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 (Angiotensing 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

Ingredients	(%)
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
Total	**100.00**

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

Ingredients	(%)
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
Total	**100.00**

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

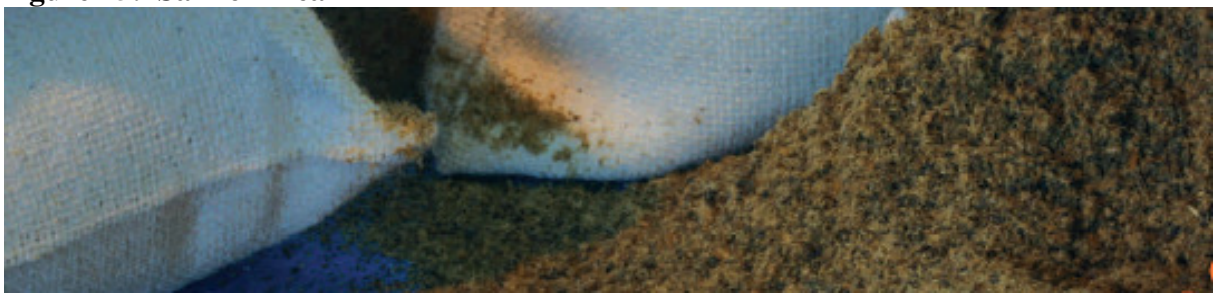
Ensiling is a rather simple process, which can be applied at farm level in small tanks or in plant processing installations with large tanks. The main additional input is formic acid, which helps with the reaction and the keeping qualities of the product. In the process, the by-products are reduced in 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.