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By-products from whitefish processing

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Report summary

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Titill / Title	**By-products from whitefish processing /** Hliðarafurðir frá bolfiskvinnslu		
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Ágrip á íslensku:	Í þessari skýrslu eru teknar saman upplýsingar um nýtingu á mikilvægum bolfisktegundum við Ísland, gerð grein fyrir hvaða afurðir séu unnar úr því hráefni sem til fellur og möguleikar til aukinnar nýtingar á hliðarahráefni kannaðir. Skýrslan er unnin í tengslum við Norræna rannsóknarverkefnið "Alt i land" sem færeyska fyrirtækið Syntesa stýrir. „Alt i land" er hluti af færeysku formannsáætluninni í norrænu ráðherranefndinni, en í því verkefni er núverandi nýting og möguleikar á að bæta nýtingu í bolfiskvinnslu í Færeyjum, Grænlandi, Noregi og Íslandi kannaðir. Meginniðurstöður úr því verkefni sýna að nýting í bolfiskvinnslu á Íslandi er umtalsvert meiri en í hinum löndunum. Auk þess að gefa út þessa skýrslu, hefur Matís haldið tvo vinnufundi í tengslum við verkefnið, þar sem hagsmunaaðilar komu saman til að ræða um möguleg tækifæri til að auka nýtingu og verðmætasköpun í bolfiskvinnslu.		
Lykilorð á íslensku:	*Nýting, fullnýting, hliðarafurðir, aukahráefni*		
Summary in English:	The objective of this report is to analyse the current utilization of the most important Icelandic whitefish species and identify possibilities for improving utilization of by-raw materials even further. The report is a part of a larger international project, called "Alt i land", which is led by the Faroese company Syntesa. Alt i land is a part of the Faroese chairmanship programme at the Nordic Ministers of council. The objective of Alt i land is to study and compare utilisation in whitefish processing in Faroe Islands, Greenland, Norway and Iceland, and to suggest how utilisation can be improved in these countries. The main results from that project show that utilisation is much higher in Iceland than in the other countries. In addition to publishing this report, Matís has facilitated a series of workshops with selected stakeholders where potentials in increasing utilization have been discussed.		
English keywords:	*Utilisation, by-products, by-raw material, rest raw material*		

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Introduction

The Icelandic seafood industry has been focused on increasing the value of each kilogram caught ever since the quota system was implemented over three decades ago. The industry has accepted that total catches are more or less fixed and the only way to increase value is therefore to utilize as much of each fish as possible into as valuable products as possible. Utilizing by-raw materials from whitefish processing is consequently very important for the seafood industry as a whole, where great economic-, nutritional- and environmental values can be obtained. Increased utilization has contributed to significant value creation from the by-raw materials and has led to better profits within the sector. In the early days the by-raw materials were mainly utilized for production of low value products such as mince, fish meal and silage, resulting in a relatively low value addition and marginal contribution to improving profits. The knowledge and available technology within this field has however grown substantially in recent years and is still growing. With increased scientific understanding of the properties of proteins and fish oil, the by-raw materials have been transformed to highly valuable products, in some cases even higher in value than the fillets.

As mentioned above, by-products can range from being of relatively low value, such as fish meal and fish oil processed from silage, which are primarily used as a feed for farmed animals; to extremely high value products included in pharmaceuticals, cosmetics and functional foods. The value-pyramid (Figure 1), demonstrates how the value increases depending on final products. Not all raw materials can be used for production of the most valuable products, but with better controlled value chains it is possible to optimize the processes so utilization can be focused on creating products that return the highest value addition. At the top of the value pyramid is the pharmaceutical sector, but valuable components such as fish oil, proteins, collagen and gelatine, enzymes and minerals can also be classified as high value products.

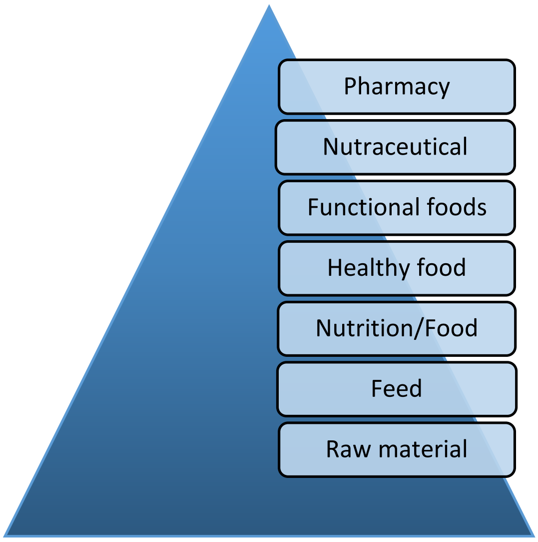


Figure 1. The value-pyramid for by-products.

It may not always be applicable or economically feasible to focus only on the most valuable end products. It depends for example on the availability and quality of the raw materials, the investments needed to produce the end products and market conditions where a processor wants to situate himself in the value pyramid.

The objective of this report is to analyse the current utilization of the most important Icelandic whitefish species and identify possibilities for improving utilization of by-raw materials even further. The report is a part of a larger international project, called „Alt i land“, which is led by the Faroese company Syntesa. Alt i land is a part of the Faroese chairmanship programme at the Nordic Council of Ministers. In addition to publishing this report, Matís has facilitated a series of workshops with selected stakeholders where potentials in increasing utilization have been discussed.

Utilization of fish by-raw materials

Cod has for decades been the most important species in Iceland and has in recent years represented 35-40% of the total export value from seafood products (Statistics Iceland, 2016). Figure 2 shows clearly how both the landing value and the export value of cod products have increased since the turn of the century, even though the catch volumes have not increased.

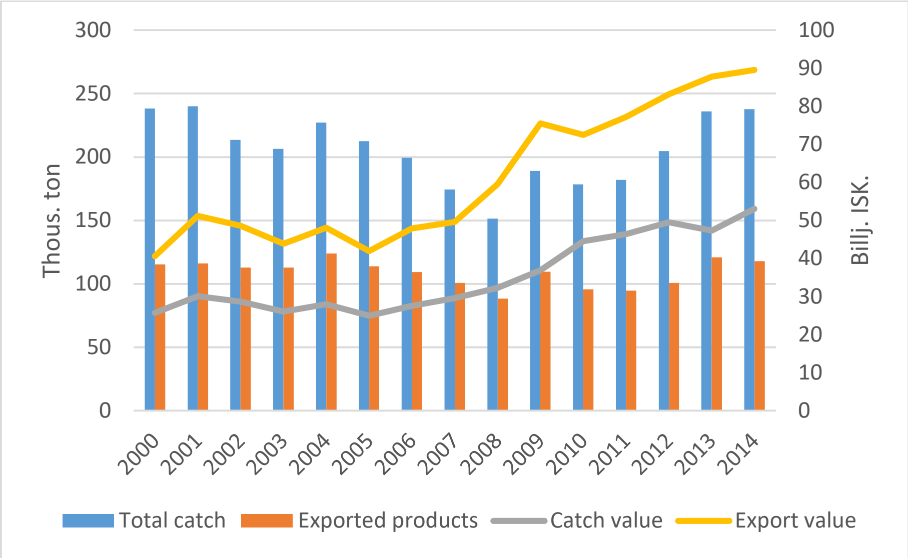


Figure 2. Total Icelandic cod catches and exported cod products in quantity and value (FOB) 2000-2014.

Most of the by-raw materials which come from cod processing ashore are utilized. These materials include, cut-offs, head, frame, skin, liver, roe and milt, skin and viscera (Figure 3).

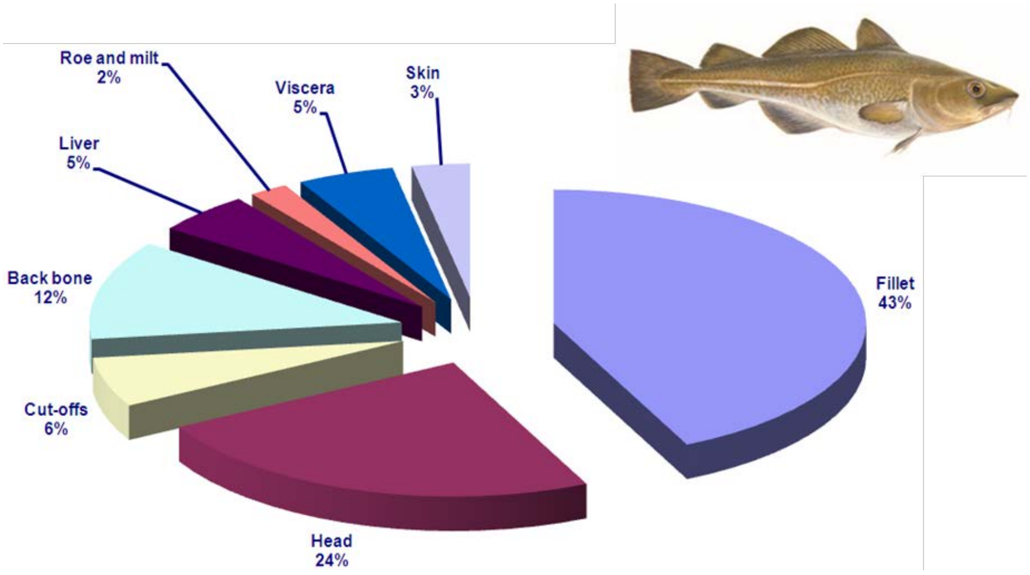


Figure 3. Ratio of the raw materials in cod when producing skinless and boneless fillets.

It is theoretically possible to utilize the entire cod as it comes on-board the fishing vessels. But with current set-up of the fishery it is not realistic to expect 100% utilization. Factory trawlers have for example difficulties with freezing and storing by-raw materials; and vessels that land gutted fresh fish are not equipped to store viscera.

Assuming that all cod raw materials would be landed and utilized, and the main product would be skinless and boneless fillets it can be argued that by-products could represent 57% of the catch volume. Following is a discussion on current and potential utilization of these by-raw materials.

Fish liver

Utilizing of liver, especially cod liver, has a long history in Iceland. The earliest sources are from 1728 in Grindavík where liver was rendered in simple cast iron pots to get the oil (Johnson & Jónsdóttir, 2008). Since then there has been a major progress in the utilization of liver. The processing of liver in Iceland can be divided into two categories, production of oil and canning. The two biggest companies producing products from liver under different brands are Akraborg ehf., who produces canned liver and Lýsi hf. who produces oil.

It was Napoleon the Great who discovered for humanity method of producing foods that could be stored for a long time. The approach was canning. The reason was that he had to bring food for his army in campaigns to distant countries. In Iceland it was an English salmon trader who was the first to try canning in Borgarnes 1858. This led to the beginning of the preserving industry in Iceland, which has been volatile through the years, but is now growing fast.

There are six companies currently producing canned liver in Iceland and the production has increased tenfold over the past decade. In 2003 the production amounted to 418 tons and ten years later the production peaked, reaching an excess of 4.300 tons valued at over three billion ISK (FOB). The production did however decrease slightly in 2014 and 2015 as shown in Figure 4 (Statistics Iceland, 2016).

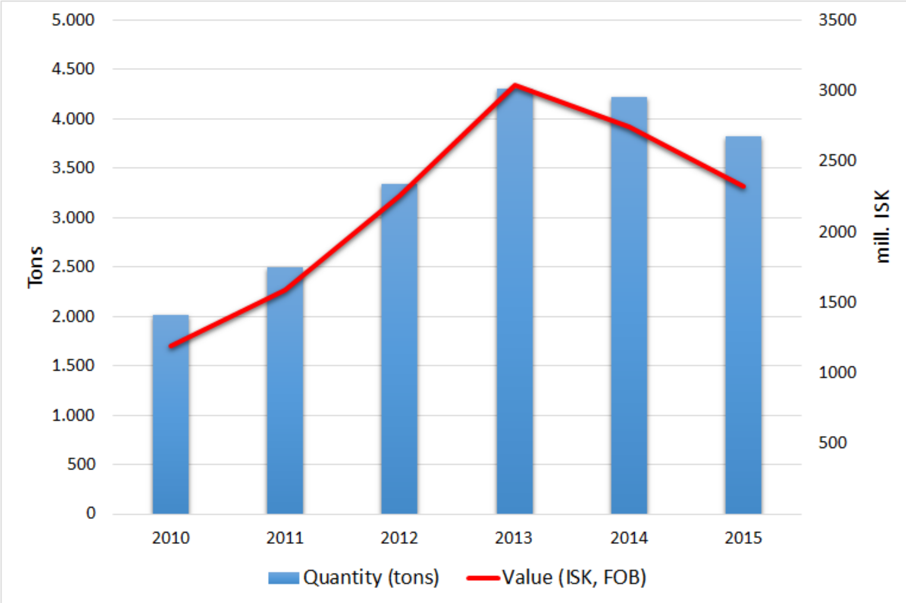


Figure 4. Export of canned fish liver 2010-2015, quantity and value (FOB).

In the past the liver was packed in 120 g cans (club) and was mainly exported to France, Germany and Denmark. Today the canning industry focuses on circular cans 180 g or more for the liver, because of new markets, especially in East Europe and USA. Countries in the west of Europe pay higher prices for the canned liver, like the French market, compared to markets in East Europe. The demand regarding price and flavour is different between countries.

Competition in the world market for canned cod liver was considerable few years ago when countries around the Baltic Sea were producing significant amounts of canned liver. The production in these countries was however stopped when dioxin measured above EU regulations. Today, the production of canned liver is mainly taking place in Iceland and Norway. For the last year, Iceland has focused on markets in Ukraine, Czech Republic and USA. The Iceland market share in West-Europe is nearly 70% (Statistics Iceland, 2016). The main export countries for canned Icelandic fish liver 2007-2015 are shown in Figure 5.

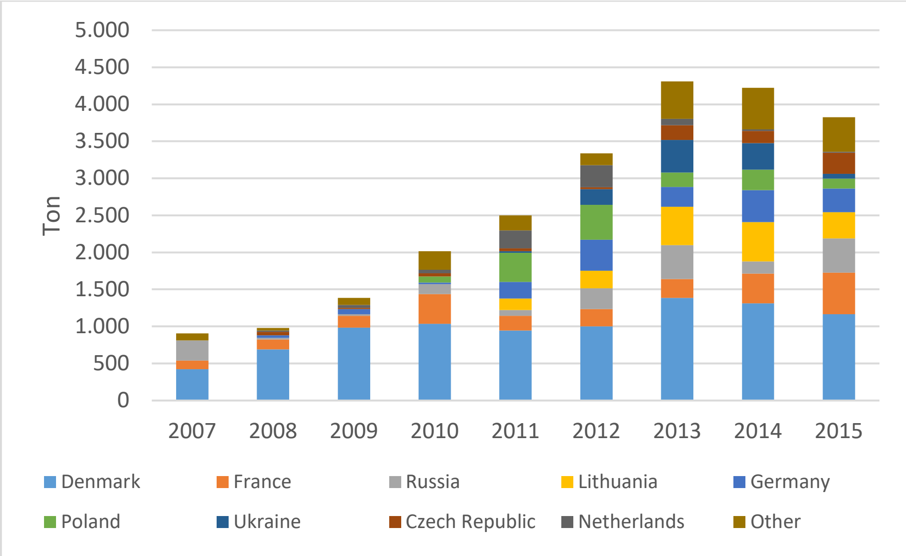


Figure 5. Main export countries for canned Icelandic fish liver 2007-2015

Akraborg ehf. is the largest canning company in Iceland, producing 2.500 tons annually (12-13 million cans), and 95% of the production are hot smoked canned liver or liver pate.

The export of liver pate has increased in recent years and culminated in the year of 2013 with 35 tons valued at 35 million ISK. Liver pate exports from 2010 to 2015 are shown in Figure 6 (Statistics Iceland, 2016).

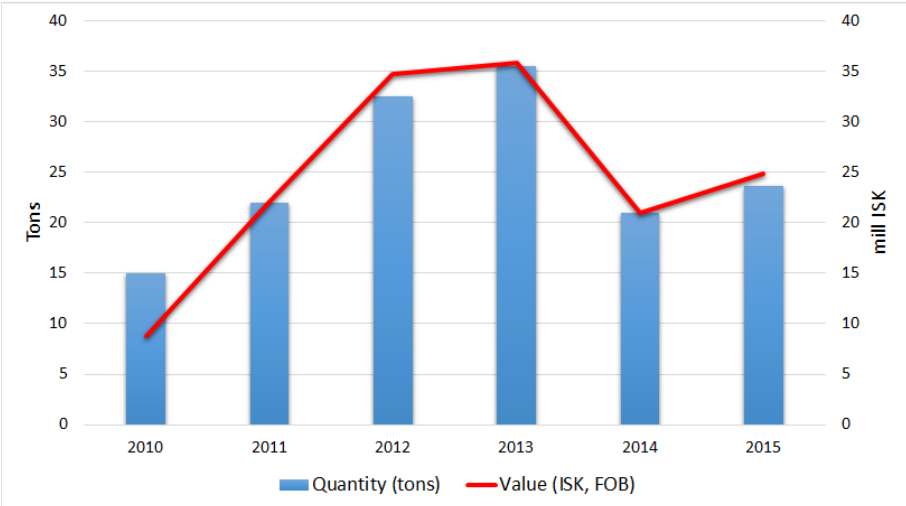


Figure 6. Export of liver pate in 2010-2015.

The production volumes and values of liver pate in the Icelandic seafood industry have been rather insignificant in recent years, as markets for these products have been limited.

In 2009 the Icelandic exports of fish oil from all species peaked, reaching 85.000 tons. The following years export decreased and was 37.000 tons in 2014, as shown in Figure 7 (Statistics Iceland, 2016)

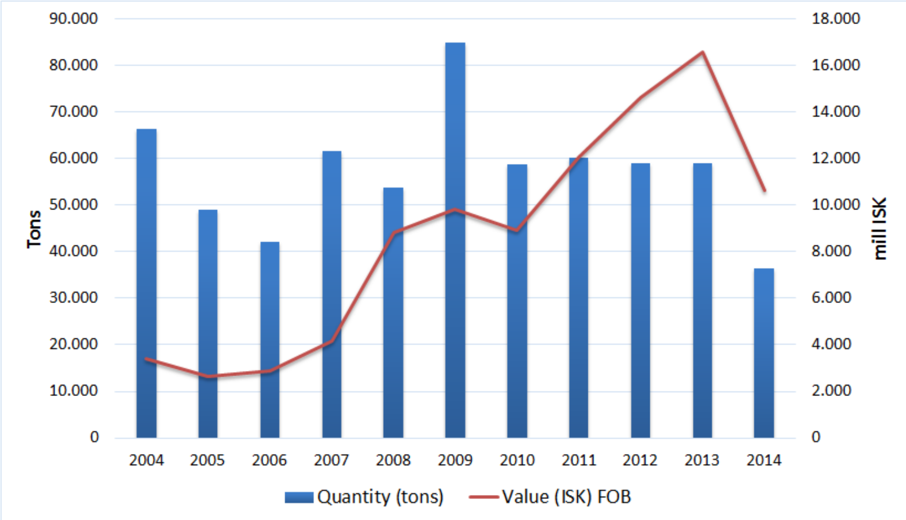


Figure 7. Export of fish oil from all fish species in 2004-2014.

Majority of the fish oil produced in Iceland is coming from pelagic species and are intended for animal feed, primarily aquaculture. Production of cod liver oil for human consumption has fluctuated between 2.500 and 4.000 tons in recent years, as shown in Figure 8 (Statistics Iceland, 2016).

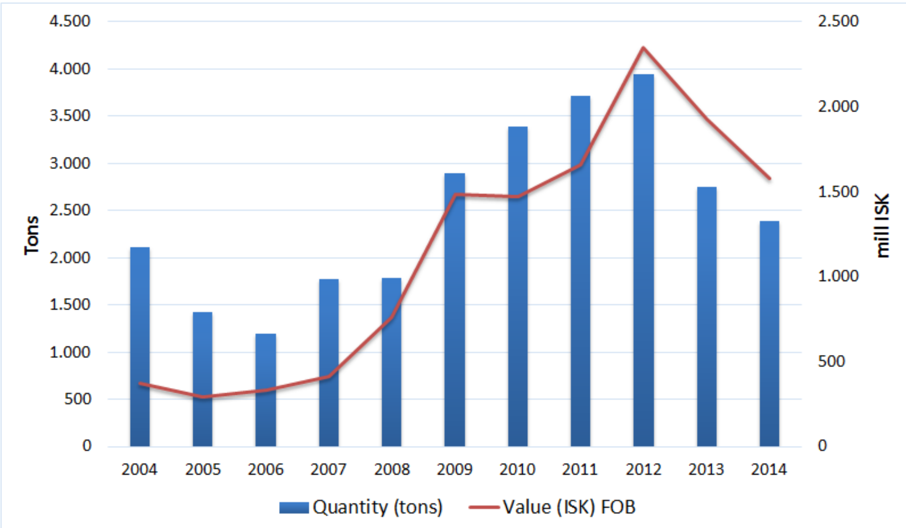


Figure 8. Exports of cod liver oil 2004-2014.

Cod liver exports in 2015 remained similar in quantity as in 2014 and the main export countries were China (22%), UK (15%), Germany (9%) and USA (7%) (Statistics Iceland, 2016).

Roes

Exports of frozen roe from whitefish were solely cod roes in the years of 2004 to 2014. Volumes and values have increased significantly in the past decade, as can be seen in Figure 9 (Statistics Iceland, 2016).

Figure 9. Exports of frozen cod roe 2004-2014, quantity and value (FOB).

Exports of salted roe have decreased for the past years and in 2014 the exports only amounted to 428 tons, as shown in Figure 10 (Statistics Iceland, 2016).

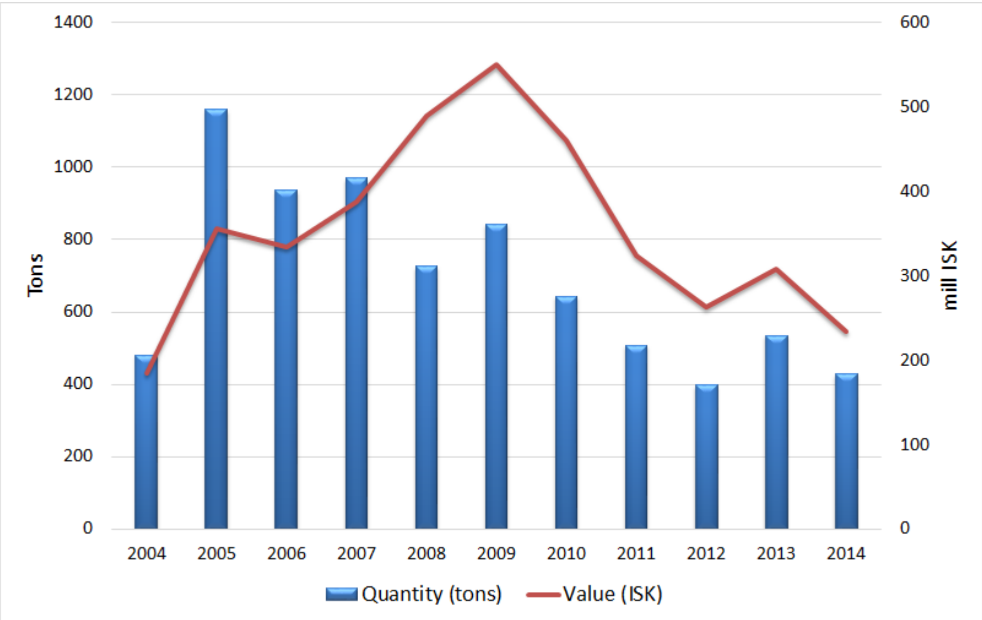


Figure 10. Export of salted cod roe 2004-2014, quantity and value (FOB).

The reason for decreasing export of salted cod roe from 2010 to 2014 is potential the increased export of frozen cod roes in the same period.

Milt

The amount of milt in cod is around 2 % (Þórarinsdóttir, Guðmundsdóttir, & Arason, 2005), but negligible amounts of this material is brought ashore; which is partly caused by difficulties with collecting and storing the milt on-board the vessels. Exports of milt products are therefore almost non-existent, even though there are considerable opportunities and established markets for such products, especially in Asia. Some years ago, companies in Iceland produced milt as canned product (Figure 11), but the competition on global markets is very difficult. In 2015 the export of canned cod milt was around 40 tons (Table 1).

Figure 11. Canned milt with garlic and paprika.

Table 1. Export of canned cod milt.

	2014	2015
Quantity (tons)	13.4	40.2
Value (mill ISK)	12.5	40.7

Cod milt is a product which is a part of traditional Japanese cuisine and is consumed in the household market as well as in restaurants. It is consumed as appetizer or as a type of snack food. In this case it is normal to pour some vinegar and drops of soya sauce over the milt and serve with some sake. Also milt is served in addition to meat, cod fillet, soybean curd, salt and vegetables cooked together in a deep pot or saucepan. Cod milt is traded in quite big volumes in Japan, and a rough estimate is 8.000 to 12.000 tons on an annual basis (Tønsberg, Wong, Hong, & Tangen, 1996). Also canned milt is a popular product in Britain, Romania and Russia.

Fish heads

Fish heads have been dried in Iceland for decades together with fish faces, tongues and cheeks which have been processed as fresh frozen or salted products. Following is a discussion of various products produced from fish heads in Iceland.

Dried fish heads

Traditionally, fish and fish heads used to be dried by hanging them on outdoor stock racks, but indoor drying began in 1978 (Arason, 2013). The first company to start drying cod heads indoor was Langeyri in Hafnarfjörður. The introduction of indoor drying technique was a turning point, as it made drying possible all year round and shortened the production time significantly (Arason, 2003a). The market conditions for dried fish heads was though difficult in the starting years of the indoor drying, but in 1985 the markets in Nigeria opened wide up and exports of dried cod heads multiplied. In the beginning of the 80's the annual production of dried fish heads was around 1.000 tons, but in 2015 the production was over 15.000 tons which equals to over 75.000 tons of wet raw materials.

Figure 12. The first company where indoor drying began was Langeyri in Hafnarfjörður (left) and stock racks for outdoor drying of cod heads (right).

Utilization of dried cod heads is considerable and most of the products are exported to Nigeria. Today, indoor drying is located where geothermal energy is found. The reason is that the cost of oil or electricity for heating during the drying process is considerably higher than the cost of using geothermal energy. Companies in Iceland which that produce dried products from fish heads are thirteen, with the largest company Haustak located in Reykjanes (Figure 13).

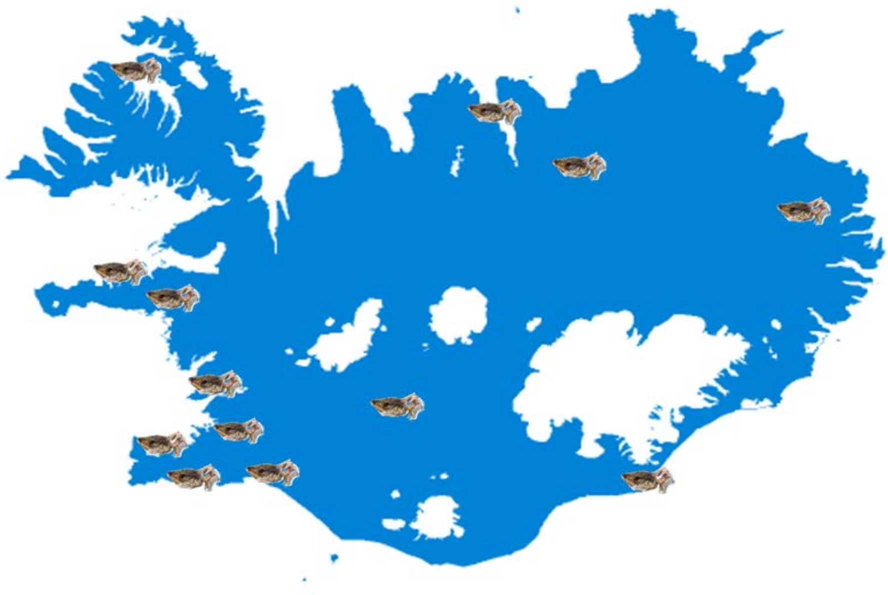


Figure 13. Fish heads drying companies in Iceland.

On September 1st 2012 a regulation came into force that obligates Icelandic fishing vessels with on-board processing to bring ashore a certain proportion of cod heads that derive from catches within Icelandic waters. It requires the largest factory vessels to bring ashore at least 40% of cod heads, medium size trawlers are to bring ashore at least 30% of cod heads, but the smallest trawlers are exempted from the regulation, but majority of Icelandic factory vessels fall within that category. The regulation has had limited effects on the amount of landed cod heads, as most factory vessels subjected to the regulation had already met with the requirements long before the regulation came into effect. It is primarily the smaller vessels that do not land significant amount of cod heads, but they are excluded from the regulation anyhow. There is potential for improved utilization of cod heads and cod head by-product on-board Icelandic factory vessels, but size, age, equipment and current operational environment for these vessels are limiting factors (Viðarsson & Þórðarson, 2015). The ratio of cod heads brought ashore has increased from 6,8% in the year 2008 to 40% in the catching period 2013/2014. In the year of 2014 the export of dried heads from all species (mainly from cod, haddock, saithe, ling and tusk) was 14.800 tons, but the volume has remained relatively even for the past decade whilst the value has increased substantially, as shown in Figure 14 (Statistics Iceland, 2016).

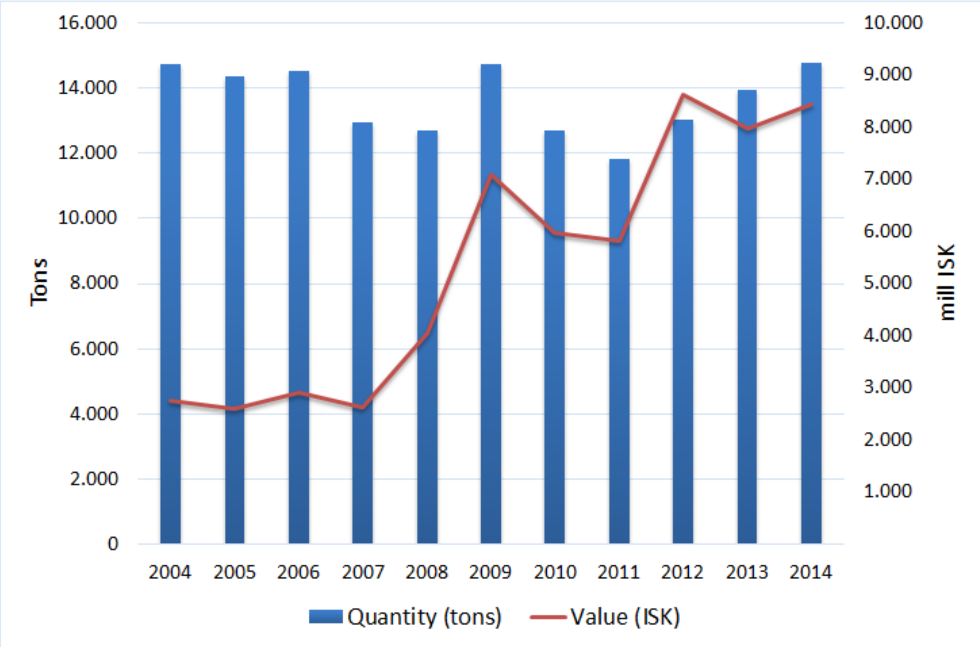


Figure 14. Icelandic exports of dried fish heads from all species 2004-2014.

In 2015 the Nigerian market for dried fish heads more or less closed, due to a collapse in the world price of oil; which is Nigeria's main export product. There are therefore uncertainties regarding market conditions for dried fish heads when this report is written. Icelandic processors are though fairly confident that oil prices will rise in near future and the markets for their products will subsequently open again.

Fish faces, tongues and cheeks

There are a number of by-products that can be produced from cod heads and many of them are of high value, especially salted products that have strong markets in S-Europe. Tongues and cheeks are the most popular, especially from big cod heads, were the small heads are more suitable for drying. Cheeks and tongues are usually salted or frozen.

Fish heads contain relatively little meat. However, the meat from the fish head is considered a delicacy due to its taste and excellent texture. If cod heads are taken as an example it can be assumed that the tongue constitutes approximately 1-4% of the weight of the head, cheeks 5-15%, collar 15-20%, and upper head meat 5-15% (Arason, 2003b).

In Iceland, as in many other countries, fish tongues and cheeks are considered delicacies. Until recently a major obstacle for processing these products at an acceptable margin was the relatively high labour costs needed, but now the Icelandic company MESA has produced a machine that can process the heads (Figure 15).

Figure 15. Production from Mesa 900 machine, upper right collar bone, down left tongues, down right cheeks.

The machine can for example process products of the cheeks and tongues from cod heads. Another machine is used for splitting fish heads and tearing the gills out. In 2013 Matís was involved in a research with Møreforskning, Norway, testing the Mesa 900 machine. Cod heads of different sizes, from cod caught by bottom trawls and longlines were compared. The results showed that the efficiency and yields from the machine are extremely good, as shown in Table 2 (Kjerstad, Jónsson, & Benjakul, 2013).

Table 2. Ratio of different fish head parts as processed by Mesa 900.

Trawl caught fish head	Cheeks	Tongues	Collars
1-1,4 kg	14,0%	2,0%	39,7%
1,6-2 kg	16,5%	2,2%	25,0%
Longline caught fish head			
930 g	21,0%	3,4%	21,3%
858 g	25,2%	3,2%	22,1%

Exports of fresh frozen tongues have increased rapidly for the past years, as can be seen in Figure 16 (Statistics Iceland, 2016).

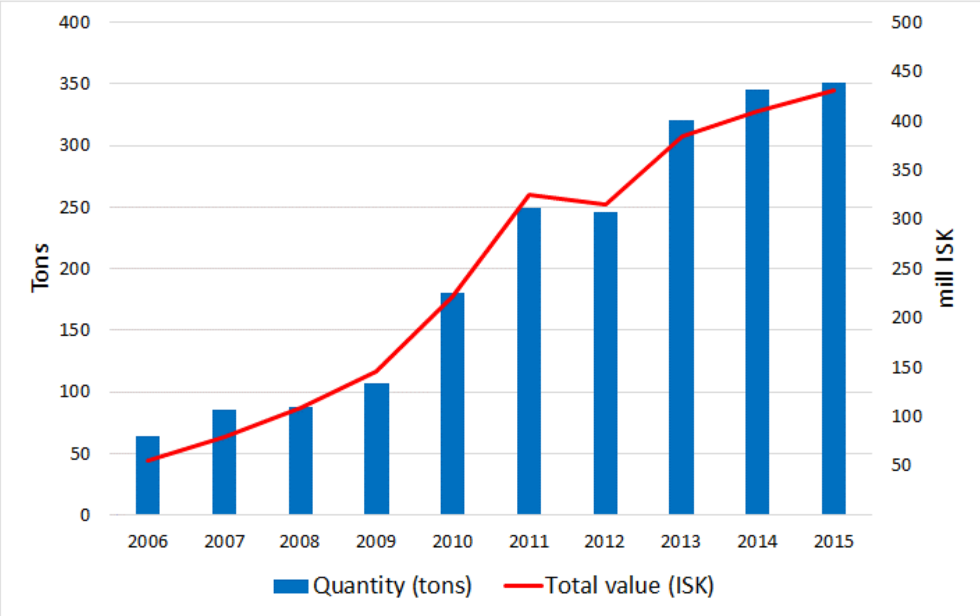


Figure 16. Exports of "fresh frozen" tongues of from cod heads 2006-2015. Value (FOB).

The largest market for fresh frozen cod tongues has been in Spain ever since 2011. Spain accounted for 45% of the exports in 2015, but other important markets are Belgium, Netherlands and Canada, as can be seen in Figure 17 (Statistics Iceland, 2016).

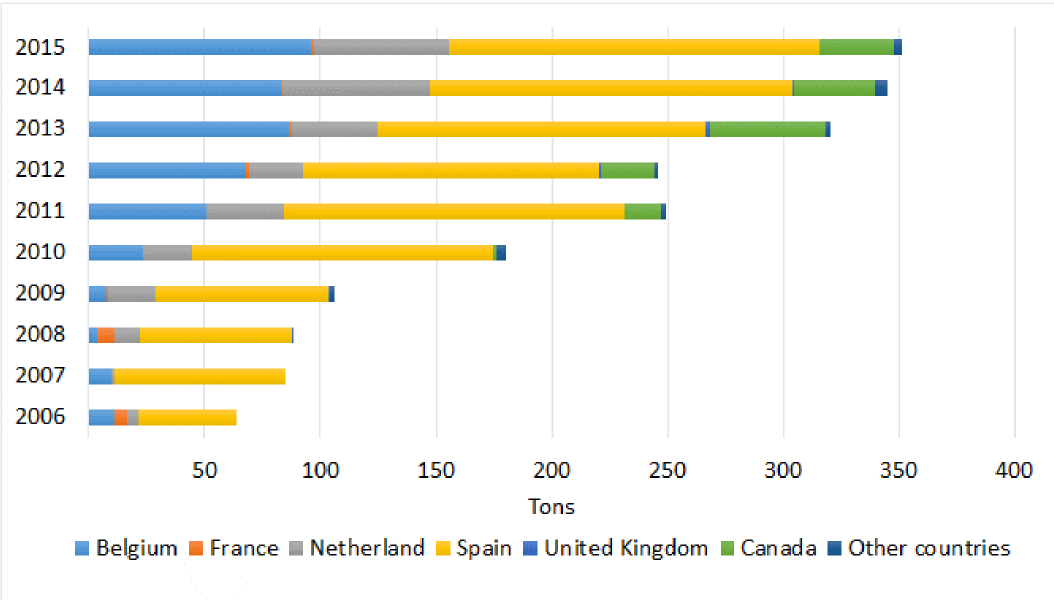


Figure 17. Export of "fresh frozen tongues" in 2015 by country. Value (FOB).

In the year of 2012 the customs code in Iceland were changed. Before 2012 the definition of cod cheeks was "*fresh frozen cod cheeks*" (Figure 18). After that it was impossible to define what was really pure cod cheeks. It was given a new customs code under the definition of "*Frozen cod heads, cod faces and tongues AND Frozen cod faces, excluded tongues*" (Table 3) This also applies for Figure 20 about "Fresh frozen fish faces from cod heads".

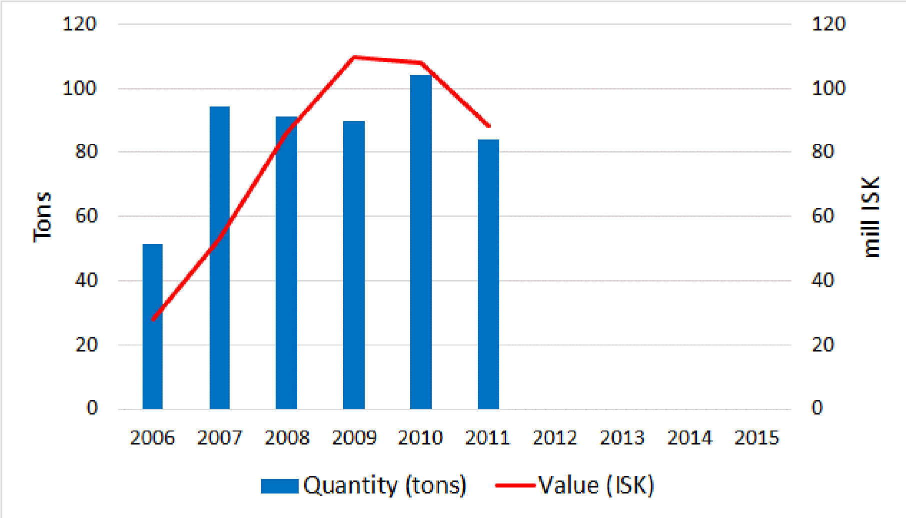


Figure 18. Exports of "fresh frozen" cod cheeks 2006-2015. Value (FOB).

In the years of 2006 till 2011 the largest market of fresh frozen cheeks was France, with 76-82% market share, as shown in Figure 19 (Statistics Iceland, 2016).

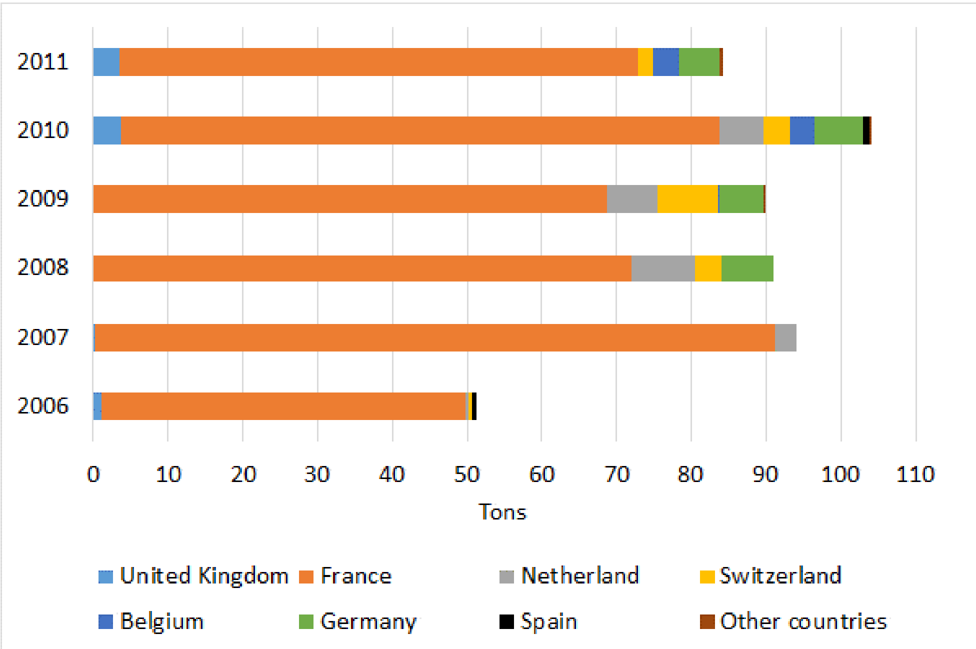


Figure 19. Volumes of exported "fresh frozen" cod cheeks 2006-2011 by country.

The largest markets for fresh frozen fish faces are Lithuania, China and Nigeria.

Last year the export of frozen cod faces without the tongues were nearly 2000 tons at a value of 170 mill ISK (Table 3).

Table 3. Export of frozen cod heads, cod faces and tongues AND frozen cod faces, excluded tongues.

Product	Frozen cod heads, cod faces and tongues			
	2012	**2013**	**2014**	**2015**
Quantity (tons)	434	222	29	122
Value (mill ISK)	64	27	7	16
Product	**Frozen cod faces, excluded tongues**			
	2012	**2013**	**2014**	**2015**
Quantity (tons)	1.166	794	1.791	1.926
Value (mill ISK)	266	68	136	170

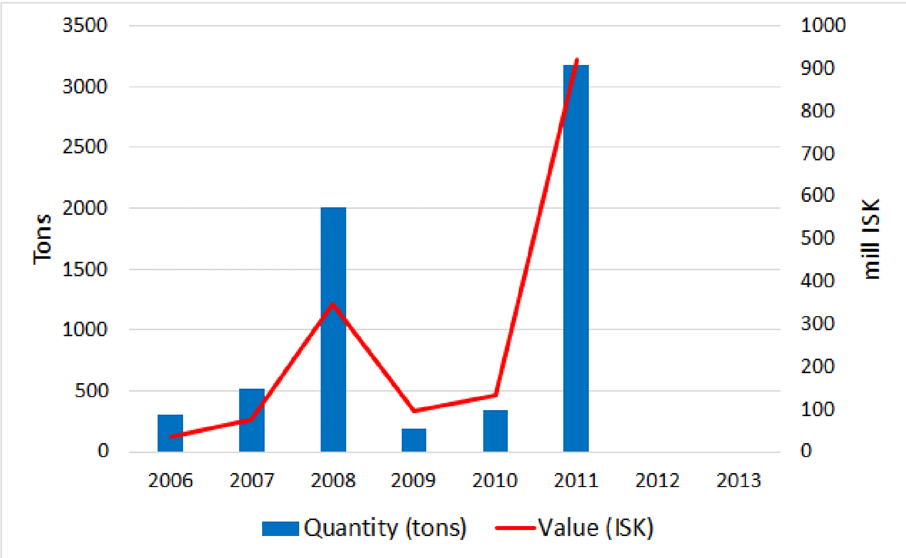


Figure 20. Exports of fresh frozen fish faces from cod heads 2006-2013. Value (FOB).

Since 2009 the export of dry salted tongues has increased rapidly, from 4 tons to 160 tons, as can be seen in Figure 21 (Statistics Iceland, 2016). The largest market for this product is Spain with a market share of 90%.

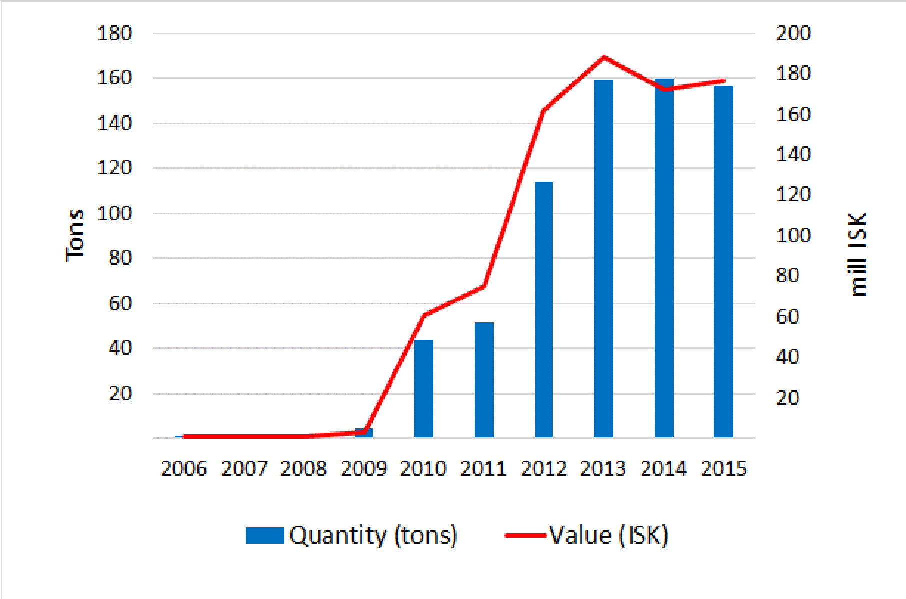


Figure 21. Export of dry salted cod tongues 2006-2015. Value (FOB).

The annual exports of brine salted fish faces have fluctuated between 900-1.700 tons in the past decade. The exports amounted to 1.600 tons valued at roughly 400 million ISK in 2015, as can be seen in Figure 22 (Statistics Iceland, 2016).

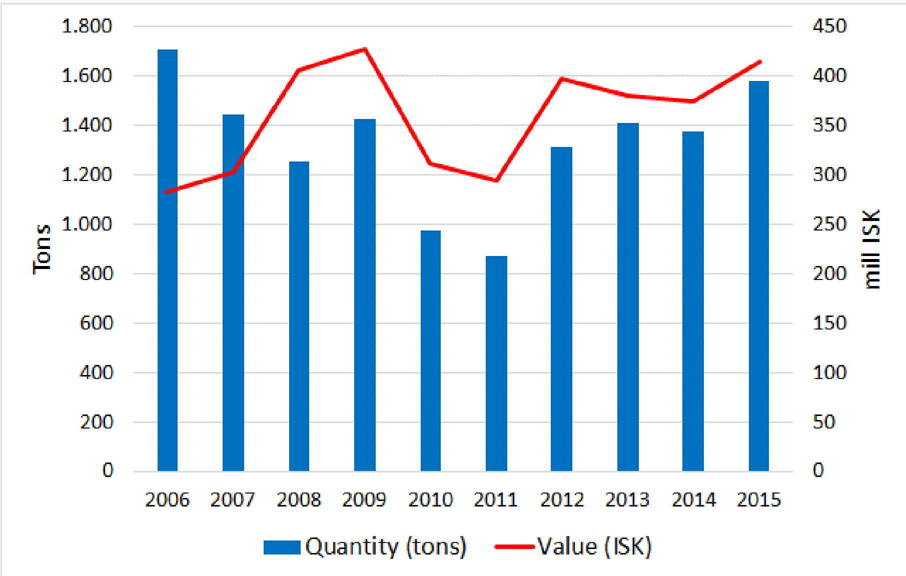


Figure 22. Export of brine salted fish faces (tongues and cheeks) from cod 2006-2015. Value (FOB).

The main market for these products is Portugal, which accounted for 90% of the exports in 2015.

Eyes

Fish eyes are important food items in many parts of the world, especially for the amino acid composition. In Japan fish eyes are generally processed for fish oil production (Tønsberg T. W., 1996).

The eyes of cod contain a high amount of vitamins. It also contains long chain polyunsaturated fatty acids, specially Docohexaenoic acid (DHA) and research has shown associations between dietary intake of DHA and improvement in brain development, cognition and behaviour (McCann, 2005).

The university of Auckland in New Zealand is looking into whether fish eyes, a low-cost by-product of the fishing industry, can be turned into corneas the clear, protective layer at the front of the eye. More than 250 corneal transplants are performed in New Zealand each year and with an ageing population, demand has grown for technology to provide an alternative to donors. Worldwide, about 10 million people are blind from damaged corneas, but only about 100 thousand transplants are performed each year because of donor shortages (website couriermail.com).

Fish cut-offs, belly flaps and mince

Cut-offs is the by-raw material left after filleting and trimming of the fish. The cut-offs have been utilized in feed processing and in the fish and meal industry. The cut-offs and belly flaps have also been processed further to valuable products. The export amount of pure cut-offs have decreased for the last five years, and was in 2015 238 tons at a value of 49 mill ISK (Figure 24).

Figure 23. Mince from cut-offs.

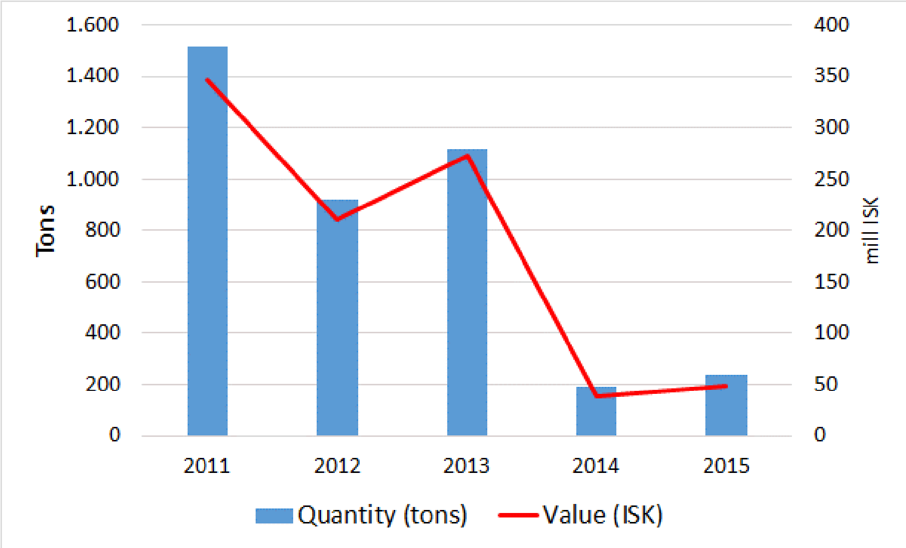


Figure 24. Export of frozen cut-offs in 2011 to 2015. Value (FOB).

Some of the cut-offs have been minced or salted and the belly flaps have been processed in mince, frozen in blocks or salted. For the last five years the export of belly flaps reached its maximum at nearly 600 tons and decreased to 400 tons in 2015 at a value of 179 million ISK (Figure 25).

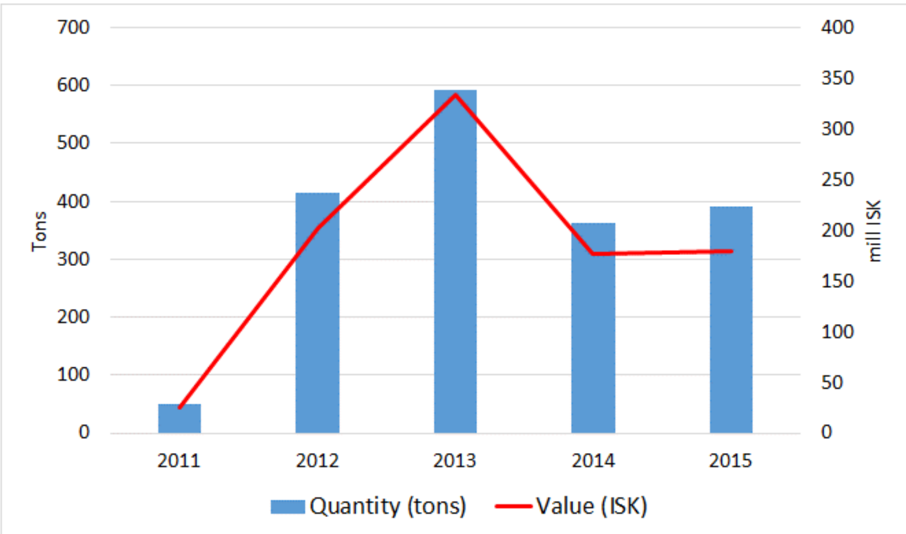


Figure 25. Export of frozen or salted belly flaps in 2011-2015. Value (FOB).

In 2015 the export of mince from cut-offs was 3.500 tons, at a value of 750 million ISK (Statistics Iceland, 2016) (Figure 26).

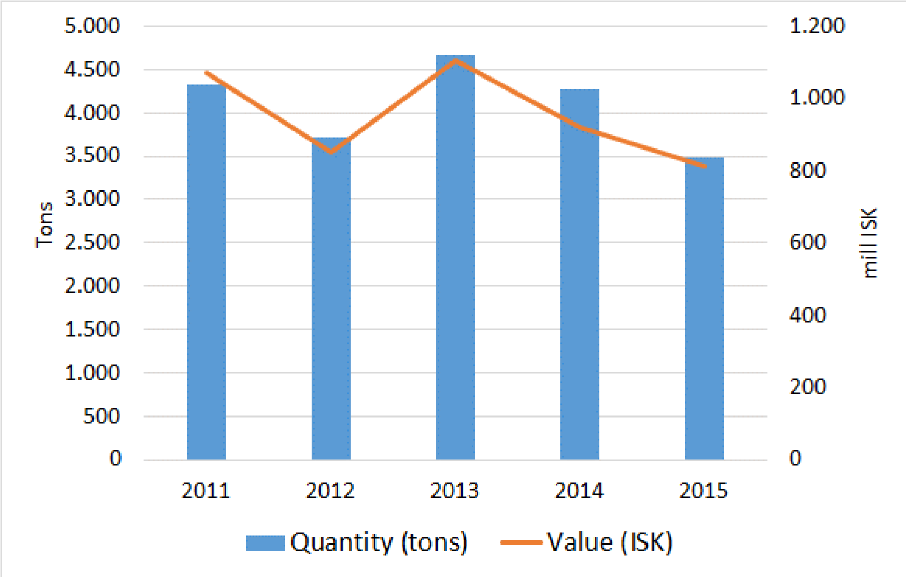


Figure 26. Export of frozen mince in 2011-2015. Value (FOB).

When fish flesh is minced the texture, flavour and sometimes the colour are changed. Mincing offers an opportunity to exercise greater control over flavour, appearance and keep quality by the incorporation of additives. Fish mince has also successfully been used directly in various food systems and physically or chemically altered form to produce nutritional and functional products.

Recently new applications for mince have emerged, as a material in protein products for fillet injection. Use of mince is known in surimi products, but surimi originates from Japan where it has been a traditional food source for centuries. Research indicates that surimi could be converted to a dried form, surimi powder (Montejano, Morales, & Diaz, 1994). In powdered form, surimi can be kept without frozen storage. The powdered surimi offers many advantages in food production because of its physical properties, such as of handling, lower distribution costs, more convenient storage and usefulness in dry mixes. The freeze-drying process does not damage the functionality of myofibrillar proteins. But freeze-drying can on the other hand lead to increased cost. The most important properties of surimi powder are its gelling ability as well as being a colourless and odourless stable protein mass. These features enable surimi to be used in various products. In the western countries, surimi products are used to imitate seafood products, such as crab, abalone, shrimp, calamari and scallop. Several companies produce surimi sausages, luncheon meats, hams and burgers. A patent was even issued for the process of making imitation steak from surimi (Hartman, Delahunt, Robert, & Gorgon, 1993). Surimi is also used to make kosher imitation of shrimp and crabmeat, using only kosher fish such as Pollock.

Fish frames, backbones, collars and tails

After filleting of round-fish, the remains are the frame and the tail, which is 15-20% of the gutted fish. When trimming, the pinone is cut off along with other trimmings, which is 1-3% of the fish weight. When splitting the backbone, the backbone is 8 % of the weight of the fish (Sigurgísladóttir, Margeirsson, Arason, & Viðarsson, 2010). This raw material is utilized as far as possible when processing on-land, where they are mainly dried and sold to Nigeria. Processing is rather easy and inexpensive in Iceland where access to geothermal energy is available. These by-raw materials are however not brought ashore from the freezing vessels, because of difficulties with freezing and storing the frames on-board.

The company Arc Tract was founded in 2011 and is located in Ísafjörður on the west part of Iceland. The company produces savory fish extracts from fish, including the remaining fish muscle from frames. The extracts are to be used to enhance and improve fish taste in fish-dishes and soups. The company sells its products in bulk packaging to industrial manufacturers or food products.

Figure 27. Fish powder and bouillon

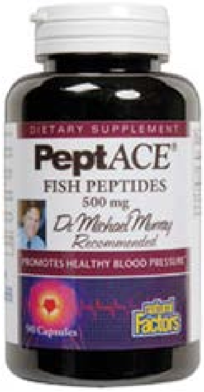
The export value of dried fishtails per kg have decreased from 516 ISK in 2012 to 462 ISK in 2015 (Figure 28).

Figure 28. Export of dried tails in 2012-2015. Value (FOB).

Usually the pinbones and trimmings are processed in mince. Considerable quantities of fish flesh can be removed from the remaining backbones and the frames after filleting whitefish. In Iceland practically no fish mince is produced except from the cut-offs from the production of boneless fillets.

Fish protein isolate

Fish protein isolate (FP) is a fish protein which has been purified to a protein content of at least 90% of the dry material and contains less than 1% fat/oil. The term FPI is in general used for pure fish muscular proteins which have been produced by pH-shift process (Kristinsson H. , 2006), (Þorkelsson, et al., 2008). The pH shift method is based on solubilize muscle proteins by subjecting diluted, finely homogenized fish meat to either very low pH (2.5-3) or a very high pH (10.8-11.2) at low temperature. Solids such as bones, scales, neutral fat and disrupted cellular lipid membranes are then removed by centrifugation and the soluble protein is precipitated by adjusting the pH to the isoelectric point of the myofibrillary proteins to give a protein isolate (Kristinsson & Rasco, 2000). Protein gels made from protein isolates recovered with the process have shown to have equal and sometimes significantly better gelation properties than those produces using conventional surimi processing techniques, and also shown to improve other functional properties (Choi & J.W., 2002); (Hultin, Kristinsson, Lanier, & J.W., 2005).



The use of multi-needle injection of fish proteins in fish fillets have been reported (Þorkelsson, et al., 2008). The fish protein injection is believed to enhance the yield and improve the frozen stability of fish fillet. FPI can be used as a dipping solution in battering and breading process to reduce absorption of oil in fried products. Also FPI can be used in production of emulsion based fish products, by mixing FPI with ingredients such as vegetable proteins, starches, wheat flour, spices etc. and forming fish pate into intended product shapes. Fish protein isolates can also be used in production of surimi. In Western countries surimi products are used as a copy of various seafood products like crabmeat, shrimps and scallops.

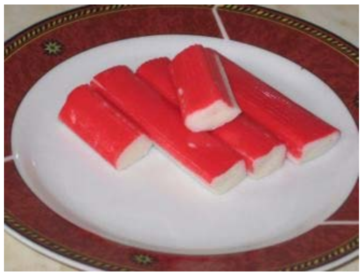


Figure 29. Surimi

Fish protein hydrolysate

Fish protein hydrolysate (FPH) is similar to fish protein isolate, except that the production process depends on using various biological processes, utilizing enzymes in particular, to cleave molecular bonds. More or less all fish raw materials can be used in FPH, where it is first grounded up and transformed into a liquid, where enzymes can for example be used for dissolving bones, scales and other materials. Once the FPH has been produced in liquid form, the water can be removed and in some cases it is even fully dried into powder. FPH is mainly used for animal feed, fertiliser and in some cases for human consumption where it is for example used as nutraceuticals and functional food additives. FPH have a number of functional and antioxidant properties and have an ability to be used in products with various desirable physical and sensory properties. FPH can also be used to produce protein enriched and oxidative stable seafood products (Duksas, Falch, Slizyte, & Rustad, 2005); (Slizyte, Dauksas, Falch, Storro, & Rustad, 2005). FPH have good functional properties and can contribute to improving water holding capacity, texture, gelling, whipping and emulsification properties when added to food (Kristinsson H. , 2006). Fish protein hydrolysates are rich in bioactive peptides, which function as immune-stimulants, have anti-carcinogenic effects and anti-anemia activity (Underland, *et al*., 2009).

Possible applications of FPH as ingredients in food system:

- Functional food ingredients
- Antioxidant
- Flavour enhancer
- Salt and monosodium glutamate (MSG) replacer
- Milk replacer
- Protein enrichment (i.e. for sport drinks)
- Bioactive ingredients

The main volume of FPH produced in the Nordic countries are for feed and pet-food industry, however there are companies that are producing food-grade FPH for the food industry.

Fish skin

Fish skins have presented a challenge for the Icelandic seafood industry, as opportunities for utilization have been scarce in the past and it has been costly to dispose of them. Many Icelandic processors have therefore exported frozen fish skins, primarily to Canada, with little or no margin. The skins that are exported are mainly used in the production of collagen and gelatine, or dried for the pet-food industry.

This is though hopefully changing now, as the company Codland is working on setting up a processing plant in Grindavík that will process collagen from fish skin. The collagen plant will be able to process all fish skins that the Icelandic seafood industry can supply.

Figure 30. Various products from fish skin.

Fish skins are also used in productions of textiles, clothes, shoes, handbags and other fashion products (Figure 30).

There have also been made attempts to produce spiced and dried snacks from fish skins in Iceland, but that has not yet lead to market scale production (Kárason & Sveinþórsdóttir, 2014).

The company KERECIS in Iceland is an example of a company that is using innovative approaches for producing products from fish skin. They have developed wound patches and tissue regeneration solutions from cod skin that assist in healing difficult wounds and transplantation of skin tissue.

The main opportunities for utilisation of fish skin in large amount are though collagen and gelatine.

Collagen

Collagen is the primary structural protein of the body, playing a vital role in the formation and maintenance of bones, tendons, ligaments, hair, nails, and skin. Collagen can be produced from different sources, including fish skins and can be used both as gelatine and hydrolysed collagen. Utilization of fish collagens are globally of interest to the food processing industry as well the health industry. Research has shown that orally administrated collagen peptides reduce the effects of ageing on skin and improves joint health. Collagen is used in medicines for arthritis and osteoporosis. Then it can be utilized in cream and other cosmetics for skincare. The high nutritional value of collagen makes it an excellent additive in functional food and food supplements. The company Codland in Iceland is preparing a production of collagen in powdered form.

Gelatine

Gelatine is derived from collagen and is primarily used as gelling agent in food, pharmaceuticals and cosmetics. Gelatine made from cold water fish skin is well known for their extremely good emulsifying and film forming properties, which makes them popular for making pharmaceutical fast-dissolving tablets. But they are also popular as protein additives for nutraceutical, cosmetic and food applications.

Fish viscera (offal)

Viscera (including liver and roe) constitute between 10-25% of the net weight of the fish. The viscera contain various valuable materials. These include oils which contain the omega 3 fatty acids eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). These acids have been utilized in health products and pet-food or feed for animals and farmed fish (Bechtel, 2003). EPA is believed to provide protection against coronary heart disease by reducing the risk of blood clotting and clot formation, as well as providing protection against atherosclerosis. DHA has an important role to play in the development of the brain and central nervous system (Horrocks & Yeo, 1999).

For many decades the Icelandic seafood industry has regarded the viscera as waste, and has therefore missed out on opportunities for utilisation. This has however been changing in recent years. This change is both fuelled by the fact that producers see potentials in producing commercial products that return some margin, but also because of increased emphasis on environmental disposal laws.

Among the simpler methods of utilising viscera is to freeze it and then use as mink-feed, which has been a common practice in many fish processing plants that are sourcing ungutted fish. More technologically advanced solutions, which provide higher margin, are though also being applied. The company Héðinn has for example developed, in cooperation with Matís, a protein plant that can utilize viscera/offal from fish; producing oils and fish meal (Figure 31).

Figure 31: The Héðinn Protein Plant

The Héðinn protein plant takes up very little space and can fit in a standard transportation container, making it possible to be placed in small fishing villages or on-board factory vessels. The Héðinn protein plant will for example be on-board a factory trawler that the Icelandic seafood company Rammi is currently having built. Also, the company Codland in Iceland have been producing the same products from viscera.

Figure 32: The factory trawler that Rammi is having built and will have the Hérðinn Protein Plant on-board

Offal ratio varies between seasons, size and maturity of the fish. For example, offal ratio in cod is at maximum just before and during the spawning period. Offal ratio can be 35% (including liver, roe and stomach full of feed) for the biggest fishes. After spawning the ratio decrease to 10-15%, and sometimes down to 5% (Jónsson, Viðarsson, & Arason, 2009); (Ríkharðsson, 1992).

Viscera and other offal can be used for producing various products such as feed, silage, fertiliser, enzymes and fuel. In addition, some of the organs can be used for production of valuable by-products e.g. gall bladder and swim bladder.

Fish silage

Fish silage may be described as a liquid product made from fish or parts of fish, like viscera, after addition of acid, such as formic acid. The liquefaction is caused by the action of enzymes naturally present in the fish, and is accelerated by the acid which creates the right conditions for the enzymes to break down the tissues and limits the growth of spoilage bacteria.

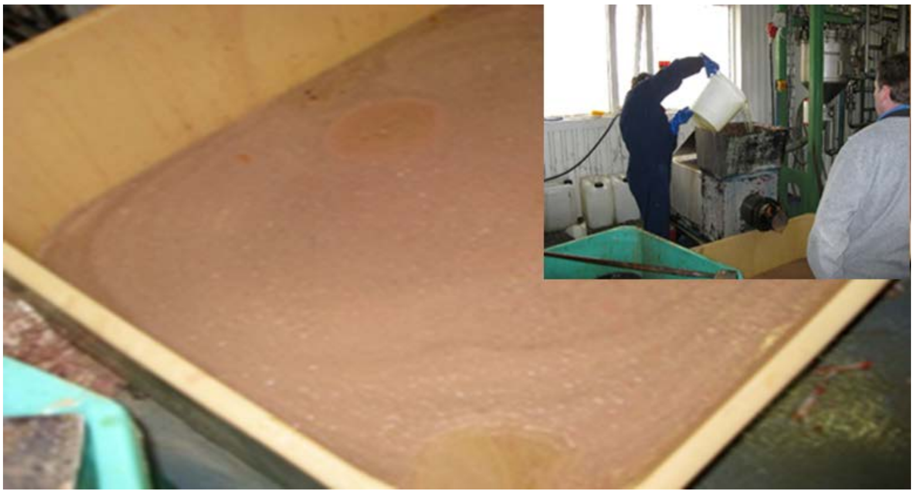


Figure 33: Fish silage ready to be spread on fields

Organic acids are most commonly used for silage production from fish, like formic acid. In some cases, industrial enzymes are added to the silage to speed up the process of breaking down the tissues (Jónsson, Ásbjörnsson, & Arason, 2014). The product then has an increased shelf life and can be further processed to fish meal and fish oil, or for the processing of fertilizers on fields and in the horticultural industry.

In the Nordic countries production of fish silage is significant, especially in Denmark and Norway. In 1976 a production of fish silage from capelin was started in Iceland and the silage was exported to Denmark and Norway during the years 1980-1990. In Norway the silage is mostly used as a feed for fur animals. Many years ago fish silage was processed and utilized in Iceland as a binding agent in grass pellets, and later this technology was used in production of feed pellets in Norway for salmon farming, with good results.

Production of fish silage in Iceland has been almost no-existent for some decades now, but this seems to be changing as producers are becoming more aware of potential value creation by utilising low value raw material into silage. There are at least three companies in Iceland that are currently producing silage; these are Rammi, Codland and Lýsi hf.

Fertilizer

The use of silage from offal as a fertilizer in agriculture for plants and fields has a long history around the world. In earlier centuries it was common in Iceland to use fish offal as a fertilizer on fields. Today it is common that silage from offal is used as a fertilizer, especially in the developing countries.

With increasing interest in organic farming, silage from fish has been the optimal fertilizer. Thus, now numerous types of organic fertilizers from silage produced from various species are on the market around the world. Many research has shown the benefits of using silage as a fertilizer for plants and vegetables (Ockerman & Hanson, 2000); (Blatt, 1991); (Levin, Witkinwski, Meirong, & Goldhor, 1988).

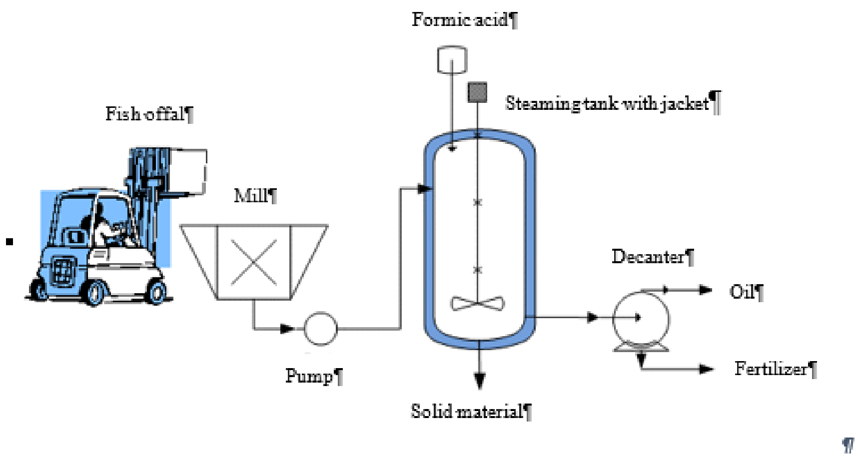


Figure 34. Typical processing line for production of liquid fertilizer from fish offal.

In many countries, agricultural pollution is a problem, mainly due to the heavy use of industrial fertilizers. A large part of the fertilizers applied on the fields are not utilized to the full, but dissolves quickly when it rains and is washed out from the soil and into the groundwater and further into the rivers and lakes.

Studies have shown that nitrogen content in fish offal is utilized more effectively than nitrogen from industrial fertilizers and manure, since much of it is lost with rainwater. The offal has more fertilizer value, where the elements are in organic forms and is slowly degradable in the soil (Ockerman & Hanson, 2000). Studies have also shown that fish products, including offal have beneficial effects on plant growth (Zhai, et al., 2009); (Celis, Sandoval, & Barra, 2008); (Stephen, Naylor, & Gordon, 1999).

The most important nutrition for plants are nitrogen (N), phosphorus (P) and calcium (K). If fish silage is spread on fields, special bacteria's in the soil synthesize particular compounds for the plant, facilitating the uptake of certain nutrients from the soil and lessening or preventing the plants from diseases (Hayat, Ali, Amara, Khalid, & Ahmend, 2010) (Figure 35).

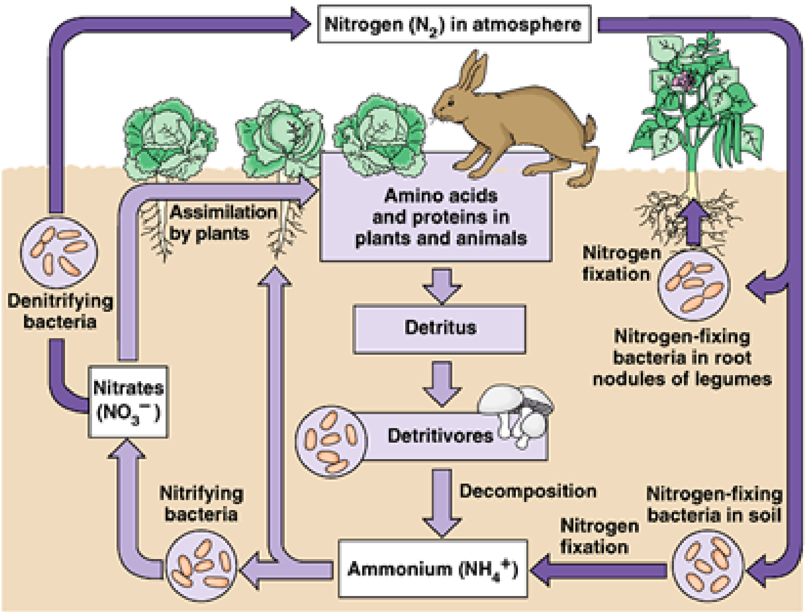


Figure 35. Synthesizing of fertilizer compounds by special bacteria's in the soil.

In 2012, Matis ohf. was involved in a project which was based on utilizing fish offal on agricultural fields. Comparison was done with cow's manure, which is typical fertilizer on Icelandic fields. The results showed that from May to July there was significantly higher protein content in grass samples treated with fish silage fertilizer compared to grass treated with cow's manure (Jónsson, Ásbjörnsson, & Arason, 2014).

Processing enzymes from viscera

The gastrointestinal tract in fish is notably rich in different enzymes, mostly aspartic and serine proteases such as trypsin, pepsin, collagenase and elastase (Shahidi & Kamil, 2002).

Hydrolytic enzyme's, especially proteinases, have many uses and potential applications in the industry, medicine and research. Among these applications are detergent production, leather processing, chemical modifications and food processing. Enzymes, isolated from cold water marine organisms, may prove to be especially useful for these purposes, as well as in medical, pharmaceutical, hygienic and cosmetic applications (Brewer, Helbig, & Haardm, 1984);

(Osness, 1985); (Ásgeirsson, Fox, & Bjarnason, 1989); (Kristjánsson, Guðmundsdóttir, Fox, & Bjarnason, 1995); (Hernandez-Cortes, Whitaker, & Garcia-Carreno, 1997).

Other applications for the enzymes are in the chill-proofing of beer, biscuit manufacture, tenderizing of meats, preparation of minimally treaded fruit and vegetable beverages and hydrolysis of various food proteins, such as gelatine, vegetable proteins and collagen. Some canning companies in Iceland have been using the enzyme Alcalase to remove the membrane of the liver before canning.

An Icelandic biotechnology company ZYMETECH has specialized in the development and manufacturing of marine-derived enzymes since it was founded in 1999. One of their products is processed from Penzyme, a pure, super-active proteinase from cod called PENZIM gel or lotion (Figure 36).

Figure 36. PENZIM from ZYMETECH

The product is a moisturizing and nourishing skin healing treatment for dry or chapped skin (Bjarnason, 2001). Another application of marine-derived enzymes is the product DermaCosmetic containing various formulations for facial skincare including body lotion, anti-aging facial serums, face mask and exfoliator treatment. The DermaZyme Health product line for troubled skin and the medical device product line consisting of PreCold, a mouth spray against common cold.

Another company that utilises enzymes within their production is NorthTaste. They produce extracts from seafood that are used for flavouring in the food industry.

Utilization of fish offal as fuel

In recent years the group "Green energy" in cooperation with the Icelandic government, has been working to promote energy shift in the country according to a report and action plan submitted to the Parliament in the end of 2011. Considerable progress has been made in these operations, for example has the number of environmentally friendly vehicles tripled since 2010. Fish offal can be used for fuel production, such as methane and bio-fuel.

Methane can be produced from all organic material, including fish offal. Methane is natural gas formed by decomposition of microorganisms of organic matter under conditions where oxygen is not available, so-called anaerobic digestion (fermentation). Such situations arise for example in wetlands and landfills, where oxygen has no access to the biomass. Methane is a good choice as a fuel source, because the burning is very clean. It forms more water than carbon dioxide when burned and very little amount of sulphur and nitrogen compounds. In methane production as a fuel from fish offal there is need to add an extra carbon source, because fish offal alone, is a rather week carbon source.

Biofuel is derived from an organic oil, for example vegetable oil that has been used for frying, oil or waste from slaughterhouses and even fish processing plants. This source of energy is common in many countries. Biofuel (Biodiesel) is much more environmentally friendly than diesel oil, and easy to create. Production of biofuel has increased in the world in recent years, especially in Europe. Such production reduces not only CO_2 emissions, but reduces the need for imported fuel to Iceland and reduces landfill waste.

Swim bladder

Figure 37. Dry swim bladder exported to Hong Kong.

Swim bladder is a popular product in China and Hong Kong and in 2013 the price in China was over 100.000 ISK/kg, if the product met consumer demands. This product is mainly used in soups or fried. The weight of the swimming bladder is only 0,05% of the weight of gutted cod. The swim bladder is both salted and dried and the biggest market for this product is in South-Europe. In many countries swim bladder is sold as a dried product. The bladder is steamed and put in mixture of spices. In Asia it is used mainly in restaurants, but also at home as a very expensive snack food. Export of dried and salted swim bladder is shown in Figure 38.

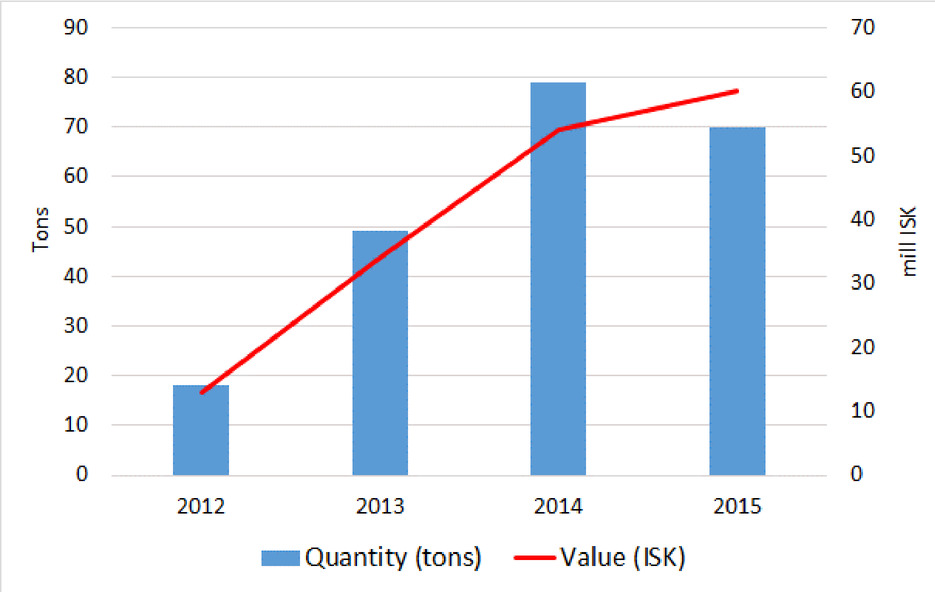


Figure 38. Export of dried and salted swim bladder in 2012-2015. Value (FOB)

The main problem with swim bladder is that the processing is very labour intensive.

Discussions

Since the quota system was implemented over three decades ago, the seafood industry has been focused on increasing the value of each kilogram of fish caught, which has resulted in increased yield and improved utilisation of all raw materials. This has for example contributed to advances in research and product development, where new processes and products have been created. Totally new sectors within the fishing industry have emerged, where high technology is being applied to make added value products from by-raw materials. Cod has for decades been the most important species in Iceland and has in recent years represented 35-40% of the total export value from seafood products (Statistics Iceland, 2016). Utilisation of cod by-raw materials have also been at the forefront when it comes to advances in developing side products, which is why majority of the products discussed in this report are derived from cod rest raw materials.

By-products can range from being of relatively low value, such as fish meal and fish oil, which are primarily used as a feed for farmed animals; to extremely high value products included in pharmaceuticals, cosmetics and functional foods. The bulk of the by-raw materials are though being used for production of more conventional by-products that have a long history of production in Iceland and established markets, such as fish oil, dried heads and canned liver.

Out of processed by-products from Iceland, the export of fish oil gives the most value of 10.500 mill ISK, with amount of 37.000 tons in 2014. Secondly, the amount of dried fish heads for export was 15.000 tons in 2014 with value of 8.600 mill ISK. The canning industry is also growing in Iceland with exported canned fish liver of 4.200 tons, at value of 2.000 mill ISK in 2014.

There are significant efforts and funds being awarded to research and development on side products in Iceland now and a large number of “untraditional” products have been introduced because of that in recent years. Cosmetics, pharmaceuticals, food supplements, fashion clothing and textiles have been marketed, and we are still to see more. The knowledge, available technology and understanding of the importance of utilising as much as possible of every fish caught is a drive that has made Iceland a world leader in utilisation of by-raw materials and has created significant value for the industry and the nation as a whole.

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