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West Nordic Fisheries

Utilization of rest raw material

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1 Introduction

Reduction of waste is a central theme which the world is currently facing. Development of a strong circular economy, where waste disposal is abolished or greatly reduced through recycling and reuse, is especially important. Many fisheries nations have forbidden all types of discarding and forced fishing vessels to bring everything ashore. But this does not always include rest raw material (RRM) like heads, liver, roes, viscera etc. There is also waste in the production sector, both at sea and in factories ashore. This is not only a waste of value but can be an environmental problem by dumping organic waste into the ocean.

Marine bio resources, especially fish, are the most important resources and of common interest to the West Nordic countries. Opportunities in Iceland, Greenland and Faroe Islands for better utilisation of marine RRMs and product development are considerable. The focus should be on increasing the value of main and side products, utilising multiple value streams, reducing waste and minimizing negative environmental impact. These actions will furthermore positively affect the economy of the region. Better use of resources within the West Nordic region, including side products, can have a vast impact on the regions small communities where the economy is almost totally dependent on the extraction and processing of marine raw materials.

Considerable efforts and funds have been awarded to research and development on the utilisation of RRMs in the West Nordic region for the last decades, especially in Iceland, but more must be done in the future. For some species, e.g. white fish and crustacean, more than half of the raw material are so called side products. It is very different between nations how those are utilized for value creation. One of the problems for traditional side products are low prices with little or no value creation. It will be a challenge in the future to find ways to increase value creation for these processes. To achieve that goal, further research is necessary, with close cooperation between the fisheries sector, the scientific community and governments.

The overall aim of this report is to give an overview over the extent and availability of biological RRMs from marine resources in the West Nordic countries, discuss promising innovation projects in each participating country and list suggested actions for their implementation in the regions. This is done with the aim of minimizing waste from marine biological resources applying new processes and technologies, creating new products and increasing value from sustainably utilised resources.

In the appendix there is a case study on Greenlandic lumpfish resource utilization and a suggestion for a research project for the 2018 season. The main purpose is to utilize the whole lumpfish as a marine resource, instead of only one third and the sub-purpose is getting better roe handling hygiene (with potentially better roe quality), better roe and body yield and better working conditions for the fishermen. Additionally, gutting fish on the processing site e.g. in a processing factory, provides better facilities for proper handling such as being cut correctly according to customer specification.

2 Fisheries and aquaculture in the West Nordic region

Fisheries and marine products are by far the most important resources in the West Nordic region (Laksá, et al., 2015) (Kristinsdóttir & Gunnarsdottir, 2016). For demersal fisheries, the fillets are the main product, but count only for less than half of the whole fish. More than 50% are therefore so-called by-products (Jónsson & Viðarsson, 2016). In Iceland, the total cod catch in 2015 amounted to 244 thousand tons in round weight and it is estimated that 77% of that biomass was utilised in one way or another, as shown in Fig. 1.

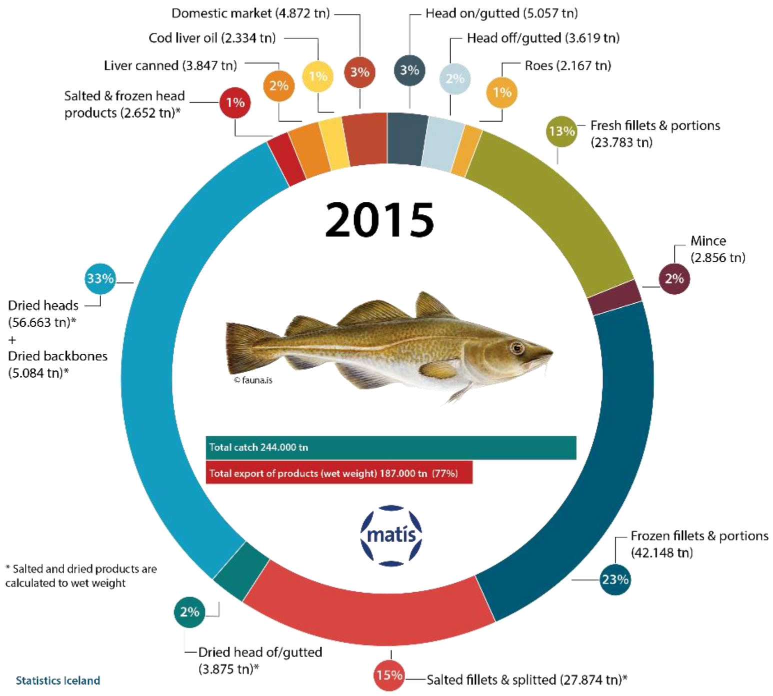

Figure 1 Total catch of cod in Iceland in 2015 (round-weight) and the total production of cod products (Pálsson, 2018)

It is theoretically possible to utilise the whole cod and if it is assumed that the entire cod catches in 2015 would have been used to produce skinless and boneless fillets the available products and RRMs would have been as shown in Table 1.

Table 1 Volume of products and rest raw materials from the Icelandic cod catches in 2015, assuming 100% utilisation and that the entire catches are used for production of skinless and boneless fillets.

Table 1 Proportion of fillets and RRMs in cod production

Products/RRMs	Proportion of round weight	Theoretical volume (ton)
Fillets	43%	104.920
Cut-offs	6%	14.640
Heads	24%	58.560
Backbones	12%	29.280
Liver	5%	12.200
Roe and milt	2%	4.880
Skin	3%	7.320
Viscera	5%	12.200
Total	**100%**	**244.000**

A total of 458 thousand tonnes of pelagic fish were caught in Iceland in 2016, and processed into various products, primarily into either fresh or frozen products for human consumption or fishmeal and fish oil for animal feed. The export of fresh and frozen products from pelagic fisheries in 2016 were 137 thousand tonnes and 80 thousand tonnes of fishmeal and fish oil.

2.1 Products

Fishmeal and fish oil, which are mainly produced from pelagic catches, are of relatively low value but high quantity and are primarily used as feed for farmed live stocks; mostly aquaculture. The bulk of the by-product production from demersal catches in Iceland have a long history of human consumption, such as cod liver oil, dried fish heads and canned liver. High value and low quantity products like pharmaceuticals, cosmetics and functional foods have been developed in recent years and are becoming more and more important within the marine sector in Iceland.

Fishmeal and fish oil are the most valuable by-products in Iceland, as 80 thousand tonnes valued at 970 million DKK were exported in 2016. Dried fish, mainly fish heads, are the second most valuable by-products, with 21 thousand tons exported in 2016 valued at 394 million DKK (Statistic Iceland, 2017). Canning of cod-liver has been a growing industry in recent years with total exports reaching 4.200 tons in 2014 at the value of 121 million DKK (Statistic Iceland, 2017).

Major development takes place in production of by-products from marine resources in Iceland with many success stories in field and most spin-offs from research and development. Here below is a list of by-products in fisheries and aquaculture from various fish production, but more detailed information can be found in the report: By-products from whitefish processing (Jónsson & Viðarsson, 2016).

- *Fish liver;* mainly from cod, used for production of fish liver oil and for canning.
- *Roes; c*od roes are sold frozen and salted. Same applies for roes from lumpfish, capelin, salmon and other species.
- *Milt;* currently milts are not used for any production and are generally not brought to shore. Some years ago, companies produced milt as a canning product, but the global market is currently difficult and no production is therefore ongoing now in the Northwest region.
- *Fish head;* fish heads are sold dried. There is also a market for parts of the fish heads like fish faces, tongues and cheeks which are sold either salted or frozen. The market for dried fish heads has however collapsed in the past years.
- *Frames, backbones and collars;* same applies for frames, backbones and collars as for the fish heads, they have primarily been sold dried to Nigeria, but the market collapsed following a financial crisis in Nigeria.
- *Bones, process water, blood, eyes, gall bladder and swim bladder;* those parts of the marine raw materials are either only used to a very limited extent or not used at all today.
- *Fish viscera (offal);* today the viscera is either sold directly to local mink farms or used for production of fish silage or fishmeal. The silage is then either sold to national processors or exported to Norway for further processing. The products in this product category have a low value and are at present mainly produced to get rid of a problem rather than to make any money for the producers.
- *Combined fish offal used as fuel;* fish offal could potentially be used for production of bio-fuel and methane.
- *Fish skin;* especially salmon skin can be used directly after processing, usually drying or frying. Some biotechnological products are already on the market. Cod skin is being processed by the Icelandic company Kerecis and sold as skin plasters for treatment of wounds and skin problems. The protein collagen can be extracted from fish skin and used a gelatine. It can be further processed to collagen hydrolysates and used as an ingredient in food products, supplements, cosmetics and nutraceuticals. The Icelandic company Codland is planning to start collagen extraction production in Iceland in the nearest future. Furthermore, in Iceland fish skin is processed into leather for fashion items (Björnsdóttir, 2017).

3 Extent and availability of biological rest raw materials from marine resources in West Nordic countries

There are enormous opportunities for the West Nordic countries to increase utilisation and value creation from biological marine RRMs and at the same time reduce environmental impact caused by the discard of organic waste. Discarding biologic materials in to the environment is harmful and causes hydrogen pollution (Biochemical oxygen) (Björnsson, 2012) in the sea. In the production process of marine biomass, it is important to prevent protein wash out and collecting protein from processing factories can create value and prevent pollution. New ideas and development is needed to use less water in the processing and prevent protein washout in the production. Lowering the production cost and keeping the proteins within the most valuable part of the product, the fillets, will give the greatest value. Collecting materials that are currently discharged and turning them into a profitable product is beneficial for everybody, as well as reducing environmental impact from the processing (Valsdottir, Stefansdottir et al. 2005). New technology and development in filtering methodology will be of importance in the future for the West Nordic countries, heavily relying on fisheries and fish production.

The value pyramid demonstrated in Fig. 2, explains the linkage between volume and value on the final products. The more specialised the production is, the less volume can be produced, since not all raw materials can be used for production of the most valuable products. But it will be the project of the future to maximize value creation from RRMs. At the top of the pyramid are pharmaceutical products with higher value, protein and fish-oil products. Collagen and gelatine products can also be quite valuable, but raw material for feed and fertilizer production is an example of low value products.

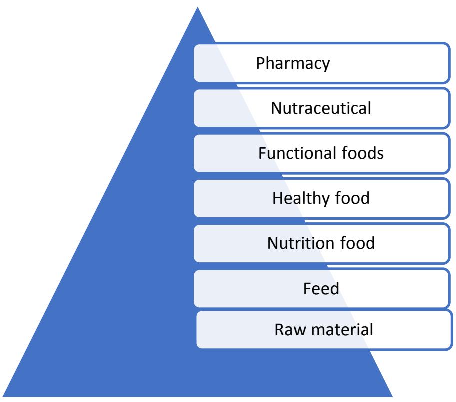

Figure 2 The value-pyramid for by-product in fisheries

The European Union is placing an emphasis on research & innovation for tomorrow's nutrition & food systems, within the focus of FOOD2030. The program is looking to increase utilisation and reduce negative environmental impacts of food production. The aim is to use as much of biological resources to feed humans as possible, as the global population is expected to reach nine billion in 2030. The importance of the West Nordic countries to contribute to food security in the future should not be underestimated, as healthy, nutritious and sustainable proteins from the Nordic marine sector have the opportunity of being regarded as a success story for other food systems. The utilisation of RRMs are therefore of great importance, not only to increase value for the companies involved, but also to demonstrate to the rest of the world that the Nordic marine sector is making responsible choices.

3.1 Iceland

Utilization of RRMs has been a high priority for the last decades in the Icelandic fishery. When solving an environmental problem and creating value at the same time it is kind of a win-win situation. It is theoretically possible to utilize all marine catches as they come on-board the fishing boats, but it is hardly realistic to reach 100% utilization rate for demersal catches. Most of them are gutted on board the fishing vessel, and today it is not economically viable to process the viscera on board, so after collecting liver and roes the rest is discarded overboard. Similarly, when demersal species are processed at sea there are RRMs like heads, frames and viscera that are, for the most part, discarded because of their low value. Regulation on minimal landing proportion of selected RRMs from processing trawlers in relation to storage space on-board has been introduced and is effective. RRM from onboard processing of pelagic species e.g. heads and viscera, are landed and processed in fishmeal plants.

3.1.1 Demersal fish

Utilization of RRMs from the catches of the demersal fleet, excluding the factory trawlers, have increased 33 times over the last 20 years. The by-products have gone from 1,600 tonnes to 53,000 tonnes (Vigfússon, Sandholt, Gestsson, & Sigfússon, 2013).

RRM from demersal fishes include heads and backbones, guts, bones, and fish skin, including materials such as enzymes, lipids and proteins, which is possible to isolate for value creation. Fish also includes important nutrients like vitamins A, D and B12 and minerals as zinc, calcium, iron, Iodine and selenium (Ottesen, Árnason, Smárason, Zhuravleva, & Björnsdóttir, 2016). Fig. 3 covers only cod, but the same by-products come from other demersal species, but the proportion differs slightly depending on species.

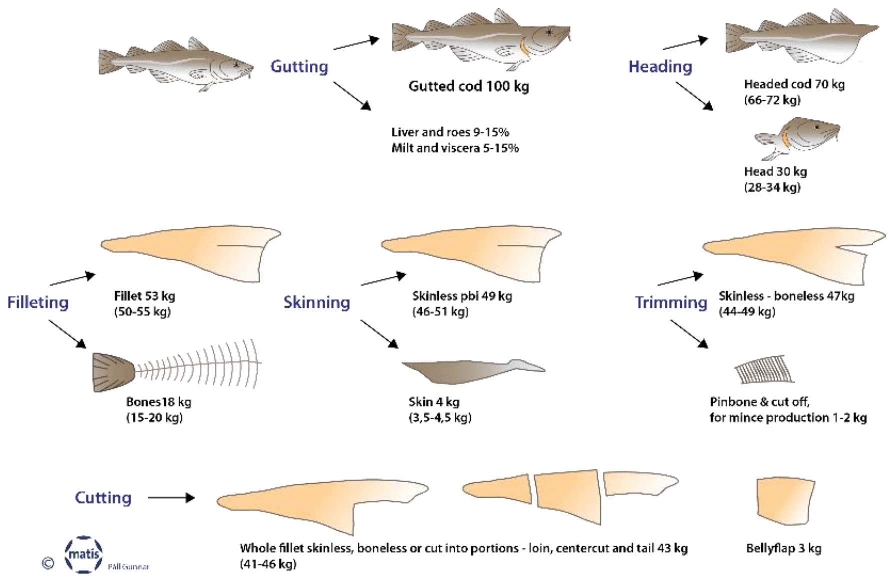

Figure 3 Product and by-product from cod filleting (Pálsson, 2018)

The heads have been the most important RRM from cod in Iceland. There are number of by-products that can be produced from cod heads, such as tongues and cheeks that are primarily exported salted or frozen to S-Europe. But dried whole heads produced specifically for the Nigerian market have represented the mainstay of the production. Traditionally the heads were dried outside on stock racks, but indoor drying with high tech factories using geothermal hot water as drying energy is common today. Heat and moisture is controlled by computers to maximise quality and efficiency. The backbones are also dried for the Nigeran market from freezing plants, but until now they have been discarded from factory trawlers.

Fish silage is a liquid product processed from RRM like viscera. By adding acid, such as formic acid into the viscera it is liquidated by enzyme actions and naturally broken down to the right conditions to limit the growth of spoilage bacteria. Here with the products (silage) shelf-life increases and can be used as raw material in fish meal and oil and used for producing aquaculture feed, animal feed and as a fertilizer (Jónsson & Viðarsson, 2016). Viscera (including liver and roe) contain various valuable materials. It includes among other things Omega 3 fatty acids, used for pet-food and aquaculture feed. It is also used for production of enzymes and used in products like Penzyme, processed by Zymetech. Using silage as fertilizer in agriculture for plants and fields has a long history around the world. It was common to use silage as fertilizer in earlier centuries around the world, especially in the developing countries (Jónsson, Ásbjörnson, & Arason, 2014). Matís was involved in a project based on utilizing fish offal on agricultural fields as fertilizer. The result showed higher protein content than in a traditional fertilizer, but problems like high cost in transportation of silage and environmental problems like smell close to urban arias was a problem (Jónsson, Ásbjörnson, & Arason, 2014).

There is a significant production of silage in Scandinavia from RRM in the fish industry, especially in Norway and Denmark. Production of fish silage in Iceland has been almost none-existent, but this could change with producers becoming more aware of potential value creation by utilising low value raw material into silage and further processing in the future for higher value products.

Utilizing of cod liver has a long history in Iceland and goes all the way to the year 1728 in Grindavík (Jónsson & Viðarsson, 2016). But there has been a major progress in the utilization of cod liver over the years; deviated into two categories, production of oil and canning. Six major producers of canned liver are currently producing and exporting the product. Cod roes are primarily frozen and exported as raw material for the caviar industry. It is also sold fresh on the domestic market during the spawning season.

3.1.2 Factory vessels

Factory trawlers in Iceland used to discharge all RRMs over-board, except for cut-offs from filleting. Estimates of the utilisation factor from fisheries in the Barents Sea is 54%, i.e. approximately 46% of the biomass is discarded (Laksá, et al., 2015). The head represents around a quarter of the round weight of each cod, and the heads have traditionally been discarded at sea because of many challenges i.e. limited freezing capabilities on-board the trawlers, lack of storage space, low value etc. (Viðarsson & Thordarson, 2015). The authorities in Iceland did however set into regulation in 2011 that factory trawlers were obligated to land a proportion of the cod heads, depending on the on-board storage space. Some factory trawlers had though started landing cod heads before the regulation entered into force, as the heads were returning enough returns to justify their utilisation. The current factory fleet is not built with capacity to process everything caught, with lack of space for processing RRM and capacity in the freezing hold to store price reduced products. The factory trawlers have though been utilizing more of the catch for the last decade, around eight thousand tonnes in 2012 and increasing, and with newly built trawlers there will be a breakthrough.

Figure 2 The factory trawler "Solberg SI" from Fjallabyggð

Renewal of the fleet has started with Rammi's new freezing vessel Solberg SI. The trawler is well equipped, including new meal- and fish oil factory from Hedinn Protein Plant. The fishmeal factory is compact, fully automatic and environmental friendly. Thereby it´s possible to process fatter fish and have a capacity for fish oil production with focus on by-products for human consumption. Solberg has full utilization of the catch that comes on board and only a small fraction of the catch is discarded from this new vessel. Having a factory stationed on board the trawler ensures freshness of the raw material with minimum time from catching to processing and the best product quality possible. The meal/fish-oil factory runs on electricity, steam and waste energy from the diesel engines and is therefore energy sufficient.

3.1.3 Pelagic fish

Significant development has taken place in the production of pelagic fish in Iceland, from meal and fish-oil for animal feed production, to products intended for human consumption. This is preferably the case for capelin and mackerel, giving more value for the products. Viscera, heads and cut offs are the RRMs from herring production. In early season, in January, part of the catch (male) is frozen and the rest is processed into meal and oil, but later in the season the female is processed for human consumption with the roes, first for Eastern Europe and later for the Japanese market. At the end of the season the roes are squeezed out of the female and processed as a valuable delicacy on high end markets, but the rest is for meal and oil production. Almost everything is utilized, even the processing liquid (blood etc.) is screened and evaporated before being processed into fish-meal. Most of the mackerel and herring is headed and gutted (H&G) before being frozen for human consumption but the rest is processed as meal and oil. Blue whiting is processed as meal and oil.

Around 28 thousand tonnes of capelin, 30 thousand tonnes of herring, 64 thousand tonnes of mackerel and 400 tonnes of blue whiting were exported from Iceland in 2016 for human consumption (Statistic Iceland, 2017).

3.1.4 Crustaceans

Side streams from fishing/farming and from crustaceans; mainly shrimps, lobsters and crabs, can be valuable for biotechnological processing purposes and there is a substantial shrimp industry within the West Nordic region.

Shrimp processing is one of the important marine industries in Greenland and Iceland generating considerable quantities of solid waste in the form of head and body carapace, amounting up to around 60% of the total raw material. Side streams from processing of crustaceans, fish and fish-farming were considered as a waste, but recently it has been considered as a RRM, important for biotechnological processing purposes. With changes in waste legislation, shellfish waste management has become increasingly difficult and expensive. This has significantly affected the shellfish processing sector, particularly the crustacean sector as there is a lack of cost-effective outlets for their waste.

Icelandic companies are currently utilizing a good share of the RRMs coming from processing factories and generating valuable products from it. Primex in Iceland produces chitosan from shrimp shells in bulk for nutritional, cosmetic, and biomedical applications, as well as producing derived health promoting products for local Icelandic markets. Genis, also located in Iceland, produces chitin oligos from shrimp shells and for medical applications.

Meal based on shrimp waste is becoming more desirable for the animal feed production than before and indicates that use of shrimp meal in blend with other protein rich fish-meal or vegetable meal can improve animal growth and the health of livestock as well as improve the colour of the product (Fanimo, Mudama et al. 1996). This is important because these markets pay higher prices and are more reliable than fish-feed markets, which have been the main markets for shrimp meal until now. The astaxanthin colourant in the shrimp meal produced from shells has been of interest to salmonid farmers but low protein content has been a drawback.

3.1.5 Lumpfish

In Iceland lumpfish is almost fully utilized. The roes are the main product, but the fish itself is frozen for the Chinese market. Most of the fish used to be cut on board the boats, but is now cut at processing plants, with much better working conditions and quality. The Chinese market demands different kind of cut to collect the roes, which is difficult to manage on board a small vessel. Before the fish was cut across the stomach, but the market is demanding a cut from the vent to the neck. The viscera are processed at fish meal factories, but used to be thrown overboard from the fishing vessels. In general, all lump-fish landed in Iceland is gutted in processing plants ashore, not onboard the vessels. In 2016 a total of 669 tons of caviar, 731 tonnes of salted roe´s and 2.700 tonnes of lump-fish were exported from Iceland, worth 889 million ISK, 686 million ISK and 509 million ISK, respectively (Statistic Iceland, 2017).

3.1.6 Aquaculture

Salmon and trout are mostly exported whole, gutted with head on from Iceland. Viscera from the production is mostly processed for animal feed as fish- meal or oil. It is not allowed to process it for human consumption due to European regulations. The blood is discharged with quite some cost, but strict regulation is set for this process for environmental purpose. Around 10 thousand tonnes of salmonid products were exported from Iceland in 2016. Most of it gutted with head on as previously mentioned. The offal rate after gutting is around 15% and is processed at Arctic Protein in Borgarnes in West Iceland.

3.2 Greenland

Available information on utilisation and RRMs in the Greenlandic fishery is somewhat lacking. The authorities are tempting to improve on this and have recently passed a regulation (11/2017) that requires each processor and fishing vessel to provide data on production and catches.

The biggest challenge in the Greenlandic fisheries and the main obstacle for improved utilization of the fish stocks are lack of infrastructure and transport ability. With many landing sites in a waste coastline and rural areas, logistics can be extremely difficult. There is very limited activity in the fisheries on the east coast, with most of the business on the west coast.

3.2.1 Demersal fish

Frevelund and Fredslund (2013) have estimated that around 60% of Greenland´s demersal catches have been landed and 40% discarded, 35 out of 87 thousand tonnes of catch. In some cases, the cod is landed H&G and the head is discarded in the sea, amounting to around a quarter of the catch. The yield in the fillet processing is only around 40%. There are two companies in Greenland accounting for approximately 77% of the total demersal fish production and export. Greenland halibut constitutes of around 42% of the demersal fishing and 69% of export value. Cod, haddock, saithe and redfish are around 30% and 22% of export value.

According to Statistic Greenland demersal fisheries were landed to 18 landing sides in 2016 (Statistic Greenland, 2017). But that is an assumption since according to data from Greenland Fisheries Control (Greenland Fisheries License Control, 2017) there are some 40-50 factories and small landing places for Greenland halibut and cod. One community can represent several towns and settlements. Around 40 thousand tons of cod and 34 thousand tons of Greenland halibut are landed, but other species are not significant. Some of the cod is filleted and frozen, but most of it is frozen gutted with head on or as H&G. The RRM is discharged.

The total export value of demersal fish catches is approx. 630 million DKK. There is no data available for utilization of RRM in Greenland, but for the cod it is probably less than 50% and around 57% and 85% in Greenland halibut. There are around 40 small communities in Greenland which are known to have small amounts of cod landed, but without any recording.

3.2.2 Pelagic fish

Most of the pelagic fish are caught by factory trawlers specially prepared for pelagic fishing. Only three vessels are originally designed for pelagic fishing in Greenland. The Greenland fleet caught 19 thousand tonnes of mackerel in 2016, but foreigners caught 16 thousand tonnes. Seventy thousand tonnes of herring were caught in Greenland waters by local fishing vessels.

There is no land based production of pelagic fish in Greenland. There is a pelagic fleet but the fish is frozen onboard and by-catch is discarded overboard. A small fraction is fished in cooperation with Icelandic companies and landed for production in Iceland.

3.2.3 Crustaceans

Around 84 thousand tonnes of shrimp were processed in Greenland 2016, from costal and deep-sea fishing, with value of 400 million DKK. There are four shrimp factories operated in Greenland; in Nuuk, Sisimiut, Aasilaat and Ilulissat. Only the Royal Greenland´s Ilulissat shrimp plant utilizes the shell (around 60%), the other three discard it by dumping the shell into the sea.

According to Statistic Greenland, approx. 84 thousand tons of shrimp were landed in these four communities, an export value of approximately 400 million DKK. The yield in shrimp processing (cooking, peeling and freezing) is around 40% so the RRM is around 49 thousand tonnes of total.

Some experiments using shrimp waste for fuel production have been conducted. Even though big differences were observed between laboratory and large scale outcomes, it was concluded that this kind of waste has potential for biogas production (Roca and Sánchez 2009). The conversion of organic waste to biogas is made in several steps. Anaerobic microorganism breaks down the biodegradable material and then the biogas obtained must be collected and treated to exploit the methane for renewable energy generation, to be used to generate energy like electricity or heat. The Crab industry in Greenland dumps the shell from the production, and only utilizes the meat. In 2016 2,900 tonnes of crabmeat were exported from Greenland, a value of 37.4 million DDK (Statistic Greenland, 2017).

3.2.4 Lumpfish

There are 10 communities with recorded landings of lumpfish in Greenland. In 2016 the Greenlandic fleet landed 5 thousand tonnes of lumpfish valued at almost 16 million DKK. Only the roes are collected, but the fish is discarded back to the ocean. The producers of lumpfish roes are only purchasing the roes, estimated as 30% of the fish in Greenland. That means that around four thousand tonnes of fish is discarded into the ocean. The lump-fish is around 17% of the demersal fishing but only around 4% of export value for the roes (Laksá, et al., 2015).

3.3 Faroe Island

Fisheries and aquaculture are the two most important contributors to the Faroese economy, accounting for over 95,7% of the total exports in 2016 (Statistics Faroe Islands, 2017). These industries are mostly based in the primary sector, where a part of it flows directly into the secondary sector, the fish processing industry. Almost three thousand people are employed in the fishing industry (both primary and secondary sectors) in the Faroe Islands. This represents 11% of the work force (Smáradóttir, et al., 2014). The export value of primary and secondary products from the catch fisheries was 4,02 billion DKK in 2016, while the export value from aquaculture products was 3,66 billion DKK (Statistics Faroe Islands, 2017). Most exports are unprocessed fish, frozen and fresh, but several companies that utilise RRMs have emerged in the last years; such as Faroe Marine Products which ferments and dries fish heads and frames for consumption in primarily Nigeria; Havsbrún which converts fish waste into feed for the extensive aquaculture industry in the Faroe Islands, and Salmon Proteins that converts waste biomass from aquaculture into silage, which is sold as feed in the pig- and mink-industries abroad.

3.3.1 Demersal and pelagic fish

The pelagic fisheries in Faroe Islands have an almost 100 percent utilisation of the caught biomass, where the rest materials are primarily utilised as feed ingredients for aquaculture.

The utilisation of the demersal whitefish, such as cod and haddock, is much lower than the pelagic fisheries. In the Faroese coastal demersal fisheries, the liver, roe and entrails are often discarded. For the long-distance fleet, the level of RRM not brought to shore depends on the type of production. Average catch of demersal fish through last decades in Faroe waters is around 116 thousand tonnes, mostly landed as H&G. Most of the liver and roes/milt is discarded into the ocean from the fishing vessel (Laksá, et al., 2015).

The factory trawlers filleting on-board discard around 65% of the catch, whilst vessels landing H&G discard the head, liver and entrails, discarding approximately 35% of the catch (Laksá, et al., 2015). The main utilisation of heads and frames from the demersal fisheries is drying for human consumption and exported to Nigeria (Faroe Main Products, 2017).

3.3.2 Aquaculture

The Faroe Islands has an extensive aquaculture industry, which exports recently exceeded that of the fishing industry. Since 2001 the utilisation of the aquaculture biomass is close to 100%, since cut-offs and frames are exported for human consumption, while the rest of the biomass is prepared for silage, which is exported as feed for pigs and mink. The blood is filtered and chemically treated before being discarded.

The company Salmon Proteins was founded by the aquaculture industry on the Faroe Islands in 2003 as a part of the veterinary agreement with the EEC. The products are high-risk silage made from self-dead fish by accident or sickness. In addition to high-risk silage products the company also produces low-risk products from RRMs from salmon slaughtering.

The low risk silage is sold primarily as pig feed to Denmark and Norway at a price of approximately 1 DKK/kg. In 2016 Salmon Proteins processed 17,329 tonnes of low risk silage. The high-risk silage is sold as mink feed or to the biogas industry, and there is a net cost to exporting the silage. In 2016 Salmon Proteins processed 3,541 tonnes of high-risk silage (Salmon Proteins, 2017).

3.3.3 Factory vessels

The Faroese fisheries in the Barents Sea were almost 30 thousand tonnes of white fish in 2014. Around half of the catch was processed in fillets but the rest was H&G. Cod represented almost 90% of the catches, but haddock was the second most important species with around 8% of the catches. More than half of the biomass is discarded into the sea, mostly the heads, which are around a quarter of the catch (Laksá, et al., 2015).

4 Projects and research

4.1 Iceland

The AVS Research Fund in Fisheries enabled universities, companies and research and development organisations to participate and undertake increased research effort in Iceland from 2003 with focus on applicable projects. Matís has been involved in many research projects focused on RRM over the years.

4.1.1 Viscera

Many research projects and articles on RRMs regarding utilization and value creation have been made in Iceland in recent years. Only a few decades ago, RRMs like cod liver, milt, heads and frames were considered as waste. The cod liver was sometimes buried in the ground and even shipped from fish plants and discharged into open sea with substantial cost. Viscera was disposed of as landfill or dumped into the ocean and fish heads were processed as animal feed and even dumped into the ocean from factory trawlers. Use of silage in Iceland was examined, but has never found footing in Iceland, which is a bit strange considering the success of the silage industry in Norway. The main reason for lack of utilization of viscera in Iceland is primarily low prices and high transport cost (Tryggvason & Finnbogadóttir, 2007).

The Ministry of fishery in the Faroe Islands in cooperation with support of Nordic Fisheries Cooperation under the Nordic Council of Ministers published a report titled “Alt I Land” in 2016 from a feasibility study that focused on improving the utilisation of the white fish fisheries in the North Atlantic Ocean. The aim was to explore the concept of bringing everything ashore and how to implement the Nordic countries in doing so. Working in close cooperation with stakeholders to analyse the reasons for the lack of utilisation of RRM and how to improve it and to maximize the highest possible value to the biomass of everything that is brought ashore (Laksá, et al., 2015).

The high cost of disposal of fish viscera and new regulation on emission of organic waste, have forced the fish industry to find more valuable utilization of RRMs. The utilization of viscera and value creation have been studied in some researches. Results from these researches have for example been published in Jónsson & Viðarsson (2016); “By-products from whitefish processing” and Jónsson, Karlsdóttir & Arason (2016) “Nýting á slógi – staðan í dag”. The conclusion of the research of Jónsson, Ásbjörnsson & Arason (2014) suggests that making fertilizer from viscera is not profitable, even though some good results came out of it, like higher protein in hey grown by using such fertilizer. Operation study of small viscera production for meal production out of that raw material reveals it is not feasible (Tryggvason & Finnbogadóttir, 2007). Such production depends on economies of scale and is not realistic to be operated around Iceland, close to fish factories, where transport and storage cost is too high for such low value production.

Disposal of fish waste (intestines) used to be an environmental problem in the West fjords from the shutdown of fish meal factories in the beginning of this century. Before, the intestines were blended with other RRM like heads and bones. The aim of a local project was to find a profitable way to process the intestines and focused on using small simple meal plants for the process. Around 12-14% of the raw material (without liver) can be processed as fish-meal or fish-oil, but 80% is water. The main problem was the small amount of raw material available in the West fjords and low product value. Transportation within the area makes it impossible to use one factory for the whole region, which still reduces the efficiency of the production (Þórðarson & Greipsson, 2012).

A research from 2007 looking into the environmental impacts and possible solutions for getting rid of viscera from processing plants, concluded that the main concern amongst processors was simply to get rid of the viscera in a responsible manner without too much cost; not necessarily to create value from it (Tryggvason & Finnbogadóttir, 2007). At the time, the goal was to get rid of organic waste in an environmentally friendly and cost-effective manner. One alternative explored was to use it for landfill, but that was considered unsuitable because of high water content in it and most of the suitable places in the West fjords, where the research focused on, have limited soil. One solution named in this report was to sail with the viscera to open sea and dump it there.

One outcome from researches is that products from viscera can be divided in two main categories based on its value creation; low-tech industries and high-tech industries. Processing fertilizer and animal feed is an example of the former, but processing of enzymes is an example of the latter. For instance, for the pharmaceutical industry and for human consumption.

Report from a recent study shows changing attitudes towards utilization of viscera, with the main aim to increase value creation from it (Jónsson, Karlsdóttir, & Arason, 2016). The main result from this report is that utilisation is much higher in Iceland than in Faroe Islands, Greenland and Norway. For utilization of viscera the main challenge is to sort it to some extent to categories, for high end production and for low end production. Around 80% of viscera is water, 3.5% fat and 13.2% protein.

Matís is currently participating in two projects to develop valuable products from silage in the aquaculture industry, from the viscera and the blood. Today there is limited value creation from salmon/trout RRM such as viscera and blood, and in some cases, it is a matter of getting rid of it in a cost-efficient way. Salmon/trout viscera including the blood are around 15% to 18% of the whole fish, so there is considerable biomass that can potentially be turned into value. The viscera are a round 80% water, 4% fat and 16% protein, and should give around 18-20% yield when processed into fishmeal and fish oil.

A new production method in viscera production has been developed in Norway giving higher value and lower cost. The normal procedure has been to process fishmeal and oil as raw material for animal/fish food. Around 60 – 80 % of viscera is water, giving low yield and high cost in this production. But new ways of making viscera extract is promising; by evaporate 50% of the water, around 60 % of the capacity of the viscera. The extract can be used directly into the feed production, delivering important benefits compared with the meal/oil production. The extract includes natural additives and binding agents, and can be used directly in the feed production, not only saving cost in the feed production, but also giving better quality. Such equipment is already on its way on board a new factory trawler in

Norway (Arason, 2017). This new way of making silage from viscera extract is both cost effective and gives also much better value as RRM.

4.1.2 Crustaceans

Shrimp waste used to be an environmental problem in the Icelandic shrimp industry. In Ísafjörður in North West of Iceland, the processing factory Kampi set up a simple meal factory to be located at the end of the production line. The process is only a one-man operation with minimum cost. In a large shrimp factory at Ilulissat in Greenland this solution has also been used for some time, processing additives for animal feed for human consumption (Möller & Sörensson, 2011). The Kampi factory is profitable, generating value and saving substantial cost of disposal. The meal is graded into two products, shrimp meal and larger shell pieces. The shrimp meal is sold to animal feed production in Australia for a reasonable price. It contains around 40% protein and astaxanthin levels have been measured from 3.5 to 8.5 mgr/kg. Larger shell pieces are sold to Genis in Siglufjordur, to be used as raw material for pharmaceutical production.

4.1.3 The story of the proteins

In 2013 Matís researched the outflow of processing water from a shrimp factory (Kampi) and from a large fish plant (Þórðarson, Högnason, & Haraldsson, 2013). The outcome showed that in a 10-hour shift around four tons of material, mostly protein, was discarded into the sea. This material was collected from waste processing water, with new type of screening equipment developed for this process. The protein collected was mixed with the shrimp meal production, and with higher protein content the product became more valuable and desirable for animal feed production.

Compact fish meal plants have been available since the early 1960´s (https://www.haarslev.com/products/compact-fish-meal-plant/). Recently, Hedinn hf. developed an automatic and compact fish meal factory capable of fish oil contraction Hedinn Protein Plant in cooperation with Matís and fish processors in Iceland. The factory can be fitted on-board larger trawlers and is considered environmentally friendly, as it runs on electricity, steam or waste heat from the fishing vessel engines. The focus in the project was to develop a fishmeal and fish oil factory to process by-products for human consumption. The aim was also to process by-products from shrimp shells and pelagic fish. Measurement of low water content in fish oil from the factory process and low-fat content in the meal, states that the new equipment is working perfectly. The protein plant is extremely compact and can even be fitted into a 40 feet sea freight container; the plant is therefore a good solution for factory trawlers in the future (Gíslason, et al., 2014). The factory has already been put on board the new factory trawler Solberg, owned by Rammi h/f in Fjallabyggð.

A study on wastewater in Icelandic fish processing plants (Valsdóttir, Stefánsdóttir, & Arason, 2005) showed that around 1% of proteins are lost from H&G raw materials through filleting and skinning. These proteins could potentially be valued at hundreds of millions ISK if utilised, but if the protein would stay on the fillets and sold as such, it could be even more valuable. Matís in cooperation with Skaginn3X conducted a study in a large fish processing plant in the West fjords in 2013 (Þórðarson, Högnason, & Haraldsson, 2013), by screening the wastewater from the process. From the fish plant around 500 kg of protein was collected from the production waste water in one eight-hour shift. Most of that was washed out by filleting and skinning of the fish.

4.1.4 The lumpfish story

A new regulation was set in Iceland for utilizing lumpfish in 2010, with regulation No 1083/2010, forbidding fishermen to discard the lumpfish after collecting the roes. The regulation obligates fishermen to bring everything ashore. This had the effect that the gutting process was moved into fishing plants in Iceland. The main challenge was to change an old procedures and mind-sets of fishermen in the industry. This change also presented some challenges for many small communities around the country. For instance, in Norðurfjörður in Northwest of Iceland, with decades of tradition in production of lumpfish roes. In this tiny community, there is only a one-phase electricity supply, which is not able to supply freezing capacity for landed lumpfish, as conventional freezing facilities require three-phase electricity. The community has poor transport conditions, specially at the time of the lumpfish season; but during early spring the maximum load for the roads is 6 tonnes and the nearest freezing capacity is at Drangsnes, 120 km away. That problem was solved in collaboration with the road authorities that made an exemption for a specific truck to carry the lumpfish for processing, under close monitoring by the Icelandic Road and Coastal Administration. This has been ongoing since 2011.

This new approach in the lumpfish industry is very important for many small fishing communities in Iceland, to have this opportunity for value creation in processing and exporting this new product. This product has increased the income for fishermen and workers, as well as for the municipalities. Before, only a fraction of the lumpfish catch was used for human consumption.

At Drangur in Drangsnes, in Westnorth Iceland, the local fish plant paid a nominal price for the fish, only 1 ISK pr/kg, to start with. It was considered a silent agreement during the start-up time for the company to develop the production line and pay for it. The fishermen were happy for not gutting the fish on board and were ready to participate in the development cost. For the season in 2017 Drangur paid 190 ISK pr/kg of lumpfish and this business is thriving for fishermen, Drangur, workers and the community of Drangsnes.

Two projects on lumpfish were conducted in 2012 (Reykdal, Ragnarsdóttir, & Þórðarson, 2012) (Þórðarson & Torfason, 2012) by Matís and lumpfish producers in cooperation with an exporter of frozen products to China. The main product in fishing lumpfish is the roes, but the fish itself used to be discarded overboard from the fishing vessels. Today the fish is collected to factories ashore and frozen for the Chinese market. The value for the fish is substantial and can pay for the fuel cost of the vessels.

In one project the chemical and nutritional content in lumpfish, caught in different places at a different time in Iceland, was analysed. These are vital information to find the right markets for the product and to view the future market for frozen lumpfish.

Included in this project is a case study program to identify challenges and opportunities regarding bringing the whole lumpfish to shore in West Greenland. Research work has been organized to be executed in the next fishing season (January-August) by Royal Greenland at a chosen landing location on the West coast. The project data will be collected and evaluated together with fishermen organization management in Greenland (KNAPK) (Appendix I).

4.1.5 Aquaculture

Matís in cooperation with a salmon farmer in the West fjords issued a report on potential utilization of by-products from salmon farming. The focus of that work was on fish that dies in the cages and can therefore not be used for human consumption. Discharging these dead fishes is difficult because of environmental reasons and it is as well quite costly for the companies. The project idea was to use this RRM to produce biogas, but one obstacle in the Westfjords is a lack of high carbon in this area, which is a necessary component for such a production (Magnusdottir, Eliasson, Smárason, Pálsson, & Sólbergsson, 2016).

Matís is currently involved in two projects to find a profitable way to utilize salmon/trout viscera including the blood.

5 Challenges and Opportunities

Further developments in processing and value creation from fish RRMs in Iceland are hindered by three factors; lack of access to good pilot plant facilities to test and develop products and ideas, need for good *in vivo* tests to verify product claims and counselling in product marketing.

Utilization of RRM is economically and environmentally important. But it can prove to be wise for some fishing vessels to discard certain parts of the catch, at least economically. But this could change in the future with new design of fishing vessels, built with capacity to process the whole catch that comes on board.

In the Faroe Islands, the costal fleet is gutting the white fish onboard the vessels, dumping the viscera in the ocean. Most of the Icelandic coastal fleet is only bleeding and chilling the fish on board and bringing it un-gutted ashore. This gives an opportunity to collect valuable RRM from the viscera, like liver, roes and entrails for further production, and the rest can be used for protein and fish-oil production. Landing sites in the Faroe Islands are not that many and the distance between them does not prevent utilization of viscera from the costal fisheries. In Greenland demersal fisheries are in many small and scattered communities, making utilization of RRM difficult; especially considering the logistical challenges in this vast country.

It will be a project for the future to maximize value creation from RRM and find ways to use it in value adding products like pharmaceuticals and cosmetics etc. There are also opportunities to use biological resources as food instead of feed with future global population expansion. There are also opportunities for the West Nordic countries to use RRM from fisheries resources as healthy, nutritious and sustainable proteins for future food security. The utilisation of RRMs are therefore of great importance, not only to increase the value for the companies involved, but also to demonstrate to the rest of the world that the Nordic marine sector is making responsible choices.

5.1 Suggested priorities

In order to maximize the value creation in the future from West Nordic fisheries, it is extremely important that the industry, R&D bodies, scientific community and governments cooperate in developing and implementing solutions. Some strategic focus and prioritation is needed though, which the authors of this report suggest should be:

1. Not all raw materials can be used for production of the most valuable by-products like ingredients for pharmacy, nutraceutical, functional and healthy foods. But the challenges of the future will be to maximize value creation from RRM and by-products in fisheries. Research and development in this field will be of paramount importance in order to maximize the utilization of the RRM. Governmental funding for research and development in this field will be needed to facilitate improvements.
2. Mapping chemical and physical properties of RRM in fisheries and farming is important to evaluate future use and to maximize value creation. It is important to evaluate local and seasonal variability in the raw material to prepare future production and find the right markets.
3. European regulations on raw material for human consumption must be reviewed. For instance, is fish oil from silage prohibited for human consumption, even though it can be made

in such a manner that it could become an alternative to oil produced from fish liver (Arason, 2017).

4. Viscera is discarded into the ocean from deep sea fishing vessels in Iceland and from costal fleet in Greenland and the Faroe Islands. It is important to find solutions to be able to collect viscera from fishing vessels in an efficient economical way. New way of viscera extract could be the solution to make it economically viable in the future.
5. Minimizing organic waste from fish/shrimp processing plants will be important in the future. Too much water usage and too much washout of proteins in the process is both an economical and an environmental problem. This is also important at slaughtering sides of farmed salmonids with blood drained into the ocean, causing disease hazards as well as environmental problems with organic waste discarded into the ocean.
6. For Greenland, the main challenge is to work out how much RRM in fisheries is available and location of landings. A study on quantity and landings of RRM and affordable utilization of it is necessary for action taken in the future. It will be challenging for Greenland, a vast country with lack of infrastructure and transportation to find a viable way of RRM utilization. There is an environmental challenge caused by organic waste which will be the future project.
7. In the Faroe Islands distances and infrastructure are manageable for better utilization of RRMs. Efforts to promote changed work methods by the coastal fleet and utilize the viscera instead of dumping it into the ocean should be manageable.
8. A common practice in the pelagic fisheries is to produce whole round fish in frozen blocks for export with close to 100% utilization. However, these products are exported to a wide range of destinations where RRM often ends up being discarded as the frozen fish is further processed for local markets often into fillets. Here is apparent potential to contribute to value creation or improved utilization in fisheries, and potentially lower transport cost with reduced carbon footprint and environmental problems in the processing country. Keeping in mind economics of scale – processing RRM at the source of the processing, initial processing facilities might be more profitable than having to collect RRM from various locations in small batches at each location.
9. This report discusses value creation and cost of utilization of RRMs. The environmental cost must be considered when pros and cons of utilization are discussed. There will always be a temptation for producers to save cost and throw away side products that do not return a profit. In such a case the legislator may need to set rules to correct this and force the industry to process by-products.

In the appendix is a Case Study report on potential utilization of lumpfish in Greenland. The main purpose is to utilize the whole lumpfish as a marine resource, instead of only one third and the sub-purpose is getting better roe handling hygiene (with potentially better roe quality), better roe and body yield and better working conditions for the fishermen. The market demands a different cutting method when gutting the lumpfish for collecting the roes, a method hardly possible on board a small dinky. The process requires good working conditions in a land based factory to satisfy the market requirements. This could be suggested for future work in the North-West region of utilization of RRM in the fisheries.

In this case study consideration on quality will always be the most important matter, both for primary- and RRM. Mishandling raw material in fisheries does not give good products and careful management throughout the value chain is always important. Prober bleeding, cleaning, chilling and packaging is a prerequisite for quality and value creation for all raw materials and products.

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7 Appendix

7.1 Case study: Lumpfish resource utilization

This case study is to identify challenges and opportunities regarding bringing the whole lumpfish to shore in West Greenland.

Background

The lumpfish (*Cyclopterus lumpus*) roe is the main part utilized of the caught lumpfish, and only a small amount of the bodies is brought to shore. The potential to utilize all the bodies in Greenland is there, because the fishermen extract the roe at sea and throw the body back into the ocean. In 2017, the total allowable catch (TAC) for lumpfish roe was 1.300 tons distributed along the west coast of Greenland. More than 90% of the landed roe is done by fishermen in dinghies with limited space.

It is shown (Hedeholm et al, 2013) that 1.300 tons roe corresponds to approx. 3.500 tons lumpfish body. Conversion factor from roe to whole fish is calculated to 3.7, but in statistical calculation 6.7 is used because of tradition. There have been smaller sales of frozen 20 kg blocks of lumpfish body to China, but no general setup and plans are currently in place to fully utilize the body. Further at the moment there are no regulation or economic incentive on bringing the lumpfish body on shore.

The objective of this project is therefore to investigate how the supply chain can be optimized and to identify advantages versus challenges by analyzing possibilities together with a specific group of fishermen and production site.

Purpose

The main purpose is to utilize the whole lumpfish as a marine resource, instead of only one third and the sub-purposes are to get better roe handling hygiene (with potentially better roe quality), better roe and body yield and better working conditions for the fishermen. Additionally, a cut in the factory secure a correct cut according to customer specification.

Scope and evaluation

During the next roe season (January/August 2018) Royal Greenland will select one location in Greenland, with focus on landing the whole lumpfish and hence extracting the roe in the factory. Focus will be practical measures, such as making agreement with fishermen organization KNAPK, development of procedure and instruction for handling at sea, handling during receiving the whole fish at the chosen Royal Greenland facility and instruction of the process for extracting and gutting the roe.

The key information, which will be gathered during the project, are yield of lumpfish roe and bodies, feedback from fishermen, quality of roe and bodies, production costs of handling both lumpfish body and roe and feedback from customers.

At the end of the project, data are collected and evaluated together with fishermen organization and management of the production.

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