

**SALMON BY-PRODUCT PROTEINS**



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## **SALMON BY-PRODUCT PROTEINS**

by

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## PREPARATION OF THIS DOCUMENT

This report was prepared as part of the Regular Programme activities of the Fish Utilization and Marketing Service of FAO's Fish Products and Industry Division with the aim to generate and disseminate information, knowledge and experience regarding by-products of salmon.

A responsible and sustainable use of fish resources, whether from capture fisheries or from aquaculture, foresees an efficient utilization of the whole fish including the use of the various by-products generated throughout the processing stage and an extraction of proteins where this is possible. As shown in the report, provided the adequate technology is used, this can have positive effects both from a commercial and a nutritional point of view; and from the world's salmon production from aquaculture expected to grow in the future, the relevance and potential of by-products as a source of protein will only increase.

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### **ABSTRACT**

This Circular describes the potential of by-products from salmon as a source of protein. It lists the main geographic sources of raw material and by-products from salmon aquaculture, namely Canada, Chile, Norway and the United Kingdom of Great Britain and Northern Ireland. It provides an overview of available technologies for preserving the nutritional value of proteins and how to obtain value from their functional properties. A detailed description is provided on the various uses and functions of the proteins deriving from salmon by-products with various cost estimates given for a number of products: hamburger patties, pet food, silage, salmon meal and hydrolysates.

The Circular describes the various markets for protein and the particularities related to the use of salmon by-products as raw material for protein production. It concludes that with adequate and cost-effective technology, by-products from salmon can provide important quantities of protein for the world's protein markets.

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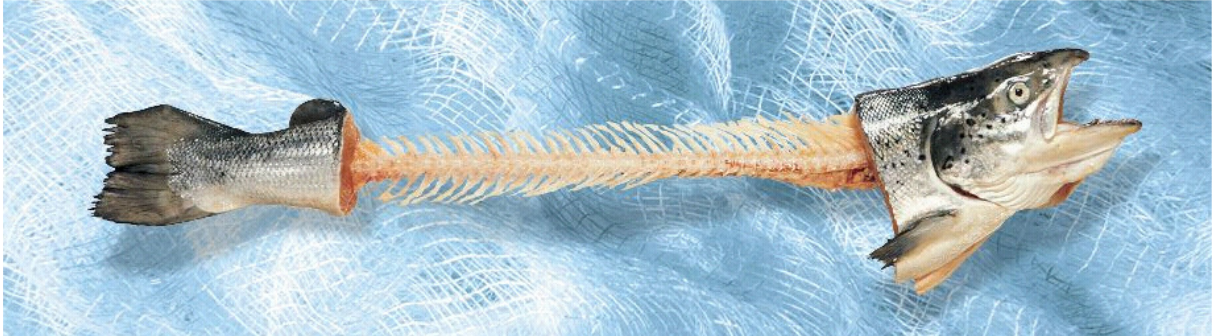
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## 1. INTRODUCTION

By-products are parts of the fish that are removed before the fish reaches the final consumer in order to improve their keeping qualities, reduce the shipping weight or increase the value of the main fish product. They include blood, viscera, heads, bones, skin, trimmings and fins.

**Figure 1: Solid salmon by-product**



*Source: Alfa Laval*

Salmon processors do not really produce by-products; they obtain them after other more valuable products have been separated from the whole fish that they have captured or harvested. Although this is a rather obvious statement, it means that the processor only thinks of by-products as something to get rid of. Depending on volumes and logistics, there are plants willing to pay for them or to provide a disposal service for them.

From a nutritional or food safety point of view, there are important quantities of fats and proteins, which could be used for human nutrition, but are not because of logistical or technological barriers. Therefore, they are mainly used in animal feeds.

Disposal implies a low value for the material being handled, and this is especially the case with mortalities in aquaculture, where the fish have not been prepared to serve as food raw material, i.e. they have not been controlled for illnesses, residual antibiotics or fasting. Furthermore, this resource is very difficult to gather fresh in significant quantities because the farms are located over vast and distant geographical areas. The solutions devised for the disposal of mortalities, therefore, involve technologies that can cope with these restrictions: silage, land filling, specially allocated fishmeal plants, incineration and composting.

When the fish is properly handled and sent to the processing plants to obtain all the range of salmon products – whole gutted fish, headed and gutted weight of fish in kilograms (HG), fillets, steaks, loins, etc. and after that all the possibilities of value addition – a number of by-products remain that could be handled in order to get more value out of them. This is where the plant should continue the processing line following all the requirements for a food product because normally after the most valuable product is obtained, the rest continues along a downgraded path becoming suitable only for feed purposes.

The simplest way of classifying the by-products is through the anatomy of the animal – heads, viscera, bones, skin, tail and fins – which somewhat represents the disassembly line used for processing. Another valuable product, in terms of its components, is the blood from the slaughtered fish, which usually undergoes water treatment at the end of the process, with only a few industries having developed methods to collect it. But from the point of view of

demand, the composition of the by-products could give a better selection on their handling systems in order to keep their nutritional or functional value.

Salmon feed producers were the first to look at oil composition in an effort to find economical sources with the right fatty acid distribution. This is still under discussion, but for the moment it means a high quantity of omega 3 is available in all salmon flesh products. Its human health benefits have been widely promoted, and the industry has been able to extract it. By maintaining its quality, a value-added price premium may be obtained. Nevertheless, the omega 3 content of salmon is lower than in other traditional species, such as sardines and anchovies, whose oil is already being used as nutritional supplements. Oil content in salmon by-products is especially high in the viscera and heads.

Protein composition is more complex because of its chemical structure and functions within the fish itself. The type of tissue involved, its modification possibilities, the amino acid (AA) composition and the bonds to other components make them difficult to separate and use in different applications. The traditional approach has been to use the valuable nutritional properties of the AA balance and produce salmon meal or silage for feed formulations.

Calcium, phosphorous and other bone components are worth considering and are already used in feed preparations, but they could be removed for human consumption, although there is stiff competition from other traditional sources.

## **2. BY-PRODUCT AVAILABILITY**

### **2.1 Description**

The distance that separates producers from markets and the types of markets are the main drivers for by-product generation. There are some market restrictions, such as the European Union protection of its canning and smoking plants, and the higher import duties for Norwegian smoked and canned salmon that encourage fillets, HG or only G salmon exports from Norway, thus reducing the amount left at the processing site. Meanwhile, the high air freight cost for fresh salmon from Chile going to the United States of America forces the exports to concentrate on direct edible parts, leaving large amounts in the country of origin.

Since by-products have always been of secondary importance, there are few statistics available for them and each country has its own approach for calculating them, considering them to be an indirect calculation.

Filleting plants handle the different by-products as they are produced in the line sequence. The following examples from figures 2 to 6 are from plants in Chile.

**Figure 2: Heads**



**Figure 3: Backbones**





**Figure 4: Bellies**



**Figure 5: Trimmings (also showing fillet)**



**Figure 6: Skins**



## 2.2 Supply by country

### Chile

Only farmed Atlantic and Coho salmon and trout are produced in Chile. The volumes for 2001 to 2004 were:

**Table 1: Round fish production ('000 tonnes)**

<b>Salmon\Year</b>	<b>2001</b>	<b>2002</b>	<b>2003</b>	<b>2004</b>
Atlantic	254	266	280	349
Coho	137	103	92	90
Trout+King	114	114	116	130
<b>Total</b>	<b>504</b>	<b>482</b>	<b>488</b>	<b>569</b>

*Source: Sernapesca*

A survey made by Sernapesca in 2000 gave the following yields of by-products from the different species:

**Table 2: Yields of by-products of different species**

<b>Salmon\By-product</b>	<b>Viscera (%)</b>	<b>Heads (%)</b>	<b>Backbone(%)</b>	<b>Skin (%)</b>
Atlantic	9.0	18.0	8.6	2.0
Coho	10.0	15.0	0.0	0.0
Trout+King	8.0	12.0	3.1	1.2

and the following generation of by-products for the different years:

**Table 3: Chile, by-product generation ('000 tonnes)**

<b>Product\Year</b>	<b>2001</b>	<b>2002</b>	<b>2003</b>	<b>2004</b>
Viscera	45	43	44	51
Heads	82	79	80	92
Backbone	31	30	30	34
Skin	8	8	8	9
<b>Total</b>	<b>167</b>	<b>159</b>	<b>161</b>	<b>185</b>

*Source: Sernapesca*

There are two shortcomings to this way of estimating them, one relates to the way the different plants answered the survey, where some backbone could be in the heads figure, and the other refers to the type of product being produced: 47 percent of value-added products in 2000, against 60 percent in 2003 and 58 percent in 2004. Nevertheless, this last concern may only mean a conservative calculation.

The share of exports considered by the industry as value-added products rose greatly during the nineties; nevertheless it has levelled off at a maximum of 58 to 60 percent of exports in volume for the last three years. Furthermore, the industry would need to use a different marketing strategy, so the forecast for by-product generation for the coming years should be based on just the growth of the industry and not on the quality of the products.

Historically, the Chilean industry has converted almost 100 percent of its by-products into salmon meal and salmon oil, with a yield of 20 to 23 percent for meal and 5 percent for oil. Silage process is not applied and other applications, such as hamburger patties and sausages, are just starting.

## Norway

Salmon and trout production in 2004 was 602 000 tonnes, leaving behind 116 000 tonnes of by-products, which could be used for further processing. There was also a certain amount of dead and rejected fish at the farms that could not be used for human consumption. According to Rubin, from the 116 000 tonnes, 15 000 tonnes were heads and the rest viscera, bones and skin. The figures for 2002 to 2005 are:

**Table 4: Available by-products ('000 tonnes/year)**

Item/Year	2002	2003	2004	2005
Total by-product	134	150	146	152.5
Mortalities	22	28	30	35.0
Available by-product	112	122	116	117.5

Source: Rubin

The same source indicates that these by-products are used 75 percent for silage, 5 percent for salmon meal and 20 percent for hydrolysates and other applications.

## The United Kingdom of Great Britain and Northern Ireland

Salmon and trout production in 2002 was about 151 400 tonnes, of which 12 percent corresponded to viscera and 23 percent to heads and bones. The analysis made by Poseidon shows that from these by-products only 26 900 tonnes (51.3 percent of the production) are left at the processing plants in Scotland and the rest is shipped outside the country.

Production in Scotland has been oscillating in recent years from 120 000 to 160 000 tonnes, which means a local availability of by-products in the range of 20 000 to 30 000 tonnes.

One ensiling company estimates that 40 percent of these by-products go to silage, and the other 60 percent is manufactured into salmon meal.

## Canada

Kontali Analyse's statistics show an estimated production for 2005 of 103 000 tonnes of Atlantic salmon, plus 21 000 tonnes of Pacific Salmon; while in 2004 production came to 89 000 and 18 000 tonnes, respectively. To estimate the availability of by-products in Canada, the same figures for the The United Kingdom of Great Britain and Northern Ireland are used considering their similarity in terms of market proximity.

### 2.3 Overall availability

Using the data for 2004, the overall availability of salmon by-products in the main producing countries is:

**Table 5: Estimated overall availability ('000 tonnes), 2004**

Country	Heads, bones, skin	Viscera	Total
Chile	134	51	185
Norway	43	73	116
Scotland	16	9	25
Canada	25	13	38
<b>Total</b>	<b>218</b>	<b>146</b>	<b>364</b>

#### 2.4 Composition and protein supply

A typical proximate analysis of the by-products from Atlantic salmon farmed in Chile can be used to estimate the protein availability:

**Table 6: Atlantic salmon by-products proximate analysis**

Analysis\By-product	Head (%)	Backbone (%)	Skin (%)
Lipid	16.7	15.2	26.3
Protein	11.3	14.1	20.0
Ash	6.0	6.4	1.0
Moisture	66.0	64.3	52.7
<b>Total</b>	<b>100.00</b>	<b>100.00</b>	<b>100.00</b>

*Source:* Gestión de Calidad y Laboratorio S.A.

Assuming that the proportion of heads, bones and skins is similar to the proportion found in Chile: 69 percent heads, 25 percent backbones and 6 percent skin; the average protein content would be 12.3 percent, and the overall salmon protein availability would be 27 000 tonnes for 2004. Although this is a likely figure it is interesting to compare the protein availability when considering the actual share of the different parts of the fish: 11 percent heads, 12 percent backbone and 3.3 percent skins. This gives a relative proportion of 42 percent heads, 46 percent backbones and 12 percent skins, or a protein content of 13.5 percent and a total availability, therefore, of 29 000 tonnes for 2004, which is not an inconsiderable difference with the more conservative figure indicated above.

#### 2.5 Plant by-products management

The overall availability gives a rough estimate of what can be done in an entire industry or a sector – the salmon industry of a specific country – but it does not consider that this availability could be split geographically or that each plant might have its own processing or handling system for its production. Examples of two plants in Chile, given below, are quite illustrative, although this industry should always be considered as a large by-product generator because of its distance from the markets.

##### Chilean Processor 1

Harvests, kills, bleeds and guts the fish in one location, and then transports the fish in ice to another location where it is further processed into fillets. In this case, blood and viscera are available in one location and heads, backbones, trimmings and skin in another. Transport may take a toll on quality, but the plant is already marketing the fillets in good condition, thus high quality by-products, if properly handled could be obtained as well.

### Chilean Processor 2

Receives the live fish at the filleting plant where the entire operation takes place at one site. Normally the whole process is pre-rigor and by-products are top quality.

For both plants, by-product handling is cumbersome and everything is usually mixed together for transport to the fishmeal facilities.


### **3. TECHNOLOGY OVERVIEW**

There are many processing alternatives to keep by-product proteins and rescue their nutritional value and also to obtain value from their functional properties. But before any conversion process is put into practice, the manufacturer should explore the possibilities of maintaining the protein as salmon flesh, which means recovering edible flesh from by-products. The list of technologies to be reviewed includes:

1. Meat separators
2. Fishmeal
3. Silage
4. Gelatine
5. Hydrolysates.
6. Protein separation
7. Extrusion
8. Surimi

#### **3.1 Meat separators**

##### Press separators

<p>There are two traditional systems to separate flesh from bones: screw or auger press and band press. In both cases the material is pressed against a mesh or perforated barrel, where the softer part passes through, retaining the bones. The auger normally produces a higher yield, while the band may give a better quality. For recovering the flesh from bones, normally the screw type is recommended. The only aspects to check are the pressure that could increase the amount of ash in the product and also the temperature that might result in colour changes or protein denaturation. Flesh recovery is 80 to 90 percent.</p>	<p style="text-align: center;"><b>Screw separator</b> <i>Source: Lima Catalog</i></p> 
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### Water jet separators

A non-traditional way of recovering meat or protein is with a high pressure water jet. This system has been tried at Oregon State University and at the University of Iceland. It is a fine approach in terms of cleaning the product, but the yield is low and the texture of the protein is not firm enough for surimi type products (Wendel, Park and Kristbergsson, 2002).

### Head flesh separators

The head, the largest by-product part of the fish, has edible portions that could be separated, such as cheeks, tongue and chin. A dried split head may have a market also, as is the case with cod. A well-known machine for this purpose that separates gills, lower jaw, cheeks and split skull is the Mesa 950 from Iceland.

#### **Head splitting machine**



*Source: Mesa LTD. Iceland.*

### **3.2 Fishmeal**

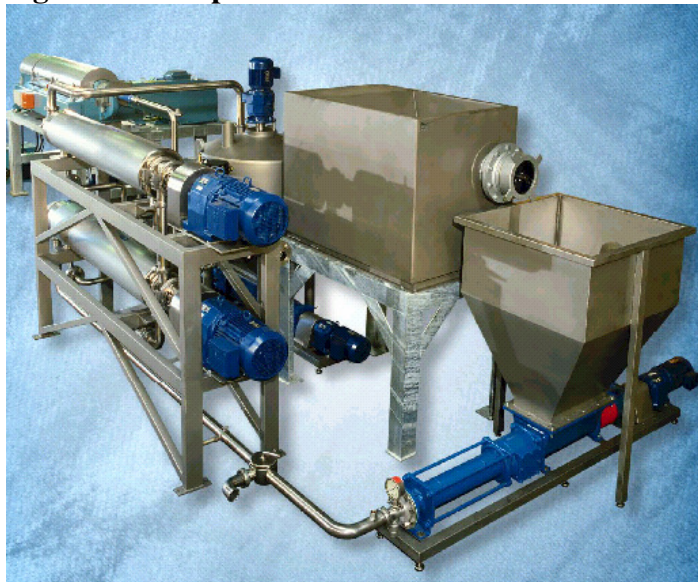
This is one of the traditional disposal systems, where there are large enough amounts to support the investment in a traditional fishmeal plant. Nevertheless, and because of the by-catches available in other fisheries, low capacity plants have been developed, such as the direct fired Ingvar from Iceland. The capacity range starts at 600 kg/hour of raw material, and if only heads and backbones are considered, this means the processing of 2 tonnes of salmon per hour, 48 tonnes per day or 15 000 tonnes per year, which is not a large salmon processing facility.

The quality of the meal, however, would be at the lower end because besides the fact of direct drying quality, its protein content would be less than in the fishmeal obtained from whole pelagic fish.

**Figure 7: Low-cost fishmeal plant**

*Source: www.ingavar.is*

There are other more sophisticated fishmeal plants, such as Alfa Laval and Atlas Stord brands, but the investment is larger and requires steam and other facilities that make the capital requirements even higher, but the quality and price of the product could easily outweigh this initial disadvantage. A fish concentrate is another possibility, where the final product is liquid.

**Figure 8: Compact fish concentrate unit**

*Source: Alfa Laval*

### 3.3 Silage

Silage production has been standardized by the Norwegian processing industry, mostly to feed fur bearing animals. The process is an acid enzymatic hydrolysis, where the natural enzymes work in an artificial acid environment, by adding mixtures of formic and mineral acids. The main purpose of the acid is to avoid bacterial spoilage, which occurs when the silage with formic acid is below pH 4; mineral acids alone give the same effect at pH 2, which is unsuitable for direct feeding purposes. This is why in spite of its higher cost, formic acid is normally included in the acid media, because the final product can be added directly in feed recipes without pH adjustment.

Salmon by-products with or without viscera should follow the silage process for oily fish, where oil is separated as soon as it is released from the flesh tissues. Oxidation of oils renders the silage unsuitable for animal nutrition, so it must be separated and stabilized independently. Another important topic is how to stop the hydrolysis. If enzymes are kept active, they continue catalysing the degradation that starts generating non-protein nitrogen, or degrading the most labile AA. The first one to suffer this process is tryptophan, and being an essential AA, the overall nutritional quality of the protein is reduced together with the protein itself. To overcome this the industry inactivates the enzymes by heating the silage, and in certain cases concentrates or dries it for easier handling and storage.

The process flow includes: reception, mincing, acid addition, mixing, hydrolysis, pasteurization, oil separation and storage; but as mentioned, concentration and drying may be added as well (Arason, 1994).

A well known self-contained unit for ensiling fish by-products on site, reaching the hydrolysis stage and leaving the separations to be done in a centralized operation, is provided by Scanbio, with facilities in Norway and Scotland.

**Figure 9: Ensiling unit**



*Source: Scanbio Scotland*

### 3.4 Gelatine

Salmon skin contains a rich supply of collagen that can be used to produce gelatine, which is the denatured collagen modified by the separation of the three alpha chains comprising its triple helix, followed by a partial hydrolysis of its polypeptides. The manufacturing process includes treatment with acid or alkali, rinsing, adjusting pH, heating to extract the protein and purification by filtration or ion exchange. The final product is a concentrate or a dried powder. Gelatine from coldwater fish gels at 8–10 °C, thus it has different applications compared to bovine gelatine, which gels at over 30 °C.

There is still some work to be done involving fat separation, because salmon has an especially high oil content compared to the raw materials now in use for fish gelatine ([www.norlandprod.com/techrpts/fishgelrpt.html](http://www.norlandprod.com/techrpts/fishgelrpt.html)).

### 3.5 Hydrolysates

Processors and scientists worldwide have long sought to develop a process for obtaining functional proteins or peptides from fish by-products. So far the major restraints have not been thoroughly overcome, and the industry is still in the development stage. Nevertheless, some important milestones augur new uses for these proteins. There are at least two hydrolysing plants: a mobile one in Alaska and a continuous one in Bergen.

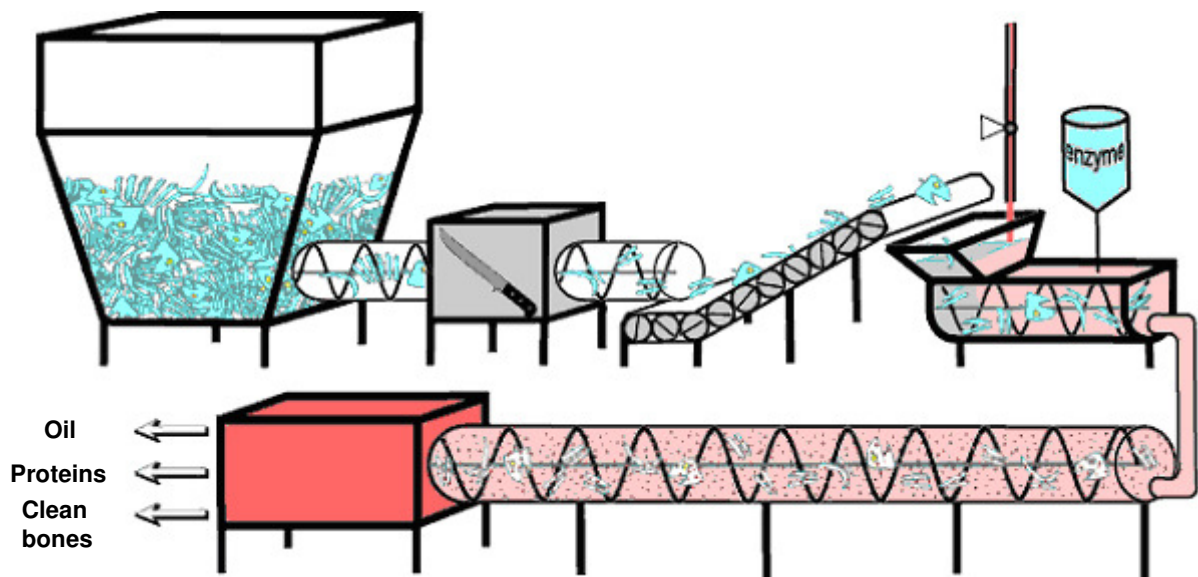
The United States of America facility is built on a barge and the process includes grinding, heating with scraped surface heat exchangers, enzymatic digestion, concentration with vacuum evaporation and pH adjustment for spoilage control. The final product is a viscous liquid with 42 percent solids, comprising 32 percent protein, 7 percent fat and 3 percent ash.

A similar product has been obtained by Rossyew in Scotland with 45 percent solids, 5 percent fat and 3.5 percent ash (Wright, 2004).

Meanwhile, the patented Norwegian Biomega process applies hydrolysis continuously, separating the different components at the end.



**Figure 10: Biomega continuous process**



*Source:* Biomega

The final product is a moderately viscous aqueous solution with more than 60 percent solids and 50 percent protein but less than 2 percent fat. The separated oil is of good quality because it undergoes only a mild heat treatment. The product may be stabilized for longer storage with phosphoric acid or spray dried. The bones can be converted into a high ash meal, which can be used in aquaculture for feeding other species.

Although the final product has very high digestibility, hydrolysis still has some disadvantages when used to obtain a functional protein for human consumption. The enzymes that are used should not give a bitter taste, which is associated with hydrophobic terminals in the peptides obtained. The reaction must be reliable, always resulting in the same final product, but this may be hampered by the use of different raw materials, plus the difficulty in controlling the end of the reaction.

Finally, the most important aspect if moving out of the seafood area is the remaining fish flavour. The cost of the enzymes plus the required addition of water for the reaction and its subsequent removal are further barriers to the final product not reaching the right quality for the premium protein market (Kristinsson and Rasco, 2002). But, in spite of these aspects, added enzymes or exogenous enzymes are the key to obtaining high protein yields and short processing times, compared to endogenous enzymes, which are used when the final aim is a feed ingredient (Guérard, Sellos and Le Gal, 2005).

### 3.6 Acid protein separation

A patented protein separation process with a better yield than the traditional surimi washing process includes acid or basic protein digestion or solubilization, followed by precipitation at the isoelectric point (Hultin and Kelleher, 1999). This process was originally developed for white fish and pelagic species but is now being used with several different species and is already commercially running with a few of them (others are in the development stage). Work is being carried out with salmon, and very soon the process will be applied commercially to salmon by-products. It is running very well, and most of the raw materials being used are frames as well as trimmings (Kristinsson, 2006).

### 3.7 Extrusion

Some research has been done with cold extrusion of by-products (Baron *et al.*, 1996), improving the texture of the original pulp, but no further industrial applications have been developed. Considering the size of the salmon industry now, further studies with both hot and cold extrusion may be advisable.

### 3.8 Surimi

Salmon surimi paste has been obtained using the traditional water washing process with poor results in terms of quality. The product lacks a firm texture because of the low activity of transglutaminase and the lower concentrations of the myosin heavy chain and  $\text{Ca}^{2+}$  (Wan *et al.*, 1995).

## 4. NUTRITION AND FUNCTIONALITY

The protein's properties, either functional or nutritional, will determine the quality of the protein and its value in the market. The term 'functional' has been used recently with a particular meaning referring only to health issues, but here it should also include the functionality that proteins have in food technology, such as their thickening or emulsion capacities. The protein's chemical structure, responsible for its functionality, is somehow altered when the protein is isolated from its natural origin. The most common modification is called denaturalization, where the basic AA chain is not modified, but its spatial configuration is somehow changed showing different properties, especially solubility. Denaturalization is normally produced by heat or pH adjustment.

### Protein uses and properties

1. Animal nutrition
2. Pet foods
3. Human nutrition and fish taste
4. Water holding capacity
5. Emulsifying properties
6. Fat absorption
7. Nutraceuticals

#### 4.1 Animal nutrition

Salmon fishmeal is well known as a feed ingredient. The protein has been denaturalized by heat, reducing its solubility but not affecting the nutritional quality of its AA chain. Considering the composition of the protein in terms of its AA content and comparing it to animal nutrient standards, such as the one issued for chickens by the National Academy of

Sciences in the United States of America, the score obtained is very high, and if human requirements are included the score is even higher.

Tryptophan seems to be the limiting AA for all diets but the difficulty in analysing it normally precludes good results, and processors prefer to declare a lower amount. So arginine for poultry seems to be the only true limiting AA in salmon meal but not in the hydrolysate where threonine seems to be the limiting one.

Digestibility is another aspect, which is related more to the solubility of the protein. Salmon meal, like other fishmeals is not 100 percent digestible, but generally has values of over 90 percent.

Hydrolysates, which undergo a process precisely to increase solubility, may have the opposite effect in terms of animal use by making all the protein available too soon for body building, and the result is that much of it is used only as energy. A fraction of the AAs are lost as ammonia in the excreta. As a result, animal breeders have found that a proportion of the protein of these products, about 3 percent for shrimp (Cordova-Murueta and Garcia Carreño, 2002), can be supplied by hydrolysates, while the rest comes from fish or salmon meal or vegetable proteins. The information from producers shown in the above table indicates interesting differences between meal and hydrolysate, which underscores the complex nature of offering a standard product with so many different raw materials. Another by-product from salmon hydrolysate is high ash fishmeal. It has been found (Toppe *et al.*, 2005) that an increased level of calcium and phosphorous could promote higher feed consumption in cod farming, with a better growth rate, which could be the case with this meal.

**Table 7: Comparison of AA content in salmon meal and hydrolysate with requirements**

Amino acid (AA)	Amino acids, % of protein				
	Salmon meal content *	Salmon hydrolysate content**	Chicken requirements ***	Adult human requirements ****	School-child requirement *****
Lysine	6.50	7.67	4.72	1.60	4.4
Serine	4.60	6.00	3.89		
Histidine	2.00	1.67	1.44	1.60	1.9
Arginine	4.30	6.33	5.56		
Threonine	4.70	3.67	3.78	0.90	2.8
Tyrosine+Phenylalanine	9.10	7.00	5.56	1.90	2.2
Valine	4.30	5.00	3.44	1.30	2.5
Methionine	3.00	3.00	1.67	1.70	2.2
Isoleucine	3.40	4.00	3.33	1.30	2.8
Leucine	6.00	7.67	5.56	1.90	4.4
Phenylalanine	6.10	3.67	3.00		
Tryptophan	0.45	1.33	0.94	0.50	0.9

Sources: \* [www.pesquerapacificstar.cl](http://www.pesquerapacificstar.cl)

\*\* Wright, 2004.

\*\*\* Nutrient requirement of poultry, 1994.

\*\*\*\* Energy and protein requirement, 1985.

## 4.2 Pet foods

Unlike animal farming, where high productivity is the producer's aim, with pet foods the consumer has two requirements: the buyer's own satisfaction and the pet's satisfaction. The second requirement is shown by the pet eating all the product, but the first one might relate to the consumer being aware of the product's nutritional value, such as how much protein it contains, or proof that what is stated on the package is true.

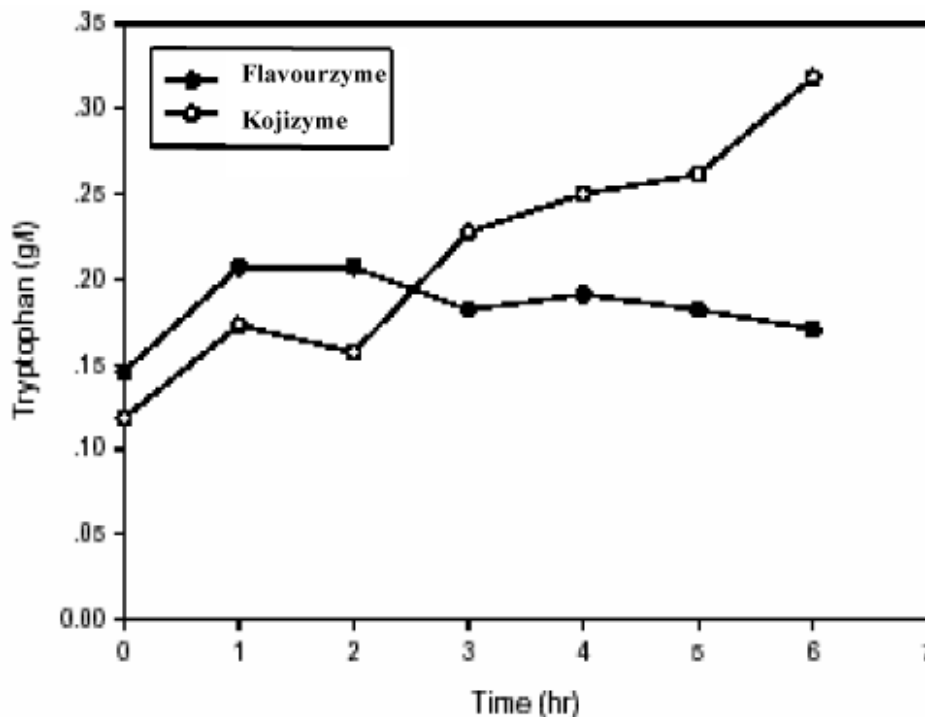
Salmon might have some characteristics that may be explored in this context. It is highly nutritious, it has a distinct fish flavour and a distinct colour, making it easy for the consumer to evaluate. In other words, because much of the recognizable flesh as possible can be separated from the by-products and used as is in moist recipes, where the final product may be canned or pouched, and when it is finally opened the salmon presence is clearly demonstrated.

## 4.3 Human nutrition and fish taste

Table 7 for animal nutrition also includes human nutrition for adults and school-age children. In both cases the salmon meal AA profile meets the requirements, with only the digestibility concept pending. Nursing infants, however, need a higher content of at least three AA, but then egg protein also has less of two AA, indicating the special nature of the protein composition available in human milk.

Regarding digestibility, hydrolysates are positioned better; nevertheless consideration should be given to the type and extent of the reaction. There are enzymes that may make some parts of AA rich proteins insoluble when soluble and insoluble parts are separated, producing a downgraded protein score. This fact has been shown by Nilsang *et al.*, 2005, working with two different enzymes.

**Figure 11: Hydrolysis time and composition**





Effect of hydrolysis time on the amount of tryptophan available in fish protein hydrolysate (Nilsang *et al.*, 2005).

Fish taste is always a difficult issue when dealing with human consumption. When the protein is solubilized through hydrolysis, the oil phase can be separated by centrifugation, and the resulting soluble protein has no fish smell and only a slight fish taste (Kristinsson and Rasco, 2000). Therefore, if the final product contains a large amount, the organoleptic properties would be affected, unless some research is done to reduce the taste even further. On the other hand, if the product is not used for direct consumption but instead to extend other high value fish proteins, for salmon feed for example, there is no problem.

#### **4.4 Water holding capacity**

Phosphates are used in protein products to retain water, improving cooking yield. They act via pH and ionic strength modification, divalent metal ion scavenging, actomyosin dissociation and attachment to protein groups. In meat products, the maximum allowed use is 0.5 percent, and excessive amounts of phosphates in the diet may affect bone health. Protein hydrolysates may replace or enhance the effect of phosphates without their disadvantages (Shahidi and Synowiecki, 1997). The ability of protein hydrolysates to bind water can be compared with other alternatives by measuring drip loss and the protein content of the drip water. In a study with alkaline proteases (Kristinsson and Rasco, 2000), some Atlantic salmon hydrolysates showed a much higher water holding capacity than egg albumin and soy protein concentrate, indicating the suitability of their use as meat extenders in other protein products.

#### **4.5 Emulsifying properties**

Two important features of oil in water emulsions that can be modified by using a protein emulsifying additive are the emulsifying capacity or the maximum amount of oil that the water phase retains, and the stability of the emulsion or the length of time that this condition is held before phase separation. There are some practical standardized methods to measure these properties, which are used to compare different proteins. Again, Atlantic salmon hydrolysates show better properties than soy protein concentrate (Kristinsson and Rasco, 2000) when the degree of hydrolysis is low; in other words, when the peptides are big enough to have hydrophilic and lipophilic capacities. If the hydrolysis is too long, the peptides are shorter and the emulsifying properties are poorer. In the same study, egg albumin has much better properties than either soy protein concentrate or salmon protein hydrolysate.

#### **4.6 Fat absorption**

The protein's capacity to retain or absorb fat is used in the meat and confectionery industry. It is measured by mixing the protein with oil, then separating the oily and solid phases and weighing the amount of oil that is retained in the solid or protein additive. Salmon hydrolysates show high oil absorption for a short hydrolysis time, which is better than for soy concentrates and egg albumin (Sathivel *et al.*, 2005).

#### **4.7 Nutraceuticals**

Natural foods or natural ingredients with a positive health effect – because they reduce the risk of common or serious illnesses, improve the immune system or have a healing ability – are becoming more and more interesting to the consumer who tries to avoid allopathic medicine by choosing a healthier diet.

One aspect that has been studied is the antioxidant properties of proteins. There are several examples of short peptides, less than 20 AAs, of marine origin that have clear antioxidant properties (Guérard, Sellos and Le Gal, 2005). Capelin, cod, mackerel, Alaska pollack and rockfish peptides, some with 13 and 16 AA residues, have shown interesting free radical scavenging activity, and salmon by-products may be another source for them, if hydrolysis is under consideration.

Other functional properties of proteins derived from fish by-products, which could be explored, include anti-hypertensive peptides or ACE (Angiotensin Converting Enzyme) inhibitors and modulators for central neuropeptide levels. (Ono *et al.*, 2006).

Seafood contains high levels of taurine, an AA known to have several positive effects on the cardiovascular system, first as an antioxidant, which may reduce the production of inflammatory products. Second, it may as well reduce blood cholesterol levels by suppressing platelet aggregation.

Care must be taken to retain these functional properties, because refining procedures to eliminate fish flavour and improve sensory attributes might reduce the amount or completely remove antioxidants and other valuable components with functional activity (Elvevoll, 2004).

## **5. PRODUCTION COSTS ESTIMATION**

By-products are now being processed in different ways to obtain value from them. The most obvious way to avoid degradation is to keep the quality of the salmon flesh by preparing some value-added products, such as hamburgers or other mixed meat products. A similar situation occurs with pet foods with added salmon pieces that are recognizable by the pet owner. The other ways being used today are silage, fishmeal and hydrolysates for animal consumption.

### **Protein uses and properties**

1. Hamburger patties
2. Pet foods
3. Silage
4. Salmon meal
5. Hydrolysates

#### **5.1 Hamburger patties**

Recovered salmon flesh or minced salmon is a valuable raw material for producing hamburger patties for the retail market, especially for schools as part of school lunch programs. In terms of costs, 40 percent meat recovery is possible, weight for weight, from filleted bones (100 kg of bones with meat on gives roughly 40 kg of recovered meat). From the nutritional point of view, these products aim to introduce fish consumption into the population and to control obesity through the high quality of the salmon fat, rich in omega-3 fatty acids. A typical formulation indicates a salmon flesh content of over 70 percent, such as the following recipe recently developed for a project carried out by Fundación Chile.

**Table 8: Salmon hamburger**

<b>Ingredients</b>	<b>(%)</b>
Minced salmon	76.70
Textured vegetable protein	12.00
Flavour hamburger base	6.00
Liquid smoke	0.10
Colour	0.20
Water/ice	5.00
<b>Total</b>	<b>100.00</b>

The total production cost, based in Chile and paying US\$100 per tonne of by-product, for frozen preformed 50 g hamburger patties, 20 per polyethylene bag in cartons containing 10 kg or 200 units, is about US\$1 400 per tonne, considering a plant capacity of 280 tonnes per year, with a marginal investment of US\$145 000 to US\$165 000. The marginal investment means that this is an additional production line in a filleting plant facility and involves only mixing, forming and packing equipment, with the use of an existing tunnel for freezing.

**Figure 12: Salmon hamburgers and sausages**

## 5.2 Pet foods

The most interesting market using salmon by-products seems to be the moist pet food market, where the product is sold canned or in retortable pouches, which is more appreciated today by consumers. In one process, the raw materials are mixed and reduced in size with a cutter in order to obtain a smooth paste, which is canned or pouched. A typical recipe is shown below.

**Table 9: Moist cat food recipe**

<b>Ingredients</b>	<b>(%)</b>
Salmon by-products	40.00
Minced chicken	1.50
Wheat bran	4.00
Textured vegetable prot.	3.50
Cat vitamins	0.20
Cat minerals	0.05
Dicalcium phosphate	0.25
Potassium chloride	0.01
Salt	0.15
Guar gum	0.20
Garlic powder	0.05
Onion powder	0.04
Carageenan	0.05
Steam/water	50.00
<b>Total</b>	<b>100.00</b>

The total production cost, based in Chile and paying US\$100 per tonne of by-product, for 24x3 oz pouches in cartons, is US\$1 580 per tonne, considering a plant capacity of 1 200–1 300 tonnes per year, with a total investment of US\$1.4 million to US\$1.5 million. If the cost of the by-products climbs to US\$200 per tonne, the pet food cost increases to only US\$1 630 because the pouch and the process have more influence than the raw material.

**Figure 13: Moist cat food**



### 5.3 Silage

Ensiling is a rather simple process, which can be applied at farm level in small tanks or in plant processing installations with large tanks. The main additional input is formic acid, which helps with the reaction and the keeping qualities of the product. In the process, the by-products are reduced in size, mixed with formic acid (about 3.5 percent) in order to reduce the pH below 4.0 and held until the solids are liquefied. The amount of acid depends on the bone content. The higher the bone content, the more acid is added to keep the right pH. There are some production facilities that prefer to separate the bones before the ensiling process to avoid the extra acid cost. Some plants remove the oil to obtain a higher revenue, and in this case the addition of antioxidants with the acid is also required, the proportion being around 200 to 300 parts per million (normally ethoxyquin). A small ensiling plant, such as the Scanbio unit shown in Technology Overview, in Scotland, for 140 to 150 tonnes of by-products per year, has an investment of about US\$16 000 and operation costs of US\$9 000 per year or US\$60 per tonne of silage, not including the cost of the by-product.

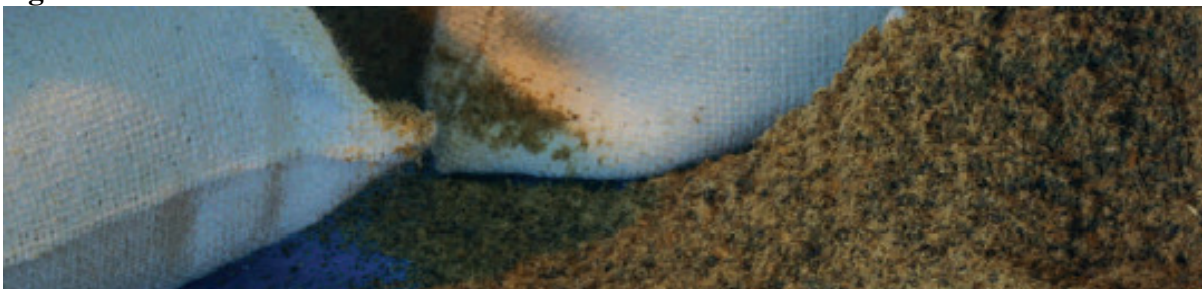
### 5.4 Salmon meal

Fishmeal processing is a well-known process that includes: mincing of the raw material (optional), heating and cooking for 15 to 20 minutes at 80 °C to 90 °C, pressing, decanting the solids, centrifugation to separate oil and water, water evaporation and final solids drying. The main developments in this process have included milder drying conditions to maintain the quality of the protein being used as aquaculture feed. Depending on the raw material, the yield is between 20 to 23 percent of fishmeal and 5 percent of fish oil. The investment for a traditional plant, handling 50 to 100 tonnes of by-products per day is around US\$15 million, and the direct processing cost in Scotland is about US\$100 per tonne of by-product, not including the cost of the by-product. If the cost of the raw material is US\$60 per tonne and the yield is 25 percent, both products, meal and oil, would have a cost of US\$640 per tonne, not considering the revenue on the investment.

**Figure 14: Salmon oil**



**Figure 15: Salmon meal**



## 5.5 Hydrolysates

A plant using the Biomega patented process for a capacity of 10 000 tonnes per year has an approximate investment of US\$4 million, including Westfalia separators and the line for drying the solids separate from the soluble protein. The production cost is quite dependent on the raw materials used; nevertheless the present price of hydrolysate is around US\$1 400 per tonne for the pet food market.

## 6. MARKETS

### 6.1 Introduction

The protein market is very dynamic, with new resources and developments based on existing ones regularly appearing and replacing the traditional ingredients. Besides the normal functional properties sought by food manufacturers, consumers have a voice regarding other issues, such as GMO free (genetically modified organism), allergens and others. Protein suppliers' R&D departments should take care to keep or improve the competitive edge of their products, to avoid being replaced and to answer current public concerns.

Protein manufacturers that use salmon by-products as raw material have a relative handicap compared to protein suppliers that use raw materials specially designed to cope with the protein market specification, which might be the case with soybeans and other pulses. The salmon farmer always aims to satisfy the salmon meat consumer, and when these aims coincide, as for example in the flesh texture, the result is positive because it is also a required characteristic of the protein; but when the farmer is adding extra colour to reach the Coho Japanese market for example, the final pink protein may have no use in bakery products.

Health and consumer awareness factors play an important part in the protein market. Milk is positioned on top, with only lactose intolerance as a consumer concern, but if the protein is separated from the sugar, this hurdle disappears. Soybeans are affected by the GMO issue, and it will depend on the development of public opinion, both in the United States of America and in Europe, as to whether or not they will retain their marketability with increased prices for the GMO free protein or if their overall acceptance will be affected by the inability, real or nominal, to guarantee identity preservation (IP). Although foot-and-mouth disease, plus the mad cow syndrome bovine spongiform encephalopathy (BSE), have affected the beef protein market, it seems that both situations are under control, and consumers are recovering their confidence in the industry, but it is unlikely that it will reach the same status that it had before the crisis.

Fish proteins have a good healthy image, but there are some concerns regarding over-fishing and because the market for human consumption is heavily affected by aquaculture, which buys most of the fishmeal of marine origin – either the traditional fishmeal from pelagic species and by-catch or the fishmeal from by-products of other farmed species – the depletion of natural stocks may affect the position of fish proteins. The positive health claim for fish consumption, for a long time only associated with the omega-3 fatty acids, has expanded to include other ingredients, such as proteins and other components. So this may drive the direct consumption of fish protein additives, which will compete with the indirect use of converting them into another species protein as a feed additive.



Health functionality, or the capacity of an ingredient to have an impact on health by controlling illness, improving natural defences, controlling weight, improving rapid bodybuilding, etc. is a powerful market driver that has been studied and promoted by protein ingredient suppliers. A food processor who is already using a protein with a food technology purpose, such as binding and emulsifying, may welcome an additive that also has a health claim and use it to replace the original one. This implies that the protein manufacturer must develop these marketing tools. There is, however, one concern, mainly affecting the United States of America market with the decline of the Atkins diet to reduce weight, which is low in carbohydrates and rich in proteins. Proteins derived from salmon by-products could be used in novel applications, typically as nutraceuticals or to replace functional – from the food technology perspective – protein ingredients, already in the market and with properties that could be duplicated by salmon proteins. The growing salmon industry ensures that this ingredient is not going to be lacking in the future, but on the contrary is more likely to be in oversupply with the corresponding cost reduction. On the other hand, if by-product processors do not tightly control their supply, there might be some problems with the consistency of specifications for the proteins produced, affecting their image in the market.

## **6.2 Protein ingredients**

### **Soy concentrates and isolates**

The concentrates obtained from soybean grits containing about 70 percent protein have a market of around 70 000 tonnes in Europe and 80 000 tonnes in the United States of America. Soy isolates obtained from the same source, but having 90 percent protein, have a market of about 30 000 tonnes in Europe and 90 000 tonnes in the United States of America.

The United States of America is a big consumer of soy proteins, because it has a tradition of soybean production, and there are important health claims even supported by the FDA, such as the reduction in heart diseases. Research has been conducted to reduce the taste and flavour of soy proteins, making them suitable for applications where bland organoleptic properties are required, and new products have appeared, such as soy cereals, coffees and milk products. Functional properties, such as emulsification and water and fat absorption, have made soybean proteins quite useful for the meat and bakery industries.

Soy proteins are very competitive in price. Isolates with about 90 percent protein are in the range of US\$4.50 to US\$5.50 per kg, and concentrates from US\$3 to US\$4 per kg in the United States of America, while the prices in Europe are somewhat lower.

### **Whey protein**

Whey is the liquid obtained after cheese or casein production, and it contains soluble proteins plus lactose, minerals and a minimum amount of fat. The separation of these components results in whey protein concentrates with a maximum of 80 percent protein, or whey protein isolate with 90 percent protein. Cheese factories used to discard the whey, or use it as animal feed, but first because of environmental considerations, and then because the development of functional and nutritional applications new food uses have been found for it.

The traditional effect of high temperature on whey proteins, modifying their properties and reducing their applications, has been studied by some suppliers who are now offering thermal

stable whey proteins. Hydrolysis has been another way to develop value, by providing pharmaceutical uses.

Cheese production continues to grow, so whey processing is guaranteed, independent of casein production, which in the case of Europe is very sensitive to subsidies that will probably see a reduction in the near future, making casein availability follow the trend.

When products have a neutral taste, which has led to the development of quite different functional applications; in some cases its solubility is used in beverages, where its wide pH tolerance allows it to be mixed with fruit components. In the case of meat products, its ability to gel and fix water to the protein matrix, is used to replace or extend the higher costing beef or pork protein. Its high digestibility, over 95 percent, and well-balanced AA score allows it to be used in nutritional products, such as sports beverages, hospital diets and infant formulas.

Prices are directly related to the protein content. In 2004 the price ratio between whey powder and concentrated whey with 60 to 80 percent protein, and isolated whey protein with more than 90 percent protein, was about one to four to eight, respectively, depending on the protein modifications and final uses. The European market for all the whey proteins is above 1 million tonnes per year, while the United States of America market is about two-thirds the European market in value.

## **Gelatine**

Gelatine is obtained from bovine or swine bones and hides. Animal-borne diseases and religious considerations have directed research to find other sources of gelatine, making fish skins and bones an interesting alternative. Coldwater fish, however, has a disadvantage regarding the gel melting temperature, which is too low for jelly manufacturing, and some work has been done to obtain a higher value, with the addition of Kappa carrageenan, for this type of application (Smidsrod and Haug, 2006).

Because it has low protein nutritional value, unless combined with other proteins, because of its lack of tryptophane, an essential AA, its value lies mostly in its functional properties in different products: jellies, marshmallows, soft gel capsules and gummy products. It is also used for its water binding and texture smoothing capacity in the meat and dairy industries.

The market for traditional protein continues its upward trend in spite of BSE and higher production costs because of its functional properties, which are difficult to substitute. The world gelatine market of about 200 000 tonnes is led by Europe with consumption around 100 000 tonnes followed by the United States of America with 40 000 tonnes.

### **6.3 Main markets for each protein**

According to their functional properties, price and availability, the different proteins find various applications within the food industry.



**Table 10: Protein distribution in different applications**

Application/Protein	Soy concentrate (%)	Soy isolates (%)	Whey (%)	Gelatine (%)
Dairy			40	6
Meat products	45	55	8	9
Bakery			12	
Functional foods		15	25	19
Confection/Ice cream			8	56
Feeds/Pet food	40	10		
Other	15	20	7	10

Source: Frost and Sullivan (2005a, 2005b)

## 6.4 Applications

There are some specific applications that could be used directly to increase the value of salmon by-products without involving any complex chemical process and just keeping the good food quality.

### Hamburger patties

Because this product has a special appeal for children, it has been used in Chile, in the School Lunch Program, to increase fish product consumption, which is very low – 5 to 7 kg per capita, per year of edible parts – in spite of the huge quantities available. The programme aims to deliver 2 million rations every day, covering almost 60 percent of the school population. If salmon hamburgers are given only one day per month, the total consumption would be 1 000 tonnes over a 10-month period. The price paid for similar fish products is about US\$1 800 per tonne, with a reasonable margin for the processors.

### Pet foods

The total market for pet foods in Europe and the United States of America is about US\$21 billion, of which US\$3 billion corresponds to moist cat foods either in cans or pouches. Dog food is another venue, but because of the traditional link between cats and fish, the analysis is done only with this pet.

Market segmentation shows a matrix with four corners: premium and standard quality with private or brand labels. In this group, the segment with the lowest price is standard quality with private label, which is the easiest market to penetrate compared to the large companies with well-positioned brands. In this case the market is about US\$280 million and the price in the supermarket is around US\$6.80 per kg; when taking away taxes, retailer and distributor margins, and transport cost, in this case from Chile, the FOB price drops to US\$1.90, giving a reasonable profit to the manufacturer.

### Silage

This is a traditional use of by-products in Scotland and Norway, where special care is taken with freshness of the raw material and overall quality. The Total Volatile Nitrogen should be below 3 percent, the total peroxide level below 20 meq and the pH below 4.0. In this case the receiving companies, such as Scanbio, pay around US\$100 per tonne to US\$110 per tonne for the silage. This figure is fine for the processing cost, but probably too low for the by-product itself when there are other more profitable alternatives.

### Salmon meal

Another traditional use of salmon by-products is for salmon meal as feed where silage has not been introduced in the industry, usually because farmers are reluctant to introduce a liquid protein. Considering the fact that they are used to dry feed, farmers would use the salmon meal in a flour or other powdered form. In Chile there are two processing companies covering more than 90 percent of the production. The salmon meal price is rather difficult to assess because it depends on the available raw materials from pelagic fisheries and soybean meal production. Nevertheless, it is close to the the pelagic fishmeal price, which is US\$100 higher per tonne, because salmon meal cannot be used as salmon feed according to the regulations. The trend here is rather complex because pelagic captures are stable, and aquaculture is increasing in a sustainable way year after year, so the price should go higher and higher, unless a competitive protein for aquaculture feeds appears in the market.

### **6.5 Regulations**

The use of salmon by-products requires, first, a definition of the term and the concept of by-products. The salmon industry, because it produces food, initially thought that clean fish heads, cuts and trimmings were waste, something to be disposed of, and they were treated as such, falling into the EU European Animal By-Product Regulation (ABPR) for the case of Europe, where it is defined as “any substance or object ... which the holder discards, intends to discard or is required to discard”.

This regulation classifies the by-products from processing plants in category 3, allowing them to be used as raw materials for pet foods, biogas, fishmeal, compost, silage, other animal feeds, incineration and category 3 processing plants. These processing facilities have specific hygienic regulations, requiring among other restrictions, that the by-products from food processing plants do not mix with lower grade by-products.

However, if the by-product coming from a food processing factory has not been contaminated or otherwise made unsuitable for human consumption, the definition of “waste” depends entirely on the holder, and the material could still be handled as food if the proper safety conditions are followed. This is also in agreement with the concept of waste prevention or minimization, avoiding treatment at the end of the processing line.

The regulations are in general not specific for fish protein products, thus the restrictions for other similar products should be considered before the dedicated regulations appear. If the fillets coming from the same fish are suitable for human consumption, the question to be answered about the by-products is if they might contain higher levels of dangerous contaminants because of the way they are deposited in the different body parts, such as antibiotics for example, or because during the process they might migrate from the bones or other parts to the protein, as could be the case of phosphorous.

The following table gives EEC Regulation No. 466/2001, specifying the maximum amounts of heavy metals for fish flesh (normal moisture content).

**Table 11: Maximum amounts of heavy metals for fish flesh**

Contaminant	mg/kg max	Analytical reference
Lead	0.20	Directive 2001/22/CE
Cadmium	0.05	Directive 2001/22/CE
Mercury	0.50	Directive 2001/22/CE
3-MCPD*	0.02	Directive 2001/22/CE

\* 3-monochloropropane-1,2-diol, included here because it applies to soy sauce and occurs in its hydrolysis process.

EEC Regulation No 2375/2001 specifies the maximum amounts of polychlorinated biphenyls (PCBs) and dioxins according to their toxicity index or WHO-TEF (toxic equivalent factors, 1997) as 4 picogram per gram of fresh weight. This limit should be considered carefully because of the different accumulation in each part of the fish body, and the variable presence in seawater, depending on the proximity to industrial areas or currents coming from them.

Residuals from veterinary drugs are another important issue. Although the industry is trying to move from remediation to prevention, using vaccines, there is always the risk of some antibiotic or its metabolites being present. The applicable EEC regulation is No. 2377/90/EEC, which gives the Maximum Residual Limits in a positive way; that is if it is not on the list it is not permitted.

**Table 12: Maximum Residual Limits**

Drug	MRL, ppb
Oxytetracycline	100
Oxolinic acid	100
Flumequine	600
Sulfonamides	100
Trimethoprim	50
Florfenicol	1 000
Erythromycin	200
Enrofloxacin	100
Amoxicillin	50
Emamectin	100

Source: Regulation No 2377/90/EEC

The only drugs that are occasionally used in salmon farming are the first three from the list above and are tightly controlled by the industry and the regulatory agencies.

All other drugs, such as hormones and beta-agonists, do not have maximum residual limits allowed and should not be present in any amount in the final product.

## 6.6 Animal welfare

Besides vegetarian diets and animal-borne diseases, one topic that is moving consumers towards dairy and vegetable proteins is animal welfare, which in the case of salmon farming refers mainly to the harvest methods. There are systems that are considered to be more or less painful or where the slaughtering is more or less humane. If the salmon by-product industry is able to demonstrate that the harvesting methods utilized are the best in terms of animal welfare, it would be prepared to handle any concern that might affect its competitiveness with other protein sources.

## 6.7 Conclusions

All the above indicates that if the technology used to separate the protein from salmon by-products yields a product with long peptide chains it could be used in meat applications: burgers and sausages, replacing soy concentrates and isolates. If fish flavour cannot be eliminated, the end use would be restricted to fish related products: fish fingers, frozen fish fillets and fish home replacement meals. During the introductory period and before unique properties can be developed in these new proteins, the price should be less than the corresponding soy isolates and concentrates.

If the hydrolysis renders a soluble tasteless protein, the functional and sports foods or drinks application would be the most interesting target, because the dairy market is rather complex, unless some health promoting property could be found or developed with the by-products. The positive consumer response to dairy products means that the replacement of another member of the family (whey) by a protein whose origin must be declared on the label would be difficult.

Salmon skins might be a good source of gelatine, and research might produce interesting properties to replace the traditional source, taking into account the willingness to find a replacement after the BSE crisis and the religious restraints for porcine gelatine.

The comparison between the protein availability, 27 000 tonnes, and the markets for these sample proteins – or proteins most likely to be replaced if the functionality could be developed in the proteins separated from the by-products – shows that there is a reasonable size for introduction and competition if the final technology is cost-effective enough.

## REFERENCES

- Arason, S.** 1994. Production of fish silage. In Martin, A., *Fisheries Processing: Biotechnological applications*. Chapman & Hall, London, 244–272.
- Baron, R., Mastail, M., Vallet, J. & Lukowska, E.** 1996. Texturation par extrusion à froid de la pulpe de poisson. *Sciences des Aliments*, 16, 69–76.
- Cordova-Murueta, J. & Garcia Carreño, F.** 2002. Nutritive value of squid and hydrolyzed protein supplement in shrimp feed. *Aquaculture*, 210, 1, 371–384.
- Elvevoll, E.** 2004. Fish waste and functional food. In Waldron, K., Favids, K., Smith, A. *Total Food 2004*, Institute of Food Research, Norwich Research Park, Norwich, England. (available at [www.totalfood2004.com/totalfood.pdf](http://www.totalfood2004.com/totalfood.pdf)).
- Frost & Sullivan.** 2005a. European protein ingredients market report.
- Frost & Sullivan.** 2005b. The U.S. protein ingredients market report.
- Gestión de Calidad y Laboratorios S.A.** 2006. Analysis Reports #149.443–6.
- Guérard, F., Sellos, D. & Le Gal, Y.** 2005. Fish and shellfish upgrading, traceability. In *Marine Biotechnology*. I. Springer-Verlag, Berlin and Heidelberg.
- Hultin, H. & Kelleher, S.** 1999. U.S. Patent 6.005,073.
- Kontali Analyse, Monthly Salmon Report**, February 2006.
- Kristinsson, H.** 2006. Personal communication.
- Kristinsson, H. & Rasco, B.** 2000. Biochemical and functional properties of Atlantic salmon (*Salmo salar*) muscle proteins hydrolyzed with various alkaline proteases. *J. Agric. Food Chem.* 48, 657–666.
- Kristinsson, H. & Rasco, B.** 2002. Fish Protein Hydrolysates and their potential use in the food industry. In Fingerman, M. and Nagabhushanam, R. *Recent Advances in Marine Biotechnology 7*, Science Publishers, Inc. Enfield, NH, 157–181.
- National Academy of Sciences.** 1994. *Nutrient Requirements of Poultry*. Board of Agriculture and Natural Resources. 9<sup>th</sup> Ed, The National Academy of Sciences, USA.
- Nilsang, S., Lertsiri, S., Suphantharika, M. & Assaving, A.** 2005. Optimization of enzymatic hydrolysis of fish soluble concentrate by commercial proteases. *J. of Food Eng.* 70, 4, 571–578.
- Ono, S., Hosokawa, M., Miyashita, K. & Takahashi, K.** 2006. Inhibition properties of dipeptides from salmon muscle hydrolysate on angiotensin I-converting enzyme. *Int. J. Food Sci. Tech.* 41, 383–386.
- Poseidon, Aquatic Resource Management Ltd.** 2004. Evaluation of fish waste management techniques.
- Rubin.** 2006. Personal communication with Mr. Arnt Fredrik Kjønhau, Kontali Analyse AS.
- Sathivel, S., Smiley, S., Prinyawiwatkul, W. & Bechtel, P.** 2005. Functional and nutritional properties of red salmon (*Oncorhynchus nerka*) enzymatic hydrolysates. *J. Food Sci.* 70, 6, 401–406.
- Shahidi, F. & Synowiecki, J.** 1997. Protein hydrolysates from seal meat as phosphate alternatives in food processing applications. *Food Chem.* 60:29–32.
- Smidsrod, O. and Haug, I.** 2006. Personal communication. Norwegian University of Science and Technology, NTNU, Trondheim.
- Toppe, J., Aksnes, A., Hope, B. & Albrektsen, S.** 2005. Inclusion of fish bone and crab by-products in diets of Atlantic cod, *Gadus Morua*. *Aquaculture* 253, 636–645.
- Wan, J., Kimura, I., Satake, M. & Seki, N.** 1995. Causes of inferior gel-forming ability of salmon surimi paste. *Fisheries Science* 61, 4, 711–715.
- Wendel, A., Park, J. & Kristbergsson, K.** 2002. Recovered meat from Pacific whiting frames. *J. Aqua. Food Prod. Tech.* 11(1): 5–18.

- World Health Organization.** 1985. Energy and protein requirements. Technical report series No. 724.
- Wright, I.** 2004. Salmon by-products. *Aqua Feeds: Formulation & Beyond*. 1, 1, 10–12.

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