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)

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

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

Salmon\By-product	Viscera (%)	Heads (%)	Backbone(%)	Skin (%)
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)

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

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
Total	**218**	**146**	**364**

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
Total	**100.00**	**100.00**	**100.00**

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

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.	**Screw separator** *Source*: Lima Catalog