material that will not be valued as human food. For the French the veterinary services department, by application of Regulation (CE) N° 1774/2002, that came into force on 1 May 2003 in the context of strengthening food security, the term co-product has no statutory existence. The set of materials derived from the production of finished products are considered as by-products.

By-products are then separated into three categories, which determine whether it is possible to value them or not, based on their potential risk to human health, animal health and the environment:

1. The first category (C1) is composed of materials that present a significant risk to public health These materials must be collected, transported and identified without delay and are destroyed by incineration or landfilling after processing and marking.
2. The second category (C2) includes by-products presenting a lesser risk to public health (products containing residues of veterinary drugs for example). These products are disposed of by incineration or landfilling after processing or can be recycled for other uses than animal feed (organic fertilizers, biogas, compost ...).

3. The third category (C3) incorporates animal by-products which present no health risk and include parts of slaughtered animals fit for human consumption and former foodstuffs of animal origin. Only Category 3 material can be used in animal feed, after application of appropriate treatment in approved processing facilities.

By-products used for any value are part of category 3. We will therefore speak only of category 3 by-products, except for application in human food where it is more appropriated to use the term "co-product".

Generation of by-products by Fish processing industry

Processors of seafood are working to add value to raw materials by putting them in line with market expectations. Therefore, the seafood can undergo numerous processing steps such as, filleting, heading, gutting, skinning or cutting. Fish by-products are composed of heads, viscera, trimmings, fishbones or cartilage, hides, tails, and eggs, whose average proportions are described in the figure below.

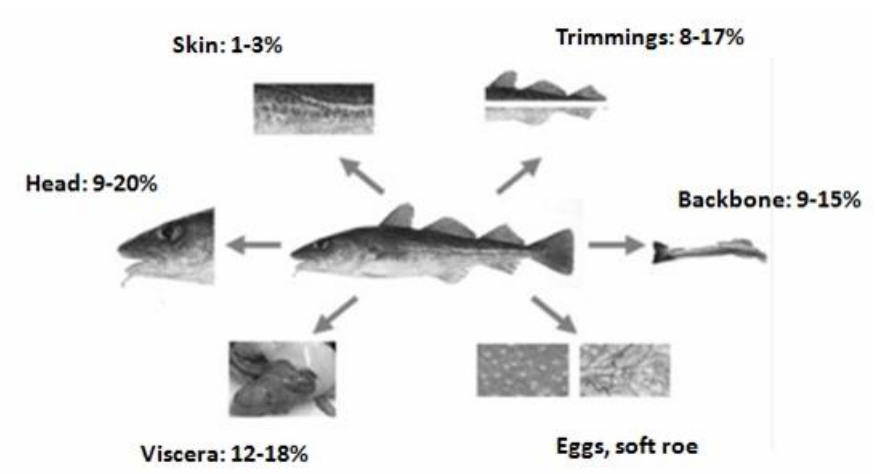

Fig. 6: Average proportion of fish by-products, Dumay (2006)

Three major types of industries generate by-products:

1. Fish trade. While generally all species landed can be transformed by the wholesalers, only white and cartilaginous fishes are usually processed at this scale.

2. Canning industry. The canning industry uses pelagic species as their fatty flesh is ideal for conservation. The species used by canners are mainly sardines, mackerel, herring and tuna.
3. Smoking industry. Although the fish smoking industry is diversifying more and more using many species, it is the salmonids (salmon and trout) that are predominantly used by these processors.

Processing practices depends on several factors such as species, market destination, proximity of processors, historical territorial habits. As an example, in southern French Atlantic coast, species landed are usually sold without any process. Red mullet or sole which are specific species landed in this area are traditionally sold as whole fish.

Methodology employed to estimate French fish by-products

Recent studies on the evaluation of volumes of marine by-products have developed estimation techniques. An indirect method that uses conversion coefficient will be first described and then a direct one dealing with surveys of professionals will be exposed.

Indirect method. In 2004, OFIMER published the results of a study conducted on a period of 6 months that allowed to present the first figures of French national assessment of marine by-products volumes in the territory (Andrieux, 2004). This study also helped to provide an inventory of existing upgrading methods for marine by-products.

The method developed for this study was complicated as many parameters were taken into account. It was based on available statistics from OFIMER as auction sells in fish markets and imports-exports for each species. As in France those data are collected and centralized by OFIMER, it is possible to develop such method.

The estimates were made according to the following procedures:

1. Fourteen representative species were studied as they are usually processed by three kind of industries: the fish trade (fishmongers), the canning industry and the smoking industry. The first point was to identify those species thanks to OFIMER's statistics.

2. The second point of this study was to determine which part of the volumes of fish available on the territory was available to be processed. Thus, the trade balance (whole fish only considered) was studied as shown:

Apparent Consumption = Fish landings + Imports - Exports

3. Previous studies on fish consumption in French households have shown proportion of each species that are generally bought processed. Thus, the processing rate for each specie has been evaluated. However, all the amount of species available is not transformed by industries as there are still whole fish that are sold.
4. Then conversion coefficients were applied to each raw material to estimate the amount of by-products generated by each processing industry. Those average coefficients are well known thanks to the available bibliography.

Taking into account all those parameters, 150.000 tons of by-products have been estimated on the French territory. An evaluation extended to 20 species has identified 215.000 tons of by-products (Perez-Galvez, 2009).

Direct method. In 2008, the «Gestion Durable» project started on the same topic even if the goal was different. Here, the main objective was to demonstrate that a better management of fish by-products could help for a better governance of fishing ports. This project was designed primarily to re-evaluate the volumes of by-products to precise the data previously acquired.

The precise location of the deposits appeared here as a key element because the goal was to understand the structure of the marine by-products industry regarding to several angles: structural, political, economic, geographic and technical.

Given the estimation method proposed by OFIMER in 2004, the «Gestion Durable» project chose to proceed another way using surveys with professionals to clarify the data regarding to some factors that were only estimated in previous works, such as purchase/imports and processing rates.The goal was to clearly identify if the apparent processing of fish raw material corresponds to the estimation previously done thanks to OFIMER's work.

1. A census of all the seafood industries was conducted for four regions of western France representing 47.5% of the landings leading to the identification of 393 industries.
2. Enquiries have been elaborated to obtain quantitative data for all those industries. They have been designed to cover the maximum of points regarding to all the subjects involved in the project. The objective of these enquiries was to quantify and qualify the raw material effectively processed, the type of process done and the by-products resulting from the process.
3. Furthermore qualitative data had been collected on sorting, storage, packaging and preservation. That is part of the innovative aspect of the project.
4. The last point of the survey aimed to collect information on the procedures for collecting by-products to identify costs, proximity to processing sites, frequency of collection, problems encountered.

Results

The first estimations given by OFIMER in 2004 reported 144, 407 tons of by-products on the French territory. «Gestion Durable» project published its enquiries results in 2011 for the four regions of West Atlantic coast (Basse-Normandie, Britanny[2] , Pays de la Loire, Poitou-Charentes). The results are based on 167 companies enquired (67% fish trade, 33% smoking, canning and other industries) representing 42% of the companies (167/393). 45,138 tons of by-products were clearly identified during the project. These deposits were declared by processors without making use of any conversion coefficient.

The quantitative results of these two methods are difficult to compare because the division of regions is not the same, so the statistics do not include the same territories. For example, if we consider the data including the areas addressed in the project "«Gestion Durable»", the volumes identified by OFIMER reach 129,990 tons of by-products because they take into account the Nord and

[2] To facilitate the enquire, Bretagne which is a region where fishing activities take an important place has been divided in three areas corresponding to north, west and south coasts. The results obtained for Bretagne correspond to the addition of those three areas.

the Aquitaine region. It is also difficult to compare two completely different methods because they each have specific, and they have also been carried out 5 years apart.

Anyway, it is still possible to discuss similar results and divergent points:

• As a preliminary result, it has to be noted that the most significant response rate were obtained in the survey areas further north during the enquiry phase of the «Gestion Durable» project. As an example, 86% of industries were enquired in Basse-Normandie against only 12% in Poitou-Charentes. Some factors may explain this like lower landings, species landed, processors or territorial habits. This can be correlated with the volumes identified by both methods. Indeed for the study conducted by OFIMER, the largest volumes of by-products are located in northern France, regions Bretagne, Normandie and Nord accumulating 80% of volumes, that is a logical correlation given the French landings.

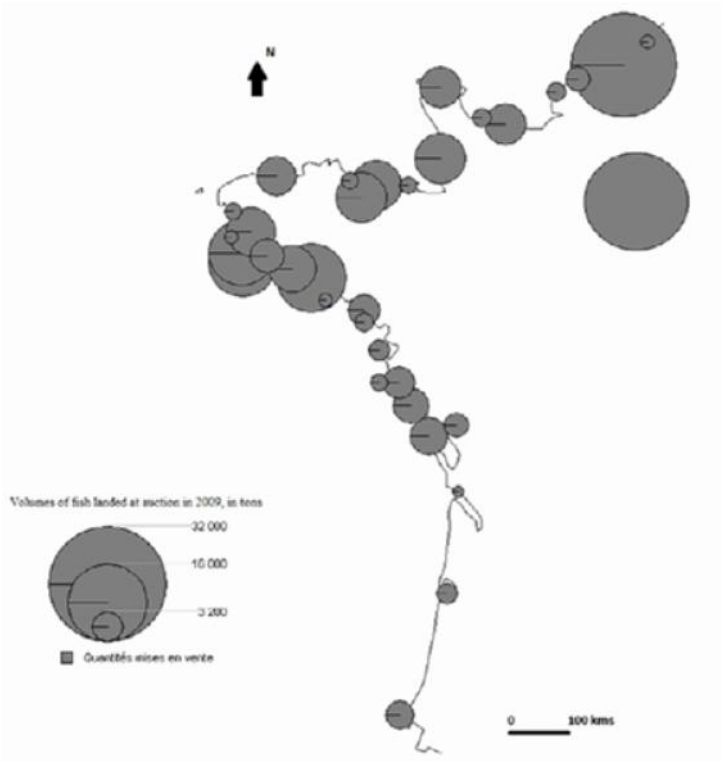

Fig. 7: Sales at auction in 2009, in tons, OFIMER (2010)

The results obtained during the project «Gestion Durable» tends to confirm this trend as 85% of the deposits were identified in Brittany which represented 65% of the companies enquired. Half part of total volumes was concentrated in the western area of Brittany.

• By-products represented in 2004 46% of the landings (OFIMER's study) while they represent only 32% of the landings according to the survey results of the project «Gestion Durable» in 2009.

• For OFIMER, fish trade is the most important generator of by-products with 70% of the total volume. The results of the project «Gestion Durable» are more nuanced but also place the fish trade first with 58% of the by-products generated. Canning industry and smoking industry then represent respectively 27% and 15% of identified deposits.

• The OFIMER's study was able to clearly identify the type of by-products generated. White fish by-products account for 40% of the volumes followed by salmonids with 31%, pelagic fish 15%, cartilaginous 7.5%, and other white fish species 6.5%. For the project «Gestion Durable», the type of by-products can not be identified for 37% of the by-products deposits which were thus classified as "various". For by-products that have been identified 28% came from pelagic species, 15% from white fish, 15% from salmonids, and 2% from cartilaginous. The remaining 3% come from other types of species such as cephalopods.

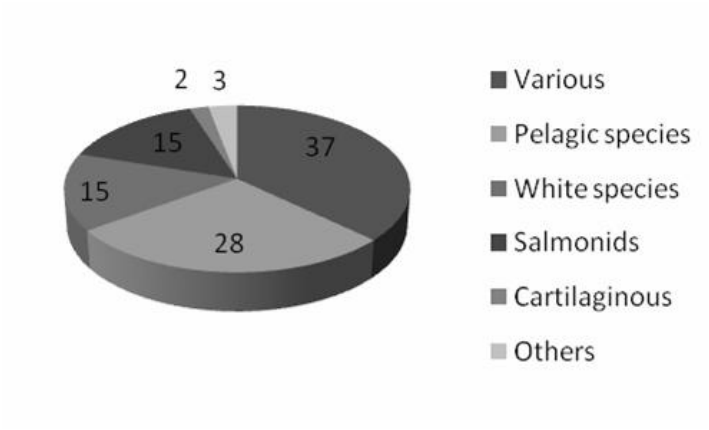

Fig. 8: Original nature of identified by-products (%), «Gestion Durable» project (2011).

Both methods have limitations that it is important to take into account:

• The direct method chosen by the project «Gestion Durable» collects real and accurate information with industry professionals as well as qualitative data and appendices what is not possible when using the conversion coefficients concerning quantitative data exclusively. The direct method seems to be more realistic and complete regarding to those aspects.

• However, it has to be noted that the enquiries are sometimes incomplete and depend on the subjectivity of the professional enquired. Also, completeness is difficult to reach with such method. There is a lack of data which has to be highlighted before presenting the overall results as they must be nuanced. As an example, Pays de la Loire and Poitou-Charentes present weak volumes but as warned previously the response rate were not as good as in the others studied areas. So the results are not enough representatives to make any conclusion. The indirect method can provide a global inventory based on information collected uniformly what allows drawing general conclusions and trends more easily, although some data do not reflect the reality.

Given these elements, it is possible to compare these two methods as each has strengths and weaknesses that can be synthesized in Fig. 9

Quantitative data			
Reality	Accuracy	Completeness	Objectivity
-	-	+	+
+	+	-	-

Fig. 9. Comparison of data collection methods between OFIMER and Gestion Durable

Fish by-products upgrading

Upgrading technologies. There are two main types of upgrading:

• The mass exploitation: the main sectors which derived from this approach are fertilizers, energy and feed

• The small volume exploitation for higher added-value for sectors as nutrition, health food, nutraceutical, cosmetic or pharmacy

They have different characteristics that can be synthesized by the following figure based on a Maslow's needs pyramid. The main differences between those upgrading ways are the capacity of absorption by the market of the derivatives and the profit that can be achieved for those who add the value. At the top of the pyramid we find, as it is expected, the sectors corresponding to the small

volume exploitation. Those activities do not need a lot of volumes but they are more constraining in quality terms. They require a rigorous sorting, low temperatures and rigorous traceability implementation.

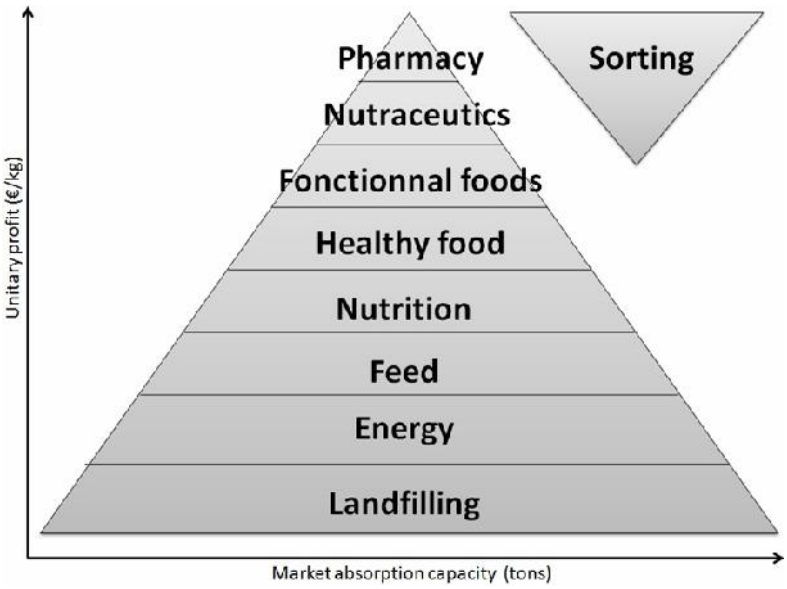

Fig. 10: Scale of marine by-products upgrading modes

The sorting is a key factor of success to upgrade by-products in high value products because the sectors which treat them work on specific molecules contained in specific type of by-products (collagen in skins), sometimes in specific species (Siki liver oil for aeronautics). The storage mode is also very important because the specifications of these activities are strict. Cold storage must be strictly adhered and the collection of by-products must be done quickly. Furthermore, the regulation for the dietetic and nutraceutical industry especially is restrictive and authorizes only a small number of products to receive food complement grades. The origin of by-products must be formally informed to ensure a perfect traceability. For the bottom of the pyramid there are fewer constraints. The sorting is not necessary and specifications are more flexible that is why nowadays the most important part of by-products volumes are treated this way.

Current situation. In the world, by-products are generally upgraded into meals and oils, mainly for farm fish which is growing steadily for several years. World production of fish meal is about 5 million tons in 2008 and production of fish oil was about 1 million tons. 22 million tons of whole fish and by-products were necessary to ensure this production. The main producers of fishmeal and fish oil are

Peru and Chile, with respectively 1.4 and 0.8 million tons produced in 2007. These flours are of first quality because they are derived from whole fish (industrial fisheries). Increasingly marine feed ingredients are coming from fisheries by-products now reached over 25% of global production (IFFO, 2009).

IFFO estimated that in 2009, 63% of global fishmeal production went to aquaculture and that was split almost equally between salmonids, marine fish, crustacean and others. 81% of global fish oil production went to aquaculture and that 68% of that went to salmonids.

Europe produces about 335,000 tons of fishmeal and consumes three times more.In European countries, fish meal comes mainly from by-products because of the legislation on industrial fisheries. In France, the situation is roughly the same, the production of fish meal and fish oil is predominant with 53% of derived products from by-products. Animal feed combine 75% of by-products uses as petfood represent 22%. Recently, hydrolysates have become important due to diversification of upgrading activities especially in Boulogne-sur-Mer (northern France) and represent nowadays 21% (Andrieux, 2004). Only 4% of derivatives are intended to high-value markets.

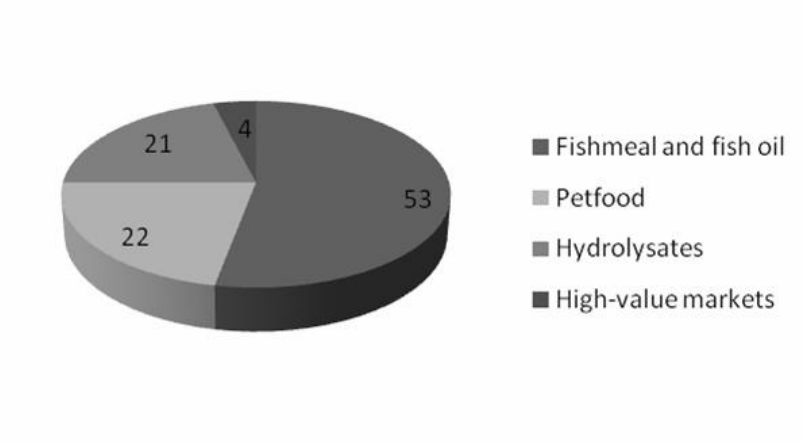

Fig. 11: Derivatives from French fish by-products (%), OFIMER (2004)

COMPARISON OF TWO FRENCH SITUATIONS

Main processors of fish by-products in France

There are two main processors of fish by-products in France which work on two different territories. The first one, Copalis (initially named CTPP for Cooperative Processing of Fishery Products) is the

collector and processor of by-products generated in Boulogne-sur-Mer . The other one, Bioceval, collects and upgrades by-products from the entire Atlantic coast. Modes of operation of these two companies are very different; their study will allow identifying strengths and weaknesses for both and highlighting trends that should be followed[3].

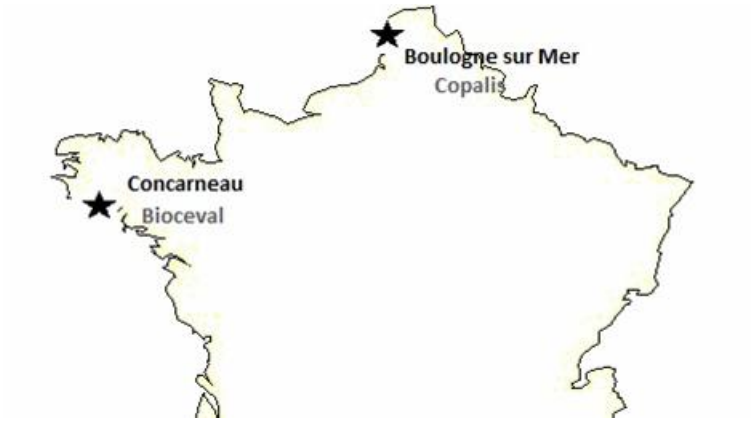

Fig. 12: Localization of the two main French fish by-products processors

Those two processors present similar characteristics even if the economical size of Copalis seems to be more important as shown on the figure below which compares some companies' details.

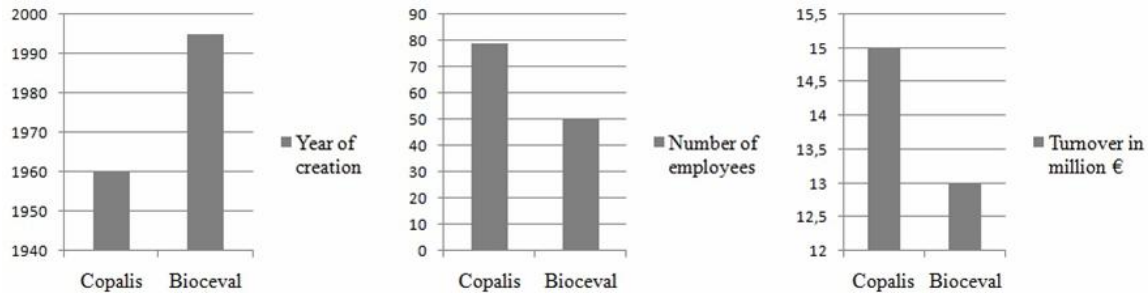

Fig. 13: Economical size comparison

A main processor for by-products: Copalis

Copalis was founded in 1960 by members of the inter-fishery of Boulogne-sur-Mer, northern France. The primary mission of Copalis is to enhance and bring added-value to by-products generated in the

[3] The data used in this chapter are based on the personal data presented orally by Copalis and Bioceval.

fishing industries of Boulogne-sur-Mer. Original producer of fishmeal and fish protein hydrolysates, Copalis has diversified its business in the late 90s with the development of new technologies (fractionation and isolation of peptides) and has established itself in the development of marine bioactives. Copalis became a global supplier of marine ingredients to market the nutraceutical, functional food, animal nutrition and cosmetics. Indeed, 75% of turnover is from exports. Located in the first European center of processing, marketing and distribution of fish, Copalis is able to collect 65,000 tons of fish by-products every year in a reduced scale.

The cooperative operating mode of Copalis ensures that profits are directly fed back into the company for better pay suppliers and so always ensure the highest quality of by-products. Such cooperative status also allows the company to control traceability and origin of raw material. This virtuous circle has contributed to its success. Furthermore, Copalis is independent unlike its French competitor Bioceval which is part of the SARIA group.In addition, Copalis features an integrated process enabling it to produce high added-value ingredients which production usually consists in extracting one or more molecules. Its strength is that it can reintroduce the residues of these extractions which represent a large part of the volumes for the production of fishmeal or hydrolysates.

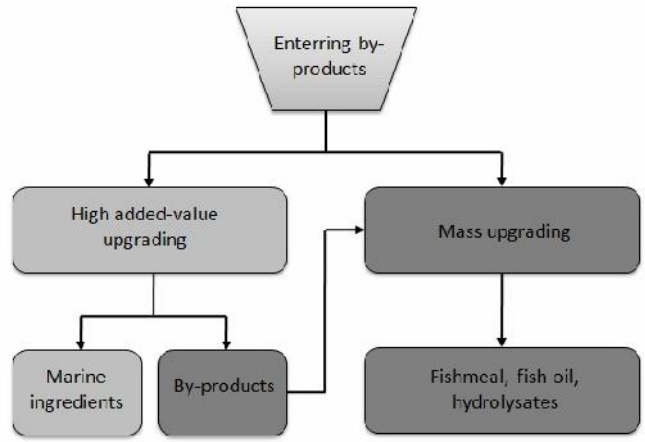

Fig. 14: Copalis' integrated process. With permission of Copalis®

A unique processor on large scale: Bioceval

Bioceval, founded in 1995, is part of SARIA Group which is specialized in the treatment of numerous kind of waste. It is the only unit in the group that works in the treatment of fish by-products to make

fishmeal and fish oil destined for aquaculture. The plant is located in Concarneau in the south of Britanny. This location can be explained by the proximity of the deposits available in Bretagne. Indeed, Concarneau is located between two main places for fishing activities: Lorient and the Cornouaille region. But, Bioceval does not work only with those two places but with the entire Atlantic coast which represents a vast territory and involves many economic, logistical and qualitative considerations.

According to figures provided by the group SARIA, Bioceval would collect 200 tons of marine by-products per day, representing 60,000 tons per year.

Focus on Boulogne-sur-Mer

An ideal location

At the meeting point of fishing areas and consumer markets, the fishing port of Boulogne-sur-Mer occupies a key position in the international market of fisheries and seafood as the first French fishing port with a diversified fleet of nearly 150 boats. Boulogne-sur-Mer is a central Europe's leading seafood with over 140 companies and over 70 different species landed and sold at the fish market every day. 35,500 tons of fresh fish are landed directly at auction (80 companies are approved as buyers at fish auction) but the strength of Boulogne-sur-Mer lies in the quantity of marine products shipped. Each year, 380,000 tons of sea products pass through this center of fisheries.

The strength of Boulogne-sur-Mer is this network of businesses on the same site where all activities of the seafood industry are present and interconnected.

Fishing industry

Fishmongers are crucial players in the seafood industry, by providing a link between production (fishing) and distribution. They prepare products in relation to market demand and expectations, and ensure their quality and traceability. The fishing industry is a fundamental pillar of the socio-economic structure of coastal regions in France. Boulogne-sur-Mer combines 70 companies, 1,500 jobs directly related to fish industry and 400 million euros of sales on an area of less than 9km².

Focus on French west coast

Many processors scattered in space

In 2011, in the four regions studied by the «Gestion Durable» project there are 28 fish auctions, 75% of sales at French auctions and 393 fish processors. Bretagne represents the area where fish sector is the most important, with 15 fish auctions and 50% of the quantities sold at auctions (FranceAgriMer, 2012). The scattering of those industries involves a large scale for collection. Indeed, taking in account the geography of the territory, the area covered by the project «Gestion Durable» is around 90,000km².

The comparison of these elements with Copalis' strategy allows to draw some conclusions. Bioceval has to collect 40 times more suppliers, a maximum distance of collecting 20 times larger and 10 times less final applications sectors as shown on the following figure.

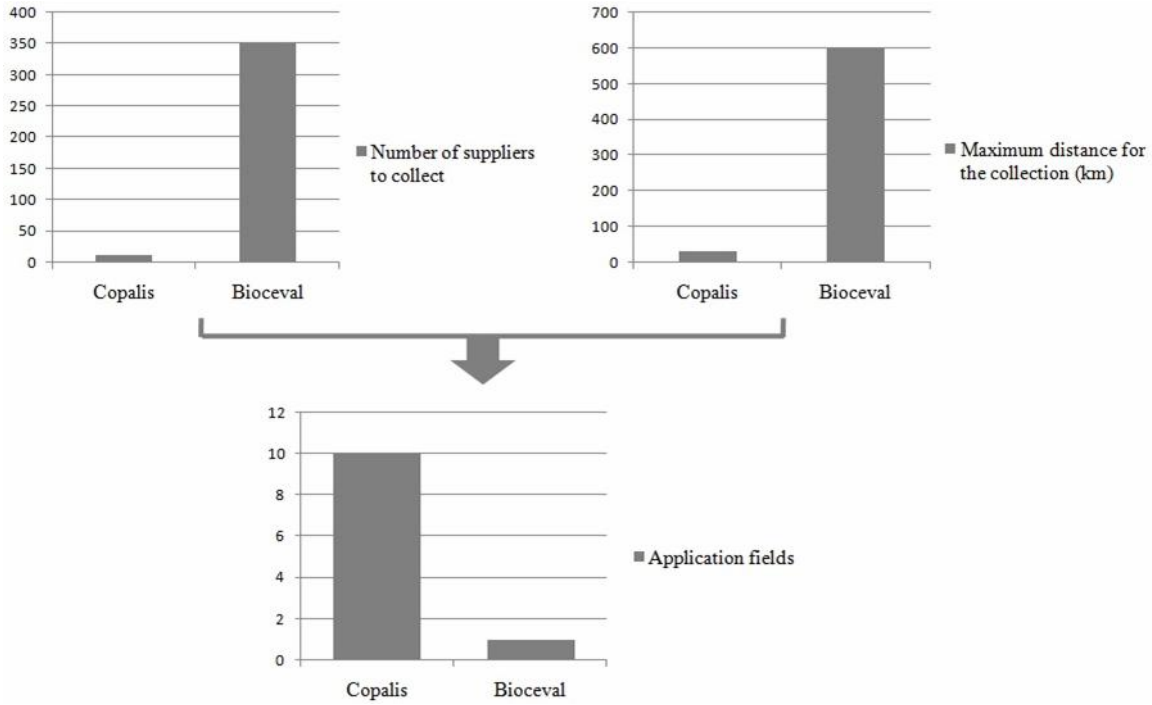

Fig. 15: Comparison between Copalis and Bioceval strategies.With permission of Copalis® and Bioceval®.

Volumes, quality, management

The results of the project «Gestion Durable» showed that this multitude of actors scattered in space engendered complications if a federation around an upgrading project involving more complex specifications was needed. Federation of actors around a quality charter takes time and requires a relationship of trust. Too many professionals involved in making it complicated.

Indeed, the ways of management of by-products are different from one place to another. In some cases, the by-products are centralized at the auction and then it is the authorities who manage the storage and choose the provider for the collection. The fixed price is then the same for all professionals, qualitative constraints as well. In other cases each professional manages its own by-products implying differences due to negotiations between industry and collection providers. These cases are distributed unevenly over the territory. Harmonization of practices is therefore difficult to implement.

Synthesis on key elements of success

The detailed inventory which has been the beginning of this paper highlights some blocking factors but also factors of success. These factors are related to three main issues related to each other: territorial, quantitative and qualitative issues.

Territorial and quantitative parameters

Proximity of deposits and processors engender logistics issues that have an effect on several points such as prices, frequency of the collection, and freshness of by-products. The volumes of the deposits are another factor that has to be considered. Upgrading activities, whether mass or high value level, have important raw material quantities requirements.

Landings are not sufficient to evaluate the fish processing. In the case of Boulogne-sur-Mer the 380,000 tons of products that pass through companies make the difference.

Qualitative parameters

Convince the industry to respect a quality charter is a lengthy process that is facilitated when the deposits are located near the treatment sites. Exchanges between industry actors are then more

effective. Copalis successfully diversified its business by producing products with high added value thanks to the trust relationship that has been established between the different parts. The number of companies to federate, the proximity of the deposits and the location of the company for forty years facilitates the establishment of such upgrading modes.

Moreover, recent studies conducted in the project «Gestion Durable» showed that, in addition to the use of chemicals and energy during the manufacturing process, transport and deterioration of by-products, which is linked to the storage mode and to the frequency of collection, have a negative impact on the environment. A greater freshness of by-products entering the process reduces ammonia emissions and the associated treatment what could allow a reduction up to 25% of some impacts on the environment, such as marine ecotoxicity, eutrophication or acidification. Those results have been carried out through the study of the life cycle assessment of fishmeal, fish oil and hydrolysates (Cesbron, 2011).

Economical parameters

Quartering was a free public service until 2005 when it was confined to dead animals elimination. Producers of byproducts had then to systematically resort to an external service to manage the collection. Before this, it did not represent any cost for professionals. Nowadays, this is private companies who are in charge and then who define the costs

The sorting and cold storage needed for any high-value upgrading represent significant costs for industry, which must be offset by compensation. Logistical costs related to the collection of by-products when producers are scattered in space do not allow any remuneration. In the case of Boulogne-sur-Mer, the proximity of industries allows a remuneration what motivates producers of by-products to meet the specifications defined by the collector. In the case of the area cover by Bioceval most of the time it is the producers of by-products that must pay. The cost is fixed by the collector and depends on several factors such as:

- Volumes of by-products to collect
- Nature of the by-products

• Distance to the treatment site

Indeed, a consequent volume of by-products available in the same site allows the collector to amortize the costs associated with transport and therefore reduce the financial repercussions on industrials. Moreover, the nature of by-products can reduce the costs of the collection. As an example, fatty fish such as salmon are used to make fish oils which are more profitable for the collector. Negotiations to reduce the cost of collection are then easier.Some companies have means to negotiate but in most cases it remains an expense or a free.

GENERAL CONCLUSIONS

1. Today, the seafood sector is facing many problems on the one hand regarding to the upstream activities (fishing, landings), and on the other hand concerning its downstream part (consumer expectations). Processing activities are in the middle of these changes and must continually adapt to the constraints that this entails.
2. French households consume more fish and buy it more and more transformed but at the same time landings volumes are falling. Thus, the use of import and aquaculture has increased. Imported products are mainly already processed.
3. The volumes of by-products on the territory are associated with these parameters which tend to mean that they will decrease in coming years if the situation of the fisheries sector does not improve.
4. Paradoxically, aquaculture that is becoming increasingly important is a heavy consumer of fish meal and fish oil made from by-products and whole fish. Production from whole fish is fluctuating and subject to the same constraint that the fisheries sector especially in producing countries where it is regulated. This suggests that the use of by-products to produce fish meal and fish oil (25% of the raw material used nowadays) will continue to rise.
5. Quantitative estimates of by-products are fluctuating as they depend on many factors that are not fixed from one year to another: the conversion rate, imports and landings. The different methods used to estimate the volumes of by-products available in the territories highlight roughly the same trends.

6. By comparing two collectors of marine by-products operating in different territories, it is possible to highlight the success factors for the development of derivatives products for several applications including those with high added-value.
7. First, upgrading processors must work with a limited number of suppliers with whom a long-term agreement is made possible thanks to many years of presence and negotiations to ensure the highest quality of by-products. Secondly, significant volumes have to be available in the immediate vicinity of the treatment site to keep a high quality and to limit transport costs.
8. This overview of fish by-products upgrading is aimed to determine what could be optimized and to find complementary alternatives in a context of sustainable development. These alternative solutions may be found at a larger scale by including other kind of organic by-products. For territories where the volumes of fish by-products are not sufficient to be treated alone and where at present they have to travel hundreds kilometers to reach their treatment site, it could be considered to upgrade them in a generic process at local or regional level with by-products from many other sectors (vegetables, meat, poultry, cereals).

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