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Utilisation of Rest Raw Materials from the Fish Industry: Business Opportunities and Logistics Requirements

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PREFACE

This master thesis is the last part of the degree in Global Production Management at the Department of Production and Quality Engineering at NTNU. The purpose of the study is to gain knowledge on the fish processing industry and processing 'waste', and to develop a concept that would allow full utilisation of the fish caught by Norwegian fishing vessels.

I would like to thank my supervisor, Anita Romsdal, for her guidance, constructive feedback, and encouragement throughout the semester, which has helped me to carry out this task. She has always found time to discuss issues and challenges of the study and answer my questions.

I would also like to thank Luis T. Antelo, who sent me information regarding the European BE-FAIR project, and Agathe Rialland, who kindly tried to help me getting information about transhipment.

Finally, I want to thank my family and friends for always being there for me, as well as my colleagues from the restaurant for the fish filleting class that gave me an interesting view on the proportion of rest raw materials generated by filleting operations!

Trondheim, June 7th, 2015

Laura Jouvenot

SUMMARY

Fish is a limited resource, and sustainability concerns arise as fish stocks and catches are decreasing. Present capture production is around 80 million tonnes per year (FAO, 2014b), and in some areas, the maximum long-term potential of fisheries has been reached. As global fish farming increases, the aquaculture industry will continue to request marine feed ingredients, and higher utilisation of rest raw materials is an alternative. The marine resources however, are limited and an optimal utilisation of all the available material is essential (Falch et al., 2007). This brings two main challenges: the first is to get the maximum quantity and quality out of the catch of high value-added raw material. The second is to upgrade low value-added raw material. In order gain knowledge and contribute to those objectives, three research questions were answered:

- *RQ1: What types of rest raw materials are generated in the fish processing industry?*
- *RQ2: What are the potential uses for the rest raw materials?*
- *RQ3: What would be the logistics requirements for collecting and bringing onshore the rest raw materials generated by onboard processing so that they could be further processed into value-added products instead of being thrown back to the sea?*

Research shows the highest potential for untapped resources lies in onboard processing rest raw materials that are for now discarded into the sea. Rest raw materials differ in relation with the types of onboard processing, but the main materials are heads, viscera, trimmings, bones and cartilage, hide, tails. They are described in Chapter 4 to answer RQ1. Those materials have many utilisation opportunities, which require different treatments and bring a wide range of products with different values. Among them are fish oils, fishmeal, nutritional products, cosmetics or pharmaceutical ingredients. The different applications and processes are described in Chapter 4 as answer to RQ2.

In order to increase the utilisation share of onboard processing waste, logistics solutions are required. One conceptual solution is presented in Chapter 5. The production of low-value products from the rest raw materials might not however offset the costs of such a solution, and the development of high-value products and of their market is required in order to make it cost-efficient. Upgrading the utilisation of rest raw materials leads to stricter requirements in processes efficiency and logistics

especially, in order to support the quality necessary for high-value upgrade. These requirements are presented and discussed in Chapter 5.

The research study was carried out in two parts. A literature study was performed to establish the theoretical background, and secondary empirical data from public databases and industry and projects reports was used to build an empirical background that constituted the base of the conceptual solution proposed to the practical problem statement.

The literature study was performed to answer the first and second research questions and to guide in answering research question three. It revealed that substantial research has been made in the field of utilisation of rest raw materials from the fish processing industry and processes have been put forward to produce high-value ingredients for different industries. The empirical background however demonstrated that these findings are not utilised by fish processors or fishermen, and low-value mass upgrading currently dominates the utilisation routes.

The study on the third research question included mapping a new supply chain and describing each of its actors together with their roles, business opportunities and logistics challenges. The material flow was also depicted and the different processes undergone by the products were presented and discussed. In addition, the information flow and collaboration within the new supply chain was discussed.

This research sets up a new concept for increasing the resource use of the fish catch, which in order to be cost-efficient needs an upgrade in the utilisation of rest raw materials. The logistics requirements of the solution are presented and discussed; this study builds the base for further research involving primary data obtained in collaboration with companies.

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LIST OF ABBREVIATIONS

CCP	Critical Control Points
CP	Cleaner Production
CRP	Continuous replenishment programmes
DNA	Deoxyribonucleic acid
EDI	Electronic Data Interchange
FAO	Food and Agriculture Organisation
FDA	Food and Drug Administration
FPC	Fish Protein Concentrate
FPH	Fish Protein Hydrosilate
HACCP	Hazard Analysis Critical Control Point
HG	Heading and Gutting
IUU	Illegal, Unreported and Unregulated
Mdir	Norwegian Environmental Agency
NFSA	Norwegian Food Safety Authority
RFID	Radio Frequency Identification
RRM	Rest raw materials
SCM	Supply Chain Management
TAC	Total Allowable Catch
UN	United Nations
VAPD	Value-added Product Development
VMI	Vendor-managed Inventory

1. INTRODUCTION

In this chapter, the relevance of the research is discussed. The research motivation, objectives, questions and scope are outlined.

1.1. Practical challenges

The world population is increasing. The UN projection expects nine billion people in 2050, and a further growth by 2100. Concurrently, the population is getting both wealthier and urbanised, leading to an increased demand for fresh food products (Parfitt et al., 2010). Food supply chains, which bring vital food products to consumers, are thus facing a major challenge, especially considering limited natural resources and a growing concern for sustainability. Fresh products, characterized by short shelf lives, imply several requirements for efficacy of the food supply systems.

A fresh food supply chain consists of some typical actors in a linear relationship: primary production for products such as meat, fish, fruits and vegetables, other suppliers for packaging material and equipment for example, then industrial production or processing unit, wholesaler and distributor, and retailers selling the products to consumers (Romsdal et al., 2011). A traditional fish supply chain is depicted in Figure 1. The primary producer varies in relation to the nature of fisheries; it can be fishermen harvesting the fish, or fish farmers in aquaculture. Processors transform primary fish into the aimed end products. Then, products are distributed on the domestic or international markets to wholesalers, retailers or food companies, before reaching the consumers.

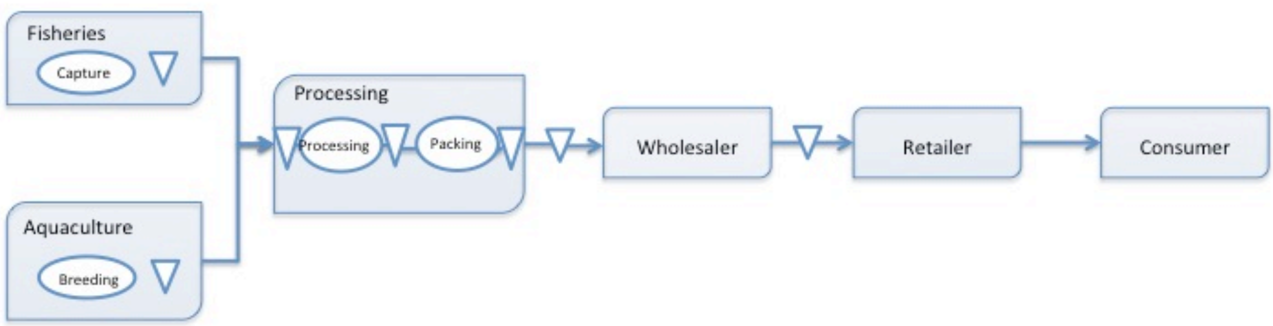


Figure 1 - Traditional fish supply chain

At each stage in the supply chain, the food changes 'ownership' and value is added. On the other hand, different types of materials are generated along the different stages of food supply chains, from primary production via post-harvest handling and storage, to food processing, distribution, retail and consumption. Most of these materials are usually considered as waste and treated accordingly, whereas they represent a potential value for the industry.

Regarding terminology, although there is no agreed definition, the term "rest raw material" is used in this paper and includes all raw material, edible or inedible, left over during the preparation of the main product (Penven et al., 2013). For example, for a fish such as cod, the main product is considered to be the fillets, and the head, backbones, trimmings, skin and guts constitute the rest raw materials (Søvik, 2005). The term "by-product" is also used in the literature with the same meaning, but it implicitly considers those raw materials as less valuable than the main product. Terminology is important, and those products need to be regarded as equivalent to the main product, and not as waste or by-products anymore (Arason et al., 2010). Rest raw materials can be differentiated from waste, which refers to products that cannot be used for feed or value-added products (Rustad et al., 2011).

In order to meet the world's growing demand for fresh food in a sustainable way, there has been an increased interest in waste, loss or spoilage of food in the past decades. Regarding the main product's supply chain, it has been found that from production to the retail shelf and consumer's fridge, the average loss of food products is estimated to be around 35 per cent of the initial production (Parfitt et al., 2010; Gustavsson et al., 2011). Gustavsson et al. (2011) estimated the following percentages for the lost products in the European fish supply chain:

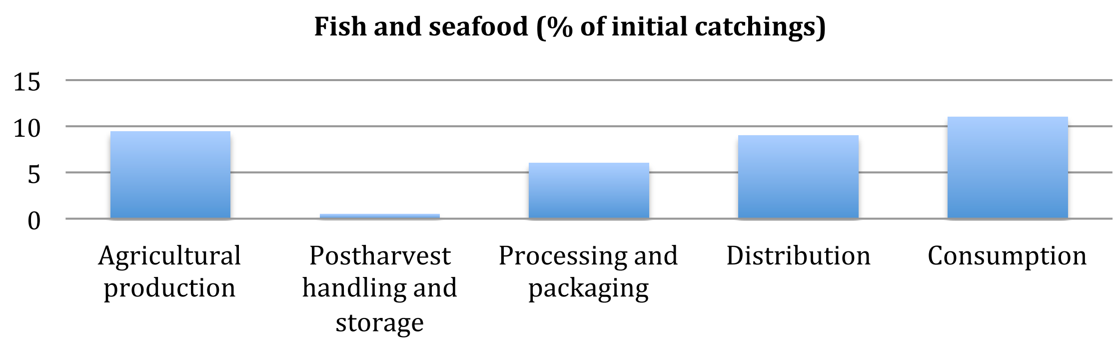


Figure 2 – Percentages of losses in the fish supply chain in Europe related to production in 2008 (adapted from Gustavsson et al., 2011)

Besides the fact that the loss of raw materials represents a potential food resource, as well as a potential source of basic components for other industries, there are ecological and environmental problems derived from an inadequate management of these materials (BE-FAIR Report, 2006). Considering the increasing importance of environmental conservation, academic institutions and research organisations have started intensive research and development activities in order to find ways to return the materials considered as 'waste' into the food supply chain (Laufenberg et al., 2003; Penven et al., 2013; Murugan et al., 2013). Research on recovery also relates to rest raw materials, which are often inedible parts separated from the main product and discarded though they could be used for other purposes. Examples of upgraded or recovered products include livestock feeds, biodiesel - fuel made from vegetable oils and animal fat -, adhesives or solvent derived from citrus oils, pharmaceuticals made from cow's and goat's milk, or juice products and vinegar made from apple peels (Kantor et al., 1997).

In the fish industry, considerable amounts of rest raw materials are generated by traditional fishing practices (FHL, 2013). According to the FAO (2014b), around 80 million tonnes of fish are processed by filleting, freezing, canning or curing globally, of which 50 to 70 per cent are rest raw materials not fully utilised. Depending on the market, some species are not processed at all, while others, especially larger fish, are often processed into fillets before reaching the end customer (Olsen et al., 2014).

Marine rest raw materials usually refer to viscera, heads, bones, skin, bycatch and fish that are damaged or not suitable for human consumption (Gustavsson et al., 2011). The discarded rest raw materials from seafood processing can account for up to three quarters of the catch total weight, consequently raising both economical and environmental issues (Rustad et al., 2011; Archer et al., 2001; Blanco et al., 2007). In addition, important quantities of products like heads, viscera, or skins are generated by vessels that process captures onboard. Out of these generated materials, only a few parts have enough commercial value to be worth keeping and sold on land. Thus, most of the rest raw materials generated onboard are usually thrown back at sea (Rustad et al., 2011).

On the other hand, the nutritional and health benefits of fish products have long been recognised, especially for their high value proteins and as a source of omega-3 fatty acids. In the 1980s it was reported that eating fish twice a week helped reducing the risks of coronary heart disease. International organisations like the FAO and World Health Organization have all acknowledged the importance of seafood in the diet. As consumers are more and more focused on the nutritional benefits of food products, rest raw materials generated by onboard processing can be seen as an interesting source of healthy and nutritional ingredients for not only the food industry, but also the animal feed industry (Olafsen et al., 2014).

Hence it is becoming increasingly important to optimise the utilisation of fishery by-products in order to provide more fish raw material for various industrial purposes (Rustad et al., 2011; Sandbakk, 2002; Olafsen et al., 2014; Digre et al., 2014; Blanco et al., 2007; Olsen et al., 2014; Arvanitoyannis and Tserkezou, 2014). Besides that fact, the parts thrown back at sea can generate ecological problems, as organic matter is disposed at sea, as well as environmental and toxicological problems, as parasites present in fish viscera are released in the sea (Arason, 2003; Blanco et al., 2007; Menon and Lele, 2015).

Raw material utilisation is not the same in a land-based operation and in offshore processing (Arason, 2003). Indeed, rest raw materials from onshore production are already almost fully utilised (Olafsen et al., 2012). The largest potential for utilisation lies in the onboard-generated rest raw materials, which are for now dumped at sea due to inadequate processing facilities and lack of space (FHL, 2013; Adler et al., 2014; Olafsen et al., 2014; Olsen et al., 2014). Estimations vary as for the volume of rest raw materials available, but generally point out that the amount of marine rest raw materials is significant and that there is a large potential for creating more value-added products. A part of the onboard-generated rest raw materials is though utilised. The utilisation varies among vessels, with some choosing to only keep fillets and some having their own meal plants on board and utilising all the harvested fish (Kristbergsson and Arason, 2007; Olafsen et al., 2014). Although this initiative shows the willingness of fishermen to utilise the whole catch, transforming the rest raw materials onboard into low-value bulk products can hamper potential higher-value applications and result in low profits for the fish industry. In addition, many new competitors are entering the market for marine oils and feed ingredients, thus threatening Norway's competitive advantage (Wahren and Mehlin, 2011). Though upgrading the utilisation of RRM to the higher-value products requires expertise, knowledge and capital, it could give Norwegian industries a competitive advantage on the market of high-value and healthy products.

But as for now, the long distance fishing fleet lacks technical and logistics solutions as well as economic incentives to bring rest raw materials ashore for higher-value upgrading, and thus disposes them at sea (Kristbergsson and Arason, 2007).

1.2. Research challenges and opportunities

The major potential for untapped resources lies in the rest raw materials available onboard fishing ships that stay at sea for several weeks and process fish onboard (FHL, 2013; Adler et al., 2014; Olafsen et al., 2014; Olsen et al., 2014). These ships allocate all their limited space to the storage of their main and more valuable products, which are often fillets or headed and gutted fish. They do so mostly because they lack economic incentives to allot space to rest raw materials' storage.

However, the legislation is evolving regarding the management of marine fisheries. Laws and policies are being passed forbidding discards of bycatch, which are fish species different from the targeted ones that are caught unintentionally. It can then be expected that the legislation, following the multiplication of publications from researchers underlining the possibilities of applications of rest raw materials, can forbid the discards of fish processing waste in the near future. In anticipation to this, it might be interesting to look into logistics solutions to bring the rest raw materials load from at-sea ships to the shore where they could be processed into high-value end products.

Such solutions encompass many different fields. There is a need for information sharing and transparency between all actors so that, for example, the processor can know what types, where and how much rest raw materials are available. This solution can be associated to supply chain management as the involvement and collaboration from all actors of the new stream supply chain is essential for its success. In addition, there is a need for technology development to have an automated separation, sorting and storage of the rest raw materials onboard to maintain them in appropriate processing conditions. The management of fish rest raw materials may represent an important cost, thus it is necessary to study the feasibility of rest raw materials' upgrading, from an environmental but also economic perspective.

The scientific literature has been underlining the potential of rest raw materials utilisation for almost twenty years, and the idea of setting up collectors ships to pick up the rest raw materials and bring them to processing has been evoked a few times, though the rest raw materials from onboard processing are still far from being fully exploited. Thus, this thesis' goal is to try to clarify the nature of the raw materials available onboard, the possible applications that can be pulled out of them, the logistics issues to consider and the needs to be evaluated and discussed in order to implement it.

1.3. Research objectives and questions

This thesis aims to first identify the different raw materials that are created by onboard processing operations, and highlight the potential applications that add value to these materials. Considering those results, the following objective is to identify and discuss the logistics issues underlying a solution proposal for collecting, transporting and upgrading the rest raw materials from onboard processing.

Consequently, the following research questions are answered:

RQ1: What types of rest raw materials are generated in the fish processing industry?

RQ2: What are the potential uses for the rest raw materials?

RQ3: What would be the logistics requirements for collecting and bringing onshore the rest raw materials generated by onboard processing so that they could be further processed into value-added products instead of being thrown back to the sea?

The key outcomes of the thesis are to estimate the business potential related to the use of rest raw materials from seagoing vessels, together with the logistics issues required to realise that potential. The research outlines also the needs for the sector to put the business in motion.

1.4. Research scope

The study is focusing on the fish industry, as using fish rest raw materials is both challenging and interesting. Fish rest raw materials include many inedible parts, for instance bones and skin, which cannot be directly used for human consumption (Adler et al., 2014). Those parts are however perceived as valuable, due to the content of high-quality proteins, lipids with long-chain omega-3 fatty acids, micronutrients, and minerals (Adler et al., 2014; FAO, 2014a). The fact that most of the rest raw materials generated by onshore operations are already utilised demonstrates the potential value of those products. The focus is thus turned towards the onboard fish processing industry, where lies the potential for creating more value-added products from rest raw materials.

Not all species of fish can be processed onboard, due for instance to factors such as size, number and fishing ground. Fish processed on-board of the large fishing vessels are mostly groundfish or demersal species. Groundfish or demersal fish are fish that live on, in, or near the bottom of the body water they inhabit. They include Atlantic cod, haddock, saithe, tusk, ling, Greenland halibut, Atlantic redfishes and Argentines (SSB, 2015).

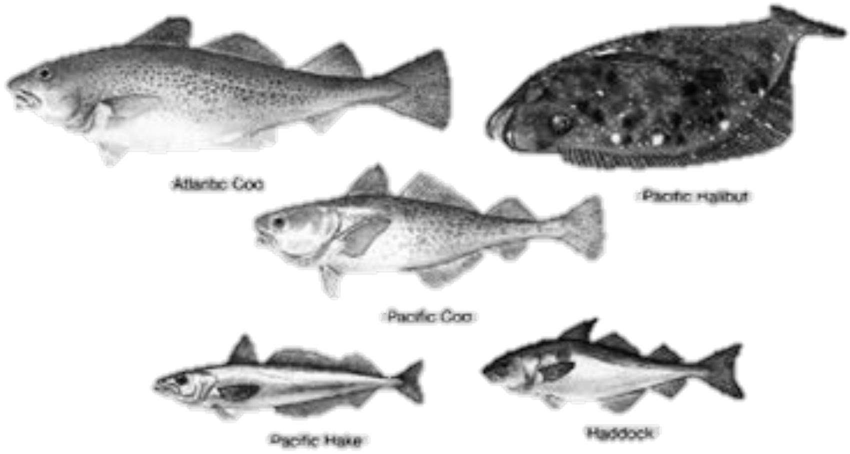


Figure 3 - Some groundfish species

It is in those species of fish that the rest raw materials' utilisation is the lowest and thus, where there is the largest potential to find a source of raw materials for upgrading applications, as seen in Figure 4 (Olsen et al., 2014; Olafsen et al., 2014; Sandbakk, 2002).

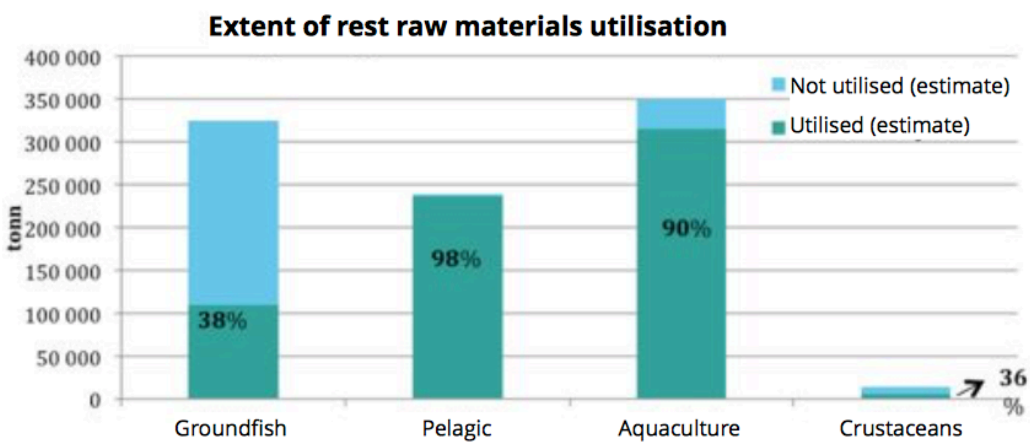


Figure 4 – Overview of the extent of rest raw material utilisation by sector (Sandbakk, 2002; Olafsen et al., 2014; Olsen et al., 2014)

The geographical area is focused on Norway, although there can be references to other interesting works in other countries.

Regarding actors constituting the traditional fish supply chain, the focus lies in the producers, that is to say the catching and processing stages. The utilisation of rest raw materials results in the creation of a new supply chain, of which the processors, wholesalers, retailers and consumer stages are described in order to study their roles and underlying logistics requirements.

In addition, as in all kinds of production, transformation of by-products into commercial products should be market-driven, with a realistic possibility of being sold with an economic margin within a reasonable time period (Olsen et al., 2014). Both regulatory status and future market potential are considered in the study, insofar as data and information could be found.

Finally, regarding the logistics requirements underlying the possible business opportunities, the focus lies in the appropriate treatment, storage and transport of the rest raw materials in order to retain the quality of the products and ensure safety and hygienic conditions. Thus, requirements for the physical logistics solutions are investigated.

1.5. Thesis structure

This thesis consists in seven chapters, the contents of which are briefly described below.

Chapter 1 **Introduction**	This chapter introduces the research area by providing a short description of the background and challenges bringing the problem statement, followed by a specification of the research objectives and research questions. This chapter ends with the delimitations of the thesis and its outline.
Chapter 2 **Research methodology**	This chapter presents the research methods used in this study, justification of the used methods, their advantages and limitations.
Chapter 3 **Theoretical background**	This chapter provides an overview of the theoretical framework of this study. It starts with presenting sustainability principles, followed by an introduction to reverse logistics and the upgrading concept. All concepts build the drivers for the need to utilise all available resources from the fish caught by Norwegian vessels.
Chapter 4 **Empirical background**	This chapter presents an overview of fishing industry in Norway based on secondary empirical data available in reports or public databases. The types of rest raw materials and their current and possible applications are presented in this chapter, answering RQ1 and RQ2. This chapter also sets up the foundation for the proposed concept in Chapter 5.
Chapter 5 **Proposed concept**	This chapter presents a conceptual solution to answer the problem statement and discusses the underlying logistics requirements that should be decided in order to implement the solution.
Chapter 6 **Discussion**	This chapter discusses the proposed concept in relation with different aspects, among which are realism, limitations, further research.
Chapter 7 **Conclusion**	This chapter discusses the degree to which the research has answered the research questions and fulfilled the research goals and objectives.

2. RESEARCH METHODOLOGY

This chapter presents the research methods used in this study and explanations of how the methods are used to answer the research questions stated in paragraph 1.3.

Research methodology is a systematic way to solve a problem; it includes procedures and techniques by which researchers collect data, describe, analyse and explain phenomena. This procedures and techniques are called research methods (Karlsson, 2009). Research methods can be described as qualitative or quantitative. Quantitative research is numerical, non-descriptive, with results presented as numbers, tables and graphs, and answers “what”, “where” and “when” questions. Qualitative research on the other hand is non-numerical, descriptive, and aims to answer the “why” and “how” questions (Rajasekar et al., 2006). Qualitative approach was chosen for this study because there was a need to explore the reasons behind the fact that there is no solution to utilise onboard rest raw materials today, and then discuss a new concept to utilise the untapped resources.

This study was carried out as a research-based project consisting of theoretical and empirical studies to answer the stated research questions. The structure of the thesis is depicted in Figure 5. This research was based on a top-down approach in order to highlight the development opportunities at a general level, but is thus also limited when it comes to local application for uncertainty regarding research activities.

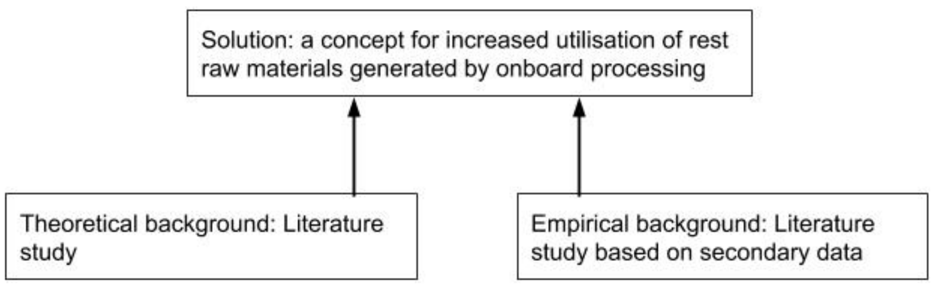


Figure 5 - Structure of the master thesis study

The theoretical background was conducted as a literature study and depicted the drivers behind this study. The empirical background was also performed as a literature study and completed by a research through secondary data sources.

2.1. Literature study

The literature study for both theoretical and empirical frameworks accomplishes several purposes in the thesis:

- It allows to describe the drivers that lead to the proposed concept
- It allows to scan the previous research made in the field of utilisation of rest raw materials, and study the different findings in terms of types of materials available and processes for the possible uses.
- It links the present study with larger academic discussions, as an extension to prior studies.
- It provides the foundations to establish the importance of the study.
- It helps limiting the scope and defining the research questions more precisely.

The focus of the literature study was based upon the problem statement and research questions. The study was divided into several categories, which are presented in Table 1.

Table 1 - Topics for the literature review

Sustainability	General background Fisheries state Sustainable SC
Reverse logistics	Product recovery Co-streams Disposal Remanufacturing, recycling, reuse
SC collaboration and Information sharing	Means Typical information
Rest raw materials generation	Types Possible utilisation Market industries
Fish processing	Processing steps Automation Onboard processing
Logistics and SCM	Distribution management Facility location
Fisheries background	Fishing vessels Regulations Fish species

The literature review was performed in several steps. The topics were first established and key words for the literature search were identified. With those key words for each topic, relevant journal articles, reports and books were found. These resources were filtered in accordance with their relevance to the topic as well as their quality in terms of the journals/proceedings they were published in. Snowball sampling technique was used after the first slot of papers was identified; the references were used to locate additional relevant papers. The literature was then read carefully and analysed.

Different databases were searched, among which Oria, Google Scholar, Science Direct and ProQuest. References were stored in EndNote reference manager.

2.2. Secondary empirical data review and analysis

The utilisation of rest raw materials has been a subject fuelling the scientific research for more than twenty years. One of the goals of the study was to build a conceptual solution for bringing resources from fishing vessels to the processing facility onshore and discuss the logistics requirements underlying this solution. This thesis is thus a conceptual study, and data should provide information for gaining knowledge and insight into a broad range of issues and phenomena.

Yin (2003) stated that the first and most important condition for differentiating among the various research strategies was to identify the type of research questions being asked. In this research, all research questions are exploratory "what" questions and therefore any of the strategies could be used.

Secondary data was used instead of primary data from specific case companies that have little or no generalisation value and would not allow the establishment of the general background that was needed. Cross-industry data should be used to assess the needs of the industry. Secondary data is data collected by someone else for another primary purpose. Primary data, by contrast, are collected by the investigator conducting the research.

Secondary data can be found in different sources:

- Official statistics: Statistics collected by governments and their various agencies and departments, for example SSB
- Technical reports, written to provide research results to research institutions, and other interested researchers, and may emanate from completed research or on-going research projects
- Scholarly Journals, which generally contain reports of original research or experimentation written by experts in specific fields

- Literature review articles, which assemble and review original research dealing with a specific topic
- Trade Journals, which contain articles that discuss practical information concerning various fields
- Reference Books, which provide secondary source material.

Secondary data is usually used at the starting place of any research activity, and to generate new knowledge and new hypotheses. Secondary data analysis was used in this thesis in order to support the previous theoretical findings and build a real-life context for the elaboration of a conceptual approach to the problem statement. It sets up the ground for further investigation where primary research will need to be executed in order to fix the different parameters highlighted in this study.

In order to estimate the quality of the information for the different resources, several points were particularly looked at:

- Purpose of the study
- Who was responsible for collecting the information
- What information was collected
- When was the information collected
- What methodology was employed

The search for secondary empirical data was designed according to a list of the information that would be of interest for the purpose of this thesis.

Table 2 summarises the advantages and disadvantages of secondary data review and analysis, adapted from the description of Yin (2003) regarding the different sources of evidence in a research.

In this study, several sources were in conflict regarding data, although they showed the same trend, and allowed to evaluate the realistic aspect of the concept. This highlights one limitation as there was no combination of data collection strategies. Further research regarding the concept model will need to include companies and work with primary data.

Table 2 - Advantages and disadvantages of secondary empirical data analysis (adapted from Yin (2003))

Advantages	Disadvantages
• Can be carried out rather quickly compared to formal primary data gathering and analysis • Can avoid duplication of effort as already existing and available data • Help monitor change over time • Informs and complement primary data collection • Stable, as can be reviewed repeatedly • Exact: exact names, references, details of an event • Broad coverage	• Data collection methods vary, and it may impair the comparability of data • Imperfect reflections of reality • Need selectivity in relation to volume of secondary data available • Quality difficult to determine • Sources may be in conflict • Different goals for different study may potentially bias the study

2.3. Conceptual solution

The theoretical and empirical backgrounds established by literature review and supported by secondary empirical data were used to build a conceptual solution to the problem statement. The logic behind the building is depicted in Figure 6, and the logistics requirements of this solution were developed and discussed based on logistics and SCM fields and activities.

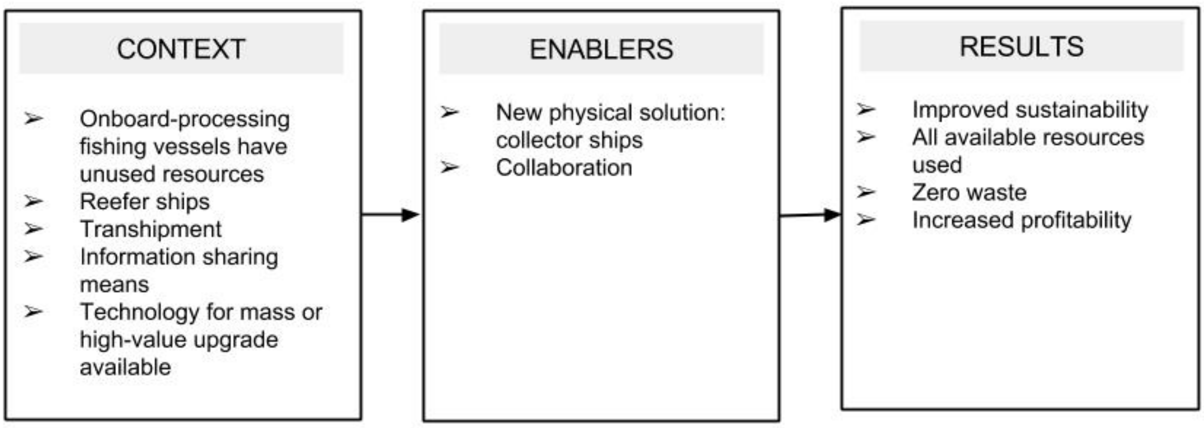


Figure 6 - Logic behind the building of the conceptual solution

3. THEORETICAL BACKGROUND

The willingness to increase the utilisation percentage of the resources is linked to major environmental themes that are present in today's society. Environmental issues have been an area of growing concern and attention for businesses on a global scale. For example, the transportation, production, storage and disposal of hazardous materials are frequently regulated and controlled. This concern for sustainability and protection of the environment can be regarded as the origin of the desire to add value to waste and avoid the loss of limited natural resources.

A part of supply chain management has focused on waste reduction, through the application of principles such as lean or agile for instance. Reverse logistics on the other end concentrate on streams where some value can be recovered, and where the outcome enters a new supply chain.

In this chapter, the theoretical background of the study is presented. The general concept of sustainability is first introduced, and then more particularly in connection with fisheries. The concept of reverse logistics is also presented, as its core idea of bringing value to parts considered as waste is underlying the motivation of this research. Finally, as information sharing and collaboration is a key enabler of the proposed concept later on, an introduction is made in Chapter 3.4.

3.1. A world with limited resources: the need for sustainability

Sustainability

One of the biggest problems arising in the twenty-first century has maybe been 'sustainability' and the growing concern with the environment. The most common definition of sustainable development is as development which "meets the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development, 1987). Sustainability can also be defined as the "capability of being maintained at a steady level without exhausting natural resources or causing severe ecological damage" (Grant et al., 2013).

The food supply chain, also referred to as food industry or food system, includes all aspects from production to products' end of life, through processing, distribution, consumer purchase, and use. Sustainability thus implies that food is produced and consumed in a way that supports the well-being of several generations (Baldwin, 2009).

The definition of sustainability stated above can further be completed with the triple bottom line concept, which emphasizes the importance of examining the impact of businesses decisions on three key areas: environment, economy and society, as described in Figure 7 (Christopher, 2011).

The key sustainability considerations relate usually to fields like energy and water consumption, effluent control or by-product development (Hall and Köse, 2013); more particularly regarding food supply, sustainability concerns include energy, waste, water, air, climate, biodiversity, food quality, quantity and price, and employment (Baldwin, 2009). Especially, food manufacturers should include sustainable practices in their operations, such as waste reduction and recovery, composting, recycling, and processing with minimal water and energy use (Baldwin, 2009).

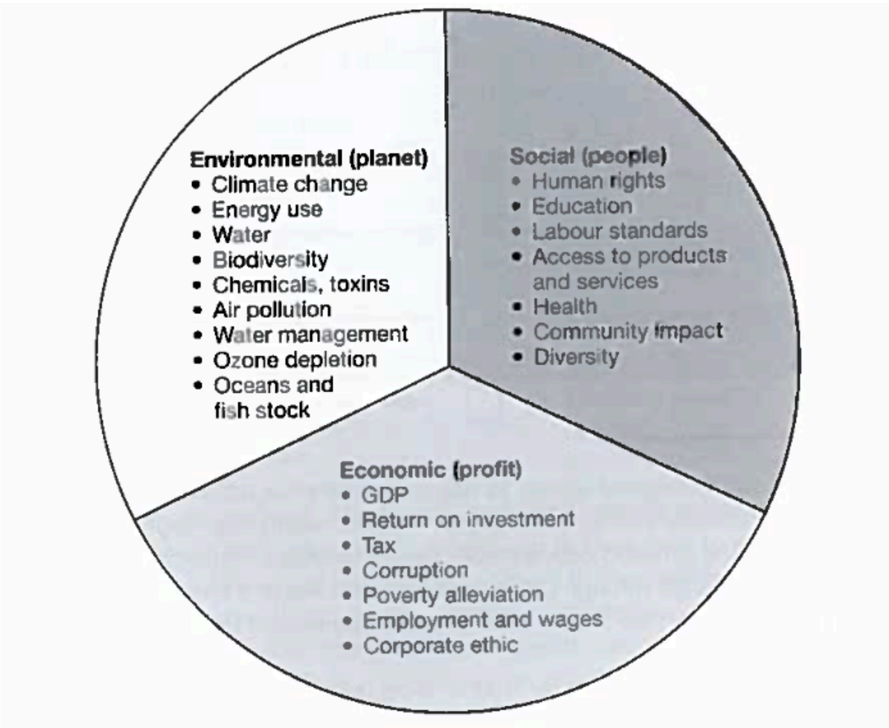


Figure 7 - Triple bottom line: planet, people, profit (Christopher, 2011)

According to Searchinger et al. (2013), the world faces a 69 per cent gap between crop calories produced in 2006 and those likely to be required in 2050 to fill the needs of the expected 9.6 billion population. To close this gap, food production would need to increase, but there are several problems that need to be considered. For instance, food insecurity is already a problem for more than 800 million people. Roughly half of the cultivable land is already used. The production of crops and animal products accounts for around 13 per cent of all greenhouse gas emissions, and combined with land use change, agriculture could consume approximately 70 per cent of the allowable budget for all greenhouse gas emissions by 2050 (Searchinger et al., 2013). Hence, there is an increased interest in reducing waste and increasing resource utilisation, as a sustainable way to increase food supply.

Sustainability and fisheries

Sustainability can be evaluated according to different themes, such as energy consumption, water consumption, effluent control or by-product development (Hall and Köse, 2013), as said before. The following table gives a few examples of environmental implications of fisheries.

Table 3 - Sustainability implications in fisheries (adapted from Hall (2010))

Activity	Implications
Fleet operation	Mechanisation and powered vessels lead to fuel consumption and GHG
Aquaculture	Energy for feed production, pollution loss of habitat and biodiversity
Processing	Energy for driving machinery, canning, smocking
	Water requirements for washing, cleaning, etc.
International trade	Fuel for transport, GHG generated, energy for processing and storage
Frozen fish	Energy for cooling, storage and transport
Post-harvest losses	Fuel for smocking/drying inefficiently applied, nutritional quality loss
Fresh fish	Energy for chilling and storage

In addition, sustainability is especially important for renewable natural resources like fisheries that are limited in supply and can be overexploited (Hall, 2010; Searchinger et al., 2013). According to the UN Millenium Ecosystem Assessment in 2005, the depletion of fish stocks is one of the significant examples of potentially irreversible changes to ecosystems that result from unsustainable practices in marine ecosystems (Garmendia et al., 2010). Overfishing concerns almost one third of all marine fish stocks, as it can be seen in Figure 8, and has led to a global reduction of fishing vessels due especially to restriction policies (Hall, 2010).

Figure 8 - Status of marine fish stocks (FAO, 2014b)

As fish stocks are already partly overexploited and thus the supply of wild fish is limited, aquaculture production has more than doubled in the last decade to meet the world's growing demand for fish, and aquaculture growth is likely to continue to meet all the increase in fish consumption (FAO, 2011; Searchinger et al., 2013). However, the development of aquaculture has caused concern over the protection of coastal environments, since aquaculture activities have negative effects on the marine ecosystem, due in particular to medication used in the pools (Arvanitoyannis and Kassaveti, 2008). Besides water pollution, aquaculture production raises concerns regarding fishmeal and fish oil demand, which is the base of fish diets. Aquaculture consumes 63 per cent of global fishmeal and 81 per cent of fish oil, so there is little to divert from other uses (Searchinger et al., 2013). Thus there is a need to find methods to meet aquaculture's demand for fish oil and fishmeal without further wild fish catch.

As for the fish processing industry, it needs to change along with the fisheries supply and pay attention to sustainability through their fuel, energy and processing efficiency in order to reduce the sector's contribution to climate change (Hall, 2010). Climate change has indeed an important impact on the state of the fisheries, for example through displacement of warm-water species towards the poles, changes in habitat sizes and productivity, changes in fish physiology and seasonality, or extreme events (Hall and Köse, 2013).

The management of waste from fishermen also has an impact on the fisheries' state. Besides the fact that throwing fish parts back at sea represents a loss as potential food resource, there are ecological and environmental problems derived from an inadequate management of these materials (BE-FAIR Project, 2006). A lot of attention has been given to discards of fish, which is defined as the unintentional capture of non-target fish species (Blanco et al., 2007), but little attention has been paid to the fate of seafood materials dumped at sea, especially far from shore. The discarded products generated by onboard processing lead to a change in the overall structure of marine trophic webs and habitats (BE-FAIR Project, 2006; Blanco et al., 2007). Mazik et al. (2005) stated that most of the marine materials actually sinks directly to the seabed and accumulates or is dispersed, but once on the seabed it can produce anoxic waters and underlying sediments that lead to changes in bacterial populations. Bluhm and Bechtel (2003) stated that dumping large amounts of materials in defined areas near Alaska is affecting water quality parameters such as biochemical and chemical oxygen demand, total dissolved solids, oil and grease content, nutrient concentrations, pH and turbidity. Biological communities such as bacteria and macrofauna can be also affected. Pierre et al. (2012) studied the impact of the discharge of fish processing waste on seabird mortality. They pointed out that this behaviour can have a negative impact on seabirds as it reduces chick survival, increase depredation, and seabirds are often killed accidentally by the fishing gear.

This thesis's main focus lies on by-product development from rest raw materials utilisation, and thus sustainability issues such as energy and water consumption are left aside.

In order to improve the fisheries' environmental impact, there is a need for collaboration and involvement of all the actors of the supply chain and collaborators such as government departments and scientists (Hall, 2010; Norwegian Seafood Council (NSC), 2013).

Increased interest in sustainable products

Baldwin (2009) stated that the consumer interest in sustainable food is mostly linked to the desire to improve one's personal and family health and safety, before environmental reasons. Therefore it can be suspected that in the years to come, as consumers learn more, the food industry will experience an increased pressure for health promoting, sustainable and natural products. Seafood is known for its healthy properties, thus leading to an increased interest in fish products. In the meantime, consumers' awareness of food quality and safety, nutritional aspects and waste reduction has also increased (FAO, 2014b; Trondsen, 2012). In order to sustain this trend, increasing attention has been paid on the utilisation rate of the catch.

In addition, the fish industry should adapt to the changes in the demand for different types of products. For example, Penven et al. (2013) noted an increased interest from French customers in frozen products for example, whereas Farmery et al. (2014) expect the percentage of the word annual seafood catch transported by air freight, which is now 5 per cent, to rise with the growing demand for fresh fish. According to Morrissey and DeWitt (2013), fresh, chilled and live seafood represents 40.5 per cent of the world fish production and trade, while processed products such as frozen, cured, or canned are now the major share of total production with 45.9 per cent.

If catch volumes and aquaculture production increase in the future, together with the level of fillet production, there will also be a major rise in the production of rest raw materials (Olafsen et al., 2012).

Cleaner production

Sustainability can be included in the concept of Cleaner Production (CP), which aims to reduce waste, generate new products and reduce energy and water consumption (Hall and Köse, 2013). Cleaner production is defined as the "continuous application of an integrated, preventive, environmental strategy applied to processes, products and services to increase overall efficiency and reduce risks to humans and the environment" (COWI Consulting Engineers and Planners et al., 2000). Another definition is presented by Laufenberg et al. (2003); they say the "goal of clean production is to fulfil our need for products in a sustainable way i.e., using renewable, non-hazardous materials and energy efficiently while conserving biodiversity". Clean production is a new holistic and integrated approach to environmental issues centred around the product, recognises that environmental problems are caused by the way and rate at which we produce and consume resources (Laufenberg et al., 2003).

One application of CP concerns the efficient use of raw materials and the reduction of waste. Many opportunities for cleaner production are related to lean production efforts. The utilisation of rest raw materials is an important "Cleaner Production opportunity" since it can generate potential revenues while reducing disposal costs (Grant et al., 2013; Hall and Köse, 2013).

Logistics and SCM trends affecting sustainability

For businesses on a global scale, environmental issues have attracted growing concern. These issues make the job of logistics and SCM more complicated, by increasing costs and limiting options.

Grant et al. (2013) presented several trends in logistics and SCM that affect sustainability. First, globalisation has increased drastically in the past decades. The geographical length of supply chain has also increased, enabled by international transport infrastructure, production and logistics cost differentials between developed and developing countries. But the scale expansion of supply chain comes with environmental issues such as fuel use and emissions.

In addition, the development of international relationships between customers, suppliers, competitors and other stakeholders have lead to increased collaboration. Outsourcing has also emerged, as companies are focusing on their core capabilities and outsource other logistics and supply chain management activities to 3PL specialist. This also enables the 3PL service provider to have economies of scale as they can combine transportation for different companies, which can save some transportation and thus impacts on sustainability. On the other hand, the companies no longer have control of the sustainability efforts of their sub-contractors.

The development of logistics and SCM activities, together with technology, also helped reducing lead times and process times by sharing real-time information and by improving its accuracy. Lean and Agile paradigms have been introduced, aiming respectively to minimise inventories and responding in shorter time frames to changes in both volume and variety demanded by customers. They also lead to increased transportation and thus environmental effects for agile supply chains aiming to achieve levels of responsiveness and flexibility.

Globalisation, technology development, lean and agile techniques have thus lead to increased standards of living but also increased logistical and supply chain activities that have been detrimental to natural environments in terms of increased resource use, waste and pollution, or inefficient movement and storage of goods (Grant et al., 2013).

Supply chain flows have been mostly focusing one way, from materials and resources to customers. With the concern for environmental issues and the impact of logistics and SCM on sustainability, there is a need for a new approach towards supply chains and collaboration. Reverse logistics have emerged in the past decade in order to increase the sustainability of logistics and SCM, and is further discussed in the following chapter.

3.2. Reverse logistics

De Brito and Dekker (2003) defined reverse logistics as the “process of planning, implementing, and controlling flows of raw materials, in process inventory, and finished goods, from a manufacturing, distribution or use point, to a point of recovery or point of proper disposal”. It is a rather new concept, as firms are used to dedicate their resources towards forward operations, thus missing the potential value that reverse logistics operations could generate (Vlachos, 2014). Recycling and reverse logistics play important roles in sustainable logistics and supply chain management (Grant et al., 2013). Reverse logistics can be derived from the concept that what is waste in one industry may be a raw materials in another industry (Dijkema et al., 2000; Laufenberg et al., 2003). Reverse logistics take care of the product’s life after its “death”, i.e. when the product is no longer functional or needed and the owner wants to discard it. Waste is also generated during the different steps of the supply chain, from extraction of raw materials, processing into intermediate or final products to consumption. Reverse logistics also allow to reduce the use of natural materials and reuse products, which is valuable with an exponential increase in the consumption of natural resources to meet human demands (Grant et al., 2013).

In addition, inadequate management of waste generated by human activities can lead to severe exhaustion of natural resources. For example, large areas are not fit for habitation because of pollution of the ground, and fish in large economically important rivers are not consumable (Grant et al., 2013). Both the company that organises recycling and the one that has to pay for disposal can take advantage of reverse logistics. As illustrated in Figure 9, waste management is classified according to a hierarchy and the level of environmental 'friendliness' (Grant et al., 2013).

- Prevention and Reducing is the most environmentally friendly option, and cleaner production principles can be used to reduce energy and materials use.
- Reuse involves the use of some parts of a used product or the entire product.
- Recycling helps to separate and sort waste into materials that can be incorporated in different new products.
- Recovery usually refers to the process of creating energy as heat or electricity from the incineration of waste, for example organic materials.
- Disposal is the last option.

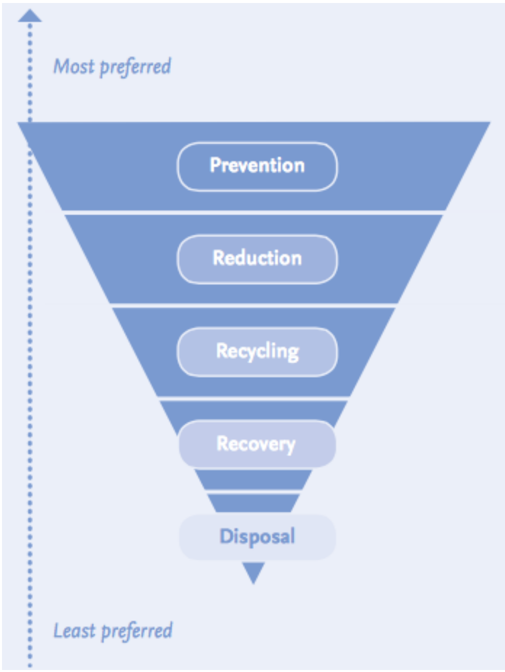
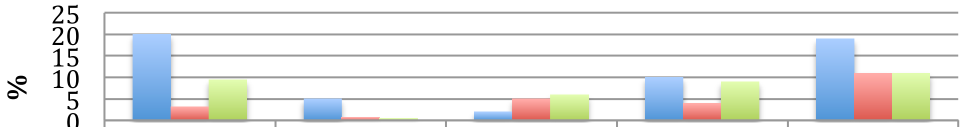


Figure 9 - Hierarchy of waste management (Hyman, 2013)

According to Cherrett et al. (2010), reverse logistics and waste management are different, as waste management deals with the "efficient and effective collection and processing of waste", meaning products that have no longer any reuse potential. A reverse supply chain is a "network of activities involved in the reuse, recycling, and final disposal of products and their associated components and materials" (Kinobe et al., 2012).

The management of reverse logistics requires specific knowledge, as there is a need to understand what and who are involved, the recovery processes, and the drivers behind the involvement of different actors (Grant et al., 2013). Reverse logistics have to deal with different issues than forward logistics. For example, return forecasting is even more complicated than demand forecasting; reverse logistics require more distribution points and specialised equipment, packaging is often damaged, pricing is vague, the product life cycle is not determined and transparency and traceability are low (Vlachos, 2014; Grant et al., 2013). In addition, there is a need for inspection and separation of products that is very labour-intensive and costly (Grant et al., 2013).

In the food industry in particular, reverse logistics are quite challenging. Regarding quantities of waste and losses in the supply chain, Gustavsson et al. (2011) carried out an assessment of Europe's food losses along the different stages of the supply chain. The results are depicted in Figure 10, and illustrate the need to develop methods to transform products lost at each step in value-added products, not only in order to reduce the amount lost, but also to create economical value out of those products. Providing proper refurbished or remanufactured goods can also give a competitive advantage to firms and brand credibility and quality for consumers (Grant et al., 2013).



	Agricultural production	Postharvest handling and storage	Processing and packaging	Distribution	Consumptio n
Fruits and vegetables (% of initial production)	20	5	2	10	19
Meat (% of initial production)	3,2	0,7	5	4	11
Fish and seafood (% of initial catchings)	9,4	0,5	6	9	11

Figure 10 - Estimation of food losses along the food supply chain for different products in Europe (adapted from Gustavsson et al., 2011)

The food industry's particular characteristics, especially the perishable nature of its products and quality and safety requirements, create major challenges for reverse logistics, and require fast and efficient logistics operations. Even a small variation in one product's characteristics can create a threat to the consumer's health. Logistics performance is affected by food features such as shelf life time, production throughput time, temperature control transportation and production seasonality (Vlachos, 2014).

Supply chain collaboration is also an enabler of reverse logistics, as supply chain partners join forces in finding and removing waste across the entire supply chain (Vlachos, 2014). Most industrialised countries are actually aiming at significantly cutting the amount of waste generated through new waste prevention initiatives, better use of resources, and encouraging a shift to more sustainable consumption patterns (Kinobe et al., 2012). The food industry is also highly influenced by regulations, which can force companies to adopt reverse logistics strategies in order to become more sustainable (Nikolaou et al., 2013).

Regarding distribution management, a centralised reverse logistics facility could have benefits such as elimination of landfill costs or the use of economies of scale (Vlachos, 2014).

Although reverse logistics have for now mostly been applied to the final product wasted at the retailer stage, it would be interesting to apply this type of thinking to other stages of the supply chain, and in particular at the processing stage, where processing operations generates high amounts of products considered as "waste".

3.3. The upgrading concept

Laufenberg et al. (2003) presented the holistic concept of food production, which can be seen in Figure 11, which is based on the fact that research in food technology is now tied to environmental considerations and a responsible management of scarce resources. This approach tries to connect differing goals: highest product quality and safety, highest production efficiency and the integration of environmental aspects into product development and food production (Laufenberg et al., 2003).

As part of environmental protection, the recycling of residues is important to every manufacturing branch and includes high developing potential. As residues will always be produced, a precautionary approach is not fit; the upgrading concept tries to add value to the rest raw materials and residues.

That is the reason why terminology is important. A transition is being made from the 'waste logic' to the 'raw materials logic', underlying that waste in one industry may be raw materials in another (Dijkema et al., 2000). Those products need to be regarded as 'raw materials', and not as 'waste' anymore (Arason et al., 2010), which refers to by definition to products that cannot be used for any value-added purposes (Rustad et al., 2011). This is highlighted by the "added value to co-products" line in Figure 11.

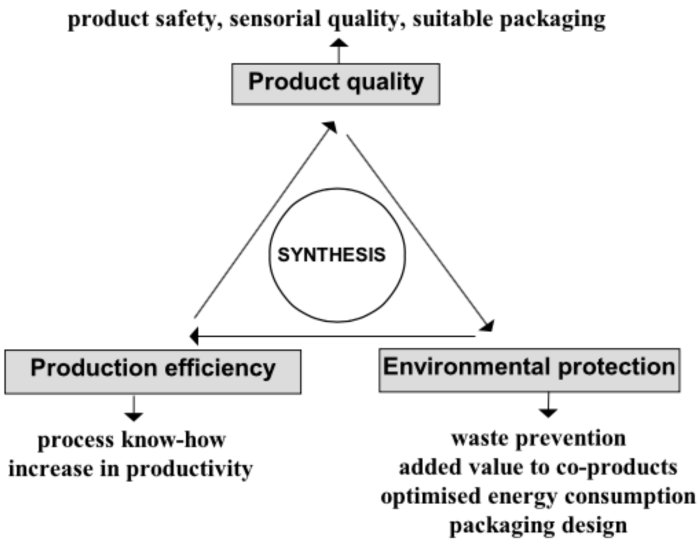


Figure 11 - The holistic concept of food production (Laufenberg et al., 2003)

The fish industry does not yet fully utilise all the rest raw materials generated from processing, especially from onboard processing where the residues are thrown into the sea. There is therefore an opportunity to apply the upgrading concept and add value to this 'waste'. Studies to estimate the quantities of waste have been conducted (see e.g. Olafsen et al., 2014), as well as the possible strategies and utilisation routes, as presented in Chapter 4.3. There is now a need for logistics solutions to implement those strategies. Developing markets of products obtained from fish rest raw materials is a key step in the process of upgrading residues. The following paragraphs are thus dedicated to introduce some facts in order to understand the driving forces for the introduction of new products in the fish industry.

Value-added product development

According to Morrissey and DeWitt (2013), the key to a successful product launch lies in five basic principles: quality, safety, convenience, taste and affordability.

The seafood industry is quite challenging for value-added product development (VAPD) regarding the range of species that are available. Then, the approach varies from species to species, since quality and safety requirements are not the same, and while cost and convenience can be the main purchasing criteria for one species, safety can be this dominant criteria for another. In addition, different factors such as supply uncertainty, regulations and industry proficiency that must be taken into account in order to be able to develop new markets. The properties of each rest raw material from different species must therefore be studied and documentation established.

Market consideration

Understanding consumer needs is essential before the launch of a product. Morrissey and DeWitt (2013) gave an example of the introduction of salmon “ready-to-eat” fillets in the 1990s. Before that, salmon was considered as a high-end product hard to cook at home, and Chile introduced a product of good quality, consistent in taste and texture, and affordable for most people. Companies should study the market opportunities for different applications, for example by considering the different cultural habits in the world.

Values

Over the past decade, values such as sustainability, environmental impacts of harvesting, producing and processing, or social aspects have had an increasing importance in marketing and sales. Products are increasingly marketed “using attributes other than their inherent nutritional or food characteristics” (Morrissey and DeWitt, 2013). Therefore, as fish products have high nutritional value, a competitive advantage could be obtained from sustainable and “zero-waste” production.

The seafood industry is also influenced by recent concepts such as buying local and direct marketing. The consumer’s interest in supporting the local fishing industry has increased, as there is also an impression of higher quality and more sustainable distribution (Morrissey and DeWitt, 2013).

Health benefits

The health benefits of fish products have long been recognised. In the 1980s it was reported that eating fish twice a week helped reducing the risks of coronary heart disease. International organisations like the FAO and World Health Organization have all acknowledged the importance of seafood in the diet. As consumers are more and more focused on the nutritional benefits of food products, it will be possible to develop new seafood products that focus on the nutritional quality (Morrissey and DeWitt, 2013). Products made from rest raw materials can use this image to boost their development.

3.4. Supply chain collaboration and Information sharing

In the supply chain management theory, it is widely recognised that there are two flows in a supply chain, one of good and an equally important one of information (Prajogo and Olhager, 2012).

Collaboration in a supply chain occurs when "two or more independent companies work jointly to plan and execute supply chain operations with greater success than when acting in isolation" (Simatupang and Sridharan, 2002). It can also be defined as a relationship between independent firms "characterized by openness and trusts where risks, rewards, and costs are shared between parties" (Sandberg, 2007). On the other hand, information sharing refers to "the extent to which data is accessible to partner firms through mutually agreed exchange infrastructure" (Olorunniwo and Li, 2010), and is an important prerequisite for collaboration (Olorunniwo and Li, 2010; Sandberg, 2007).

Developing a logistic solution in order to collect and utilize the rest raw materials generated from onboard processing will require information sharing and collaboration between the different actors of the supply chain. In reverse logistics, information sharing and collaboration occur in the context of a multi-tier network; it goes beyond the buyer-supplier, it may involve the manufacturer, retailer, customer, and 3PL (Olorunniwo and Li, 2010). In addition, enhancing the utilisation of marine raw materials is linked to sustainability issues, and Wognum et al. (2011) stated that improving sustainability requires cooperation between all actors of the supply chain, since ultimately the customer at the end of the chain decides on the premium which is granted for all the efforts.

Several studies have highlighted that information sharing has a significant benefits, for example in reducing the bullwhip effect and supply chain costs (Huang et al., 2003; Prajogo and Olhager, 2012); moreover, information sharing is a great enabler of waste reduction (Mena et al., 2011; Kaipia et al., 2013), especially when the product is perishable.

Lee and Whang (2000) listed the typical types of shared information in a supply chain:

- Inventory level, using for example VMI and CRP
- Sales data
- Order status for tracking/tracing
- Sales forecast
- Production/Delivery schedule

Organizations take advantage of information sharing technology in managing their logistical processes, and base decisions on accurate and timely information. However, many technologies enabling information sharing, such as electronic data interchange (EDI) or radio frequency identification (RFID) and Internet marketplaces, are more costly and complex than previously thought. In addition, information sharing is discouraged by different IT systems used by different companies, which thus have different data formats, software, etc. Collaboration may then require that a company can view and change its partner's database (Olorunniwo and Li, 2010).

As well as information sharing, traceability is an important component of contemporary supply chains in the production industry. Traceability can be defined as "the ability to trace the history, application or location of an entity by means of recorded information" (Engelseth, 2009). Bosona and Gebresenbet (2013) gave a more developed definition of food traceability as "part of logistics management that captures, stores, and transmits adequate information about a food, feed, food-producing animal or substance at all stages in the food supply chain so that the product can be checked for safety and quality control, traced upward, and tracked downward at any time required".

Product traceability involves competence in informing about past goods supply from a logistics perspective, including production, and transactions directing this supply from a marketing perspective. It therefore involves inter-organizational capabilities, as various supply chain actors need to coordinate their expertise to achieve economies of scale and scope, but also efficient linkage of resources managed and operated by different firms (Engelseth, 2009).

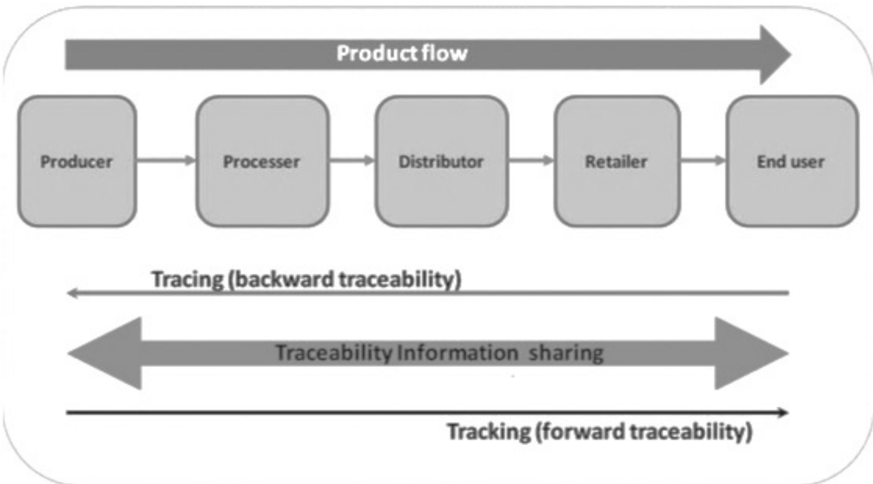


Figure 12 - Conceptual representation of material and traceability information (Bosona and Gebresenbet, 2013)

The need for traceability in the food supply chain is widely recognized, especially considering the specific sensibility due to the link with human and animal health (Bosona and Gebresenbet, 2013). The food quality and safety is influenced by all food operators in the food supply chain. If the product becomes dangerous for human consumption at one point, information sharing between all actors is crucial, as well if there is a need to trace all compromised batches and pull them out of the market (Anica-Popa, 2012). Several events such as the “mad cow disease” have attracted special media and consumer attention (FAO, 2014b; Frederiksen, 2002; Ismond, 2002; Bosona and Gebresenbet, 2013; Engelseth, 2009). In addition to risk to public health, food crises lead to economic crises due to direct and indirect – such as damage to reputation- costs of product recall (Bosona and Gebresenbet, 2013).

In order to provide consumers with product information about the food they purchase, information must be recorded along the supply chain and communicated with accurate and efficient methods (Donnelly and Olsen, 2012). Due to the high degree of globalization in the seafood trade and the lack of existing standards for information exchange, this is rather challenging in the seafood industry (Donnelly and Olsen, 2012). Fish products can be traced through labelling of product, external tags, chemical marking like tattooing or with inorganic substances, physical marking or using DNA markers (Bosona and Gebresenbet, 2013).

Traceability can also contribute to the implementation of sustainability initiatives, for instance to hamper the depletion of fish stocks. In addition, good visibility and traceability can help prevent Illegal, Unreported and Unregulated fishing (IUU), which threatens ocean ecosystems and sustainable fisheries.

Product information is handled by multiple actors in the supply chain, representing the “flow of information” as usually called in logistics literature. The quality of product traceability depends accordingly on the degree of network transparency (Engelseth, 2009).

Transparency is a wider concept that includes traceability. Indeed, the aim to improve the sustainability of the food production system usually leads to higher costs in the short term, whereas the revenues are uncertain. Then, creating added value by improved sustainability implies creating transparency, as the consumers have to be shown and convinced that the higher prices are justified by the measures to improve sustainability. This information influences the consumers’ willingness to pay (Wognum et al., 2011). Traceability is an enabler, as it offers the possibility to follow a product and the processes it undergoes, thus making it possible to offer specific information to the customers (Wognum et al., 2011).

3.5. Summary of theoretical background

The theoretical concepts mentioned in this Section are summarised in Figure 13, through a causal link that highlights the need for utilisation of rest raw materials.

Following these concepts, there is now a need for an empirical background in order to set up a base to build on a conceptual solution to improve rest raw materials utilisation in Section 5.

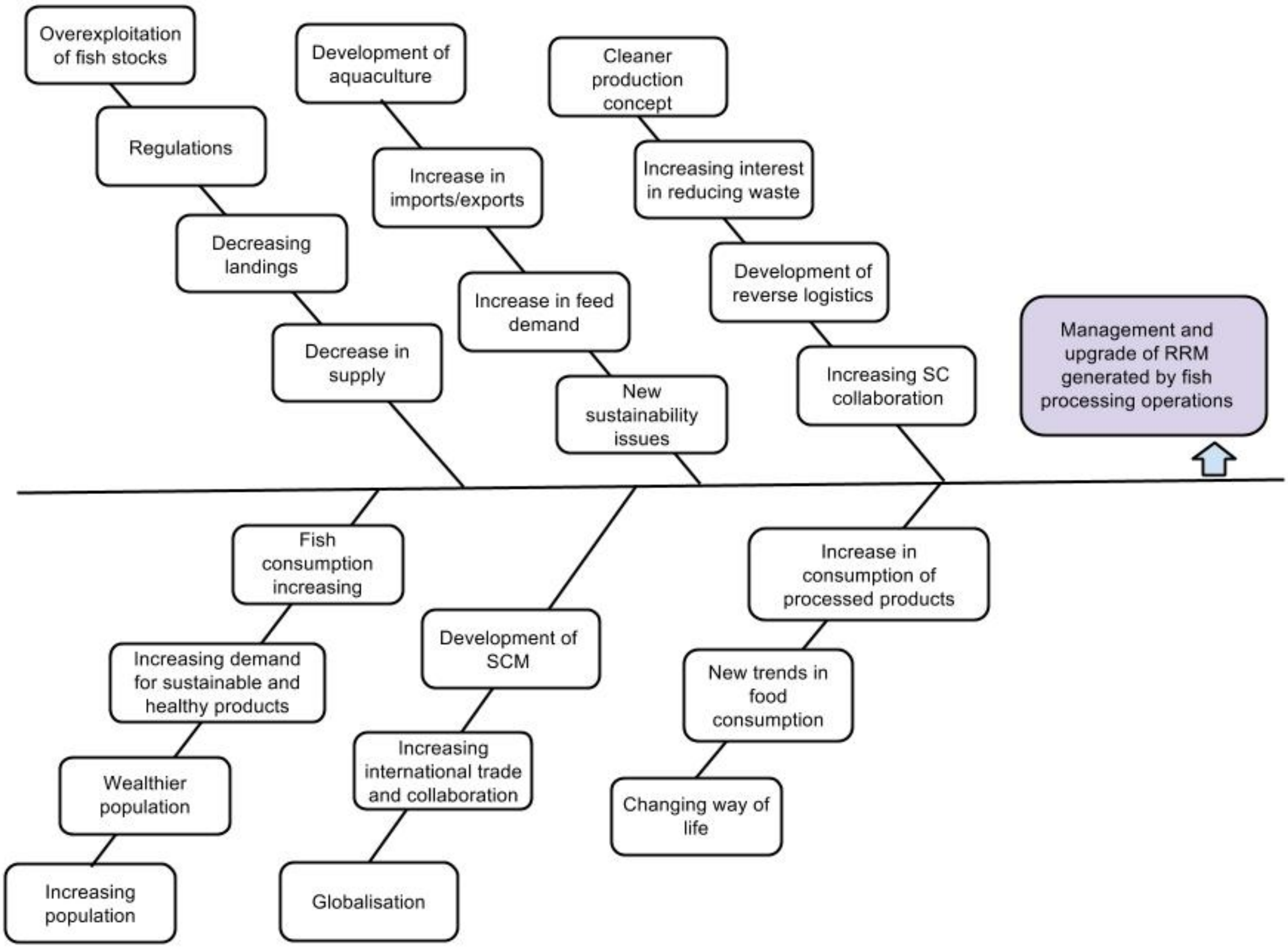


Figure 13 - Theoretical framework and causal link to the need for management and upgrade of RRM

4. EMPIRICAL BACKGROUND

This section is based on a literature study and aims to establish an empirical background of the fishing industry's situation in Norway with regard to rest raw materials' generation and utilisation. It first introduces some facts regarding the Norwegian fisheries, the different types of fish production and the fish species and products in focus. Then, the fishing fleet is presented, as well as onboard processing and the regulations determining their operations. Finally, a paragraph is dedicated to introduce the rest raw materials available and the different applications that can be pursued for their utilisation. The section ends on a brief outline of the current situation regarding the utilisation of rest raw materials in Norway and other potential opportunities. The objective of this section is to set a realistic base for a concept to increase the utilisation of rest raw materials.

4.1. Introduction to the Norwegian fish industry

4.1.1. The fisheries-based supply chain

Norwegian fisheries

Norway is one of the world's leading nations regarding the production of marine fisheries and aquaculture with a coastline of more than 83,000 km including fjords and islands (FAO, 2011).

As the degree of exploitation of the fish stocks is in concern, fisheries need a responsible and sustainable management in order to be able to maintain the catch in some regions and the recovery of depleted stocks (Hall, 2010; Penven et al., 2013). Fisheries are managed according to different objectives, encompassing biological, economic, social and political. Harvests are controlled by different input or output methods. Input controls refer to indirect control of the catch through restrictions on fishing like number of fishing licences or gear selection, while output controls refer to limiting the amount of fish that can be harvested per period, known as the Total Allowable Catch (Farmery et al., 2014). Indeed, the Ministry of Fisheries and Coastal Affairs has set quotas for the different fisheries, based on stocks assessments and environmentally related targets (FHL, 2013), which have protected the ecosystems in the Norwegian waters. The stocks in the Barents Sea for example are well within sustainable levels compared to other stocks in the world fisheries. Norway has also had a ban on discards for cod and haddock since 1987, which has been gradually expended to more species, and since 2009 all catches must be landed (Gullestad et al., 2015).

The fisheries sector is a key industry in Norway, responsible for both settlement and employment along the entire coast. In 2009, Norway produced 3.5 million tonnes of seafood, of which about 25 per cent came from the aquaculture industry (FAO, 2011). Over the last few years, landings by Norwegian vessels have been relatively stable at around 2.5 million tonnes per year. 67 per cent of the catch was used for consumption, while 33 per cent was used for the production of meal, oil, or animal feed (SSB, 2015). However, there have been rather large variations within individual species groups.

The Norwegian seafood is based on two main pillars: fish farming and capture fishery. Capture fishery is mostly affected by the variation in the access to resources, which can lead to considerable changes in both volume and prices from one year to another.

Different types of supply

Capture fisheries are usually defined in terms of the people involved, species or type of fish, area of water, method of fishing, class of boats, or purpose of the activities (FAO). The types of fisheries in focus are capital-intensive fisheries using relatively large vessels, with a high degree of mechanization, and which usually have advanced fish finding and navigational equipment. Such fisheries have a high production capacity. During the past decades however, the annual fish catch has been stabilizing, and according to fish biologists, further growth is not likely to happen in the future (Murugan et al., 2013; Arvanitoyannis and Tserkezou, 2014).

Aquaculture is the farming of aquatic organisms, including fish, molluscs, crustaceans and aquatic plants. It occurs both in inland areas with freshwater, and in seawater areas. Norwegian aquaculture is largely industrial, modern and highly competitive. Aquaculture production has more than doubled during the last decade (FAO, 2011). Although Europe’s production volumes are quite small compared to Asia and Central-America, as it accounts for approximately 2 per cent of the total aquaculture production, the Norwegian production of salmon has increased substantially and now accounts for over half of the world’s salmon supply (FAO, 2011). In addition, the Nordic countries have huge possibilities in becoming a leading region in sustainable aquaculture with the local resources, know-how and clean image (I Thorarinsdottir et al., 2011). The main farmed species are Atlantic salmon, rainbow trout and Atlantic cod.

Although capture fisheries continue to play an important role in the fish industry, their resources are limited and it can be expected that aquaculture will become a major driver in value-added processing in the future (I Thorarinsdottir et al., 2011; Morrissey and DeWitt, 2013). In 2010, aquaculture represented 38 per cent of the total fishery production and 45 per cent of all seafood directed to human consumption (Morrissey and DeWitt, 2013).

Aquaculture is out of the scope of the study, but it is worth mentioning considering that its expansion is also highly linked with fishmeal availability. The main cost factor in aquaculture is the cost of feed (I Thorarinsdottir et al., 2011). Besides costs, both environmental and economical concerns are raised with regards to increased needs for feed ingredients from marine sources. Aquaculture industries need to develop innovative solutions for a future sustainable aquaculture and to maintain the competitiveness of the Nordic countries in seafood production (I Thorarinsdottir et al., 2011).

Fish species

There are thousands of fish species in the world and they all have different nutritional compositions. Among them:

- Whitefish, part of demersal species
- Blue fish, part of pelagic species
- Salmon species
- Cartilaginous species like sharks

The possible utilisations of the different parts differ between the groups, especially for mass upgrading. Whitefishes are usually lean, which divert them towards fishmeal production, whereas pelagic fishes are fattier and directed towards oil production.

Not all species of fish can be processed onboard, due for instance to factors such as size, number and fishing ground. Fish processed on-board of the large fishing vessels are mostly groundfish or demersal species. Groundfish or demersal fish are fish that live on, in, or near the bottom of the body water they inhabit. They include Atlantic cod, haddock, saithe, tusk, ling, Greenland halibut, Atlantic redfishes and Argentines (SSB, 2015). The main captured species in Norway include herring, cod, capelin, mackerel, saithe, blue whiting and haddock, as described in Figure 14 (SSB, 2015). Cod fishing was the most important of capture fisheries in 2014, with a catch of 473 400 tonnes for a value of NOK 4.6 billion.

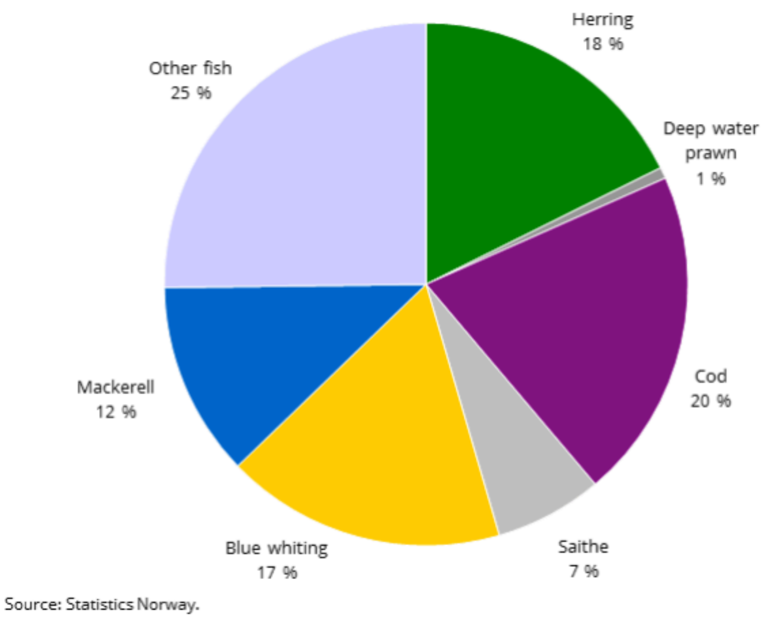


Figure 14 - Catch by fish species in 2014 (SSB, 2015)

Demersal fish are abundant in the Barents Sea, in the north of Norway. Cod is the most abundant, followed by haddock, redfish, Greenland halibut (Institute of Marine Research, 2014). Over 90% of the total catch of cod happens in the Barents Sea (FiskeriDirektoratet, 2014).

Fish products

Fish is a highly perishable product, and needs to be properly handled, processed, packaged and stored after harvesting, otherwise it could become unfit to eat and possibly dangerous for the health (FAO, 2014b). Norway has been an important producer of raw materials and semi-processed products for the seafood industry, although the last decade has seen a number of changes in the Norwegian fish processing industry, "driven by high costs, negative trends in exchange rates, and increasing difficulties to access EU markets" (FAO, 2011). A part of the production leads to processed products such as frozen fish fingers, fish balls and fish cakes (FAO, 2011). In 2012, 46 per cent of the fish marketed for edible purposes was in live, fresh or chilled form; 12 per cent was utilized in dried, salted or smoked forms, 13 per cent in prepared or preserved forms, and 29% in frozen forms (FAO, 2014b).

To obtain a high-quality product, fish should be processed as quickly as possible after harvesting (Kose, 2010). When fish is processed, freezing is the favoured method, accounting for 54 per cent of total processed fish for human consumption in 2012, followed by canning and curing (FAO, 2014b; Hall, 2010).

4.1.2. Fishing vessels and onboard processing

Norway has a diversified fishing fleet ranging from larger ocean vessels to smaller coastal ones (FAO, 2011), although the number of fishermen has decreased steadily in the last 50 years. Fishing vessels can be divided in two categories, the fishing fleet in the coast-area that can deliver to the harbour on a daily basis, and the fleet operating far from the coast, which stays offshore for several weeks (Sandbakk, 2002).

The size of the boat depends on the planned operations, carrying capacity, as well as the type of equipment that will be onboard. The first group for example includes smaller vessels without equipment for processing or freezing, which deliver fish on a daily basis. These types of boats are out of the focus of this thesis, as the domain of interest lies in the rest raw materials generated by onboard processing.

The second group includes several types of boats, which can stay at sea for several weeks at a time, and have processing facilities onboard. The boat layout is highly dependent on the fish species to be processed and the types of processing activities, which range from freezing to filleting and waste management operations like fishmeal plants (Sandbakk, 2002). Handling, storing and processing fish onboard creates more challenges for the plant design than for onshore plants, due mostly to space limitations, safety issues, freshwater consumption and living activities (Hall and Köse, 2013).

Figure 15 - Fish processing vessel

For the main groundfish species, the most utilised fishing techniques are trawling and long lining according to the FAO. The different techniques are illustrated in Figure 16. Goundfishery mainly uses nets, trawl, lines and Danish seines.

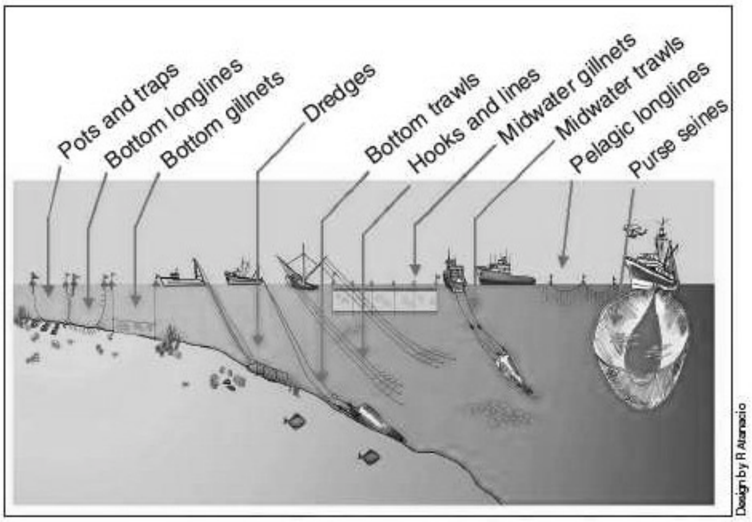


Figure 16 - Different types of gear for fishing vessels

Several types of ships are further presented in the following paragraphs.

Factory ships – freezer trawlers, factory trawlers

The trawler vessel group takes part in various fisheries, and the vessels' sizes range from open boats to large freezer trawlers and factory trawlers. Trawling is the most important fishing method used in the world (FAO, 2001). Trawls consist of cone-shaped nets dragged by the boats (BE-FAIR Report, 2006).

The economically most important species targeted by trawlers is cod, caught either alone or in a mixed fishery with haddock and/or saithe (Hermansen et al., 2012), which makes it particularly interesting for this research as cod, haddock and saithe belong to the groundfish species that are into focus. Vessels are allocated yearly quotas, and it is the responsibility to the fishermen to plan the utilization of their quotas.

The largest factory trawlers usually have a length superior to 45 meters, which ensures the boat to have large buffer capacity. Factory ships or catcher-processors usually catch, sort, process and freeze fish within their own facilities. Some vessels also have a fishmeal plant in order to use the whole fish (Kose, 2010). Thus the main products of factory trawlers are deep frozen fillets, fishmeal and surimi products. These ships are equipped with a processing plant including mechanical gutting and filleting equipment, as well as a freezing installation (FAO, 2001).

Freezer trawlers are medium and large vessels, on which the fish is preserved by freezing. They usually do not have filleting processing facilities onboard, but can have heading and gutting processes. The majority of trawlers operating on high seawaters are freezer trawlers.

Factory bottom long-liner

Factory longliners are large size vessels, over 45 meters long, working mostly on distant waters, and are also equipped with a processing plant including mechanical gutting and filleting equipment together with freezing installations, and sometimes fishmeal and oil plants. Longliners deploy one or more fishing lines with a series of baited hooks hanging on them.

Motherships

Motherships are vessels that “process but do not harvest fish and operate on the fishing grounds, receiving deliveries from smaller vessels that are engaged only in harvesting activities” (Kose, 2010). The mother ship usually operates in water far from the shore. They process fish caught by other ships; the deliveries are either made by the ships themselves or through tender ships. Once processed, onboard facilities allow to freeze the products and perform advanced processing such as surimi production (Kose, 2010).

Tenders

Tenders are transport vessels that deliver the catch from other boats to the processing plants. Some tenders have a high capacity of storage and can take deliveries from a dozen catching vessels before heading to the processing plant. On another level, tenders bring fuel, water and supplies to the catching boats (Kose, 2010). This type of ship is interesting to mention regarding the proposed concept developed in Section 5.

According to Digre et al. (2014), between 2011 and 2013, Norwegian exports of unprocessed raw materials increased from 33,000 tonnes to 87,000 tonnes, while Russian exports of onboard-produced cod fillets increased from 20,000 tonnes to 36,700 tonnes of fillets destined to the European market. Meanwhile, the exports of unprocessed frozen fish towards low-cost production countries like China and Poland is increasing. Norway is thus losing market share and potential jobs in fillet production to other countries, while the environmental impact of fish is increasing, as it is first transported to lower production costs areas to be processed and sent back to the European market.

On this basis, a question arises whether onboard production could be considered as a strategy to increase employment and scope of fillet production, and whether it could create new supply chains linking land and sea (Digre et al., 2014).

Onboard producing fleets have been seen as a direct competitor to land-based processing facilities regarding the access to and use of the resource based in the Norwegian Economic Zone (Standal, 2008; Digre et al., 2014). However, with the increase of exports of unprocessed fish to for instance China and Poland, this argument has lost legitimacy. In addition, Digre et al. (2014) cited Olsen (1990) who showed that onboard production can be considerably more profitable than land-based production based on deliveries of frozen fish for filleting ashore. On-board processing has several advantages (Kose, 2010; Digre et al., 2014):

- Availability of high-quality and fresh fish: when frozen in a correct way, the fish quality is as good as freshly caught.
- Control of the time for better price: frozen storage allows a waiting time until the price is up.
- Flexibility: possibility to wait until the hold is full, thus saving fuel and time spent on extra trips.
- As harvesting and processing stages are integrated onboard in the same place, it saves a part of transportation/shipping of fish that usually occurs in a fish supply chain, as well as one of the freezing process – of catch and then final product.

However, over the years, on-board production of fillets has reduced, as well as the number of vessels, driven especially by regulations and quotas from the Norwegian government (Standal, 2008; Digre et al., 2014). According to Digre et al. (2014), at the time of writing there was only three trawlers and 2 autoline vessels producing fillets in Norway. The Directorate of Fisheries stated however that there were 251 boats of 28 meters and over in 2014, and 89 of 60 meters and over (FiskeriDirektoratet, 2015).

The majority of large Norwegian fishing vessels are suspected to be catcher-processors, whose only operations onboard are gutting and heading. This impacts on the types of rest raw materials generated onboard of Norwegian fishing vessels. Indeed, according to Digre et al. (2014), onboard production of headed and gutted fish generates an amount of rest raw materials equivalent to 30 per cent of live weight, while fillet production generates over 60 per cent of rest raw materials. Then, while ships that conducts onboard filleting operations can find it profitable to process the rest raw materials, only a few of the ships with heading and gutting processes find profitable to carry the rest raw materials.

Figure 17 presents the different steps that the fish go through to produce either headed and gutted fish or fillets.

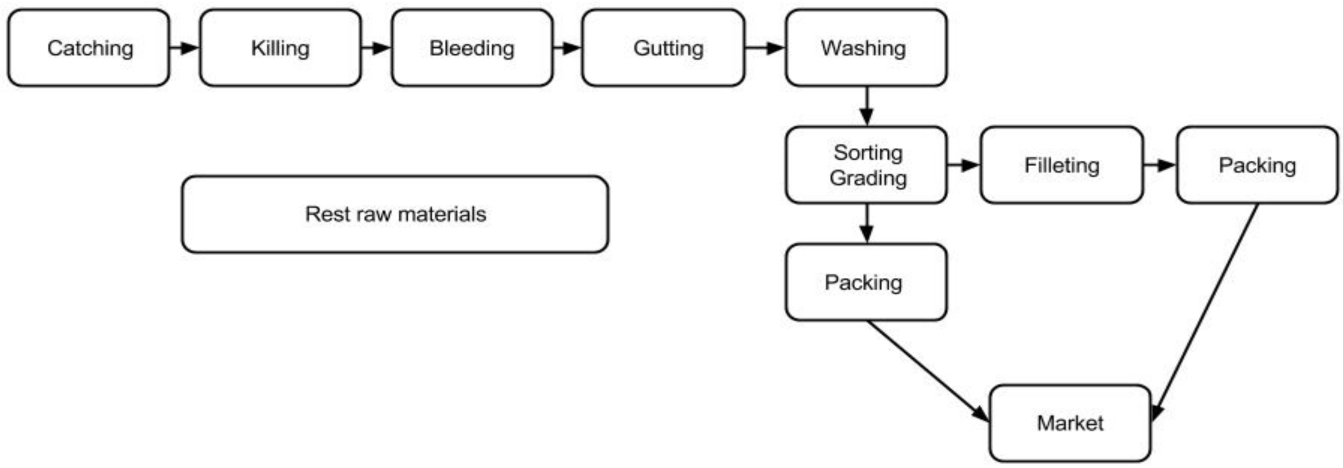


Figure 17 - Process steps for onboard treatment of the fish (adapted from Digre, 2013)

Fish are first harvested by a large variety of methods, implying different types of nets, hooks, gears, etc., as described before.

The stunning step consists in a period of asphyxiation until the fish die; the stress caused to the fish can however alter the quality of the future products. Another method to slaughter the fish is electrical stunning, which provokes enough movements to break vertebrae, but can result in blood spots (Borderías and Sánchez Alonso, 2011).

Though most of the steps are common, the order can vary depending on the species so that the quality of the fish is enhanced. For example, stress caused to salmon lead to softer flesh, which is essential when slicing smoked salmon (Sigholt et al., 1997).

A bleeding step can be executed, depending on factors such as species, size, and season of catch. Correct bleeding is vital for the quality of the fish, and it should be done quickly after the fish is brought on board (FHF et al., 2013). The fish should be handled properly after the step, so that there are no blows and bruises. Different methods can be used, and fish can be alive or dead. Fish can be bled while they are alive, so that the pumping of the heart helps bleeding out the fish.

The gutting step can be done manually or mechanically, and can vary by species. It is done by cutting, although some machines perform gutting by sucking the viscera out and cleaning the belly part through the mouth. The second method makes it difficult however to evaluate how well the fish is cleaned (Borderías and Sánchez Alonso, 2011).

After the gutting step, fish should be washed thoroughly in order to remove traces of blood and debris and to wash bacteria and intestinal content out the gut cavity, skin and gill of fish (Borderías and Sánchez Alonso, 2011).

Many species are filleted in order to satisfy the customer demand. Different standards can be used, such as removing only the backbone, or removing visible fat, pin bones and skin. The fish filleting industry has a product yield of 30 to 50 per cent, which means that 50 to 70 per cent of the fish are rest raw materials generated during processing (FAO, 2014b; Murugan et al., 2013). The last operation onboard is packing, and then the boxes are usually stored in the freezer.

When it comes to the possibility to use rest raw materials, the facilities onboard constitute the most important limitation. First, conserving the rest raw materials implies the allocation of storage space for parts that are considered of lower value. Also, the space available onboard restrains the possibility to add sorting equipment. Another issue is the lack of gutting equipment that is careful enough to keep the rest raw materials intact, and gutting and sorting fish manually is time-consuming (Sandbakk, 2002).

4.1.3. Regulations

Regarding fish processing, the most known safety control system is the Hazard Analysis Critical Control Point (HACCP) programme, which identifies and controls the critical steps in the production (Cato, 1998). It originated in the United States, monitored by the Food and Drug Administration (FDA). The system is based on seven principles:

- Identify potential safety hazards
- Determine Critical Control Points (CCP), i.e. where and when hazards need to be controlled
- Establish critical limits for each CCP
- Implement procedures to monitor CCP and data
- Identify corrective action to be taken when process controls are lost
- Establish record keeping systems

Many countries, including Norway, have decided to implement preventive procedures based on HACCP principles, in order to ensure to a large extent food safety in seafood processing (fisheries.no, 2014). Several agencies or institutes are responsible for different roles in seafood safety in Norway. For example, the Norwegian Food Safety Authority (NFSA) is responsible for the development of legislation, inspections and monitoring. The Norwegian Environmental Agency (Mdir) is responsible for the development of legislations, inspections and monitoring related to environment pollution. Due to EEA-agreement, the Norwegian legislation is harmonized with the EU. The NFSA is responsible for the evaluation and implementation of EU food regulations in Norway (fisheries.no, 2014). Norwegian fisheries are managed mainly by the Ministry of Fisheries and Coastal Affaires, which places great importance on sustainable and environmentally friendly fisheries and aquaculture management, based on a thorough knowledge and understanding of fishery resources dynamics and their environment (FAO, 2011). Access limitations in the form of licenses have been widely used, as well as registration requirements.

In addition, the disposal of waste, particularly food waste, is highly regulated and the legislation is constantly evolving (Archer et al., 2001). The directive 2008/98/EC of the European Parliament relating to waste management states that the states should ensure that any waste producer or holder carries out the treatment of waste himself or has it handled by another party. These principles are the basis for waste management and thus rest raw materials management. The European Union is also trying to place a ban on discards of usable fish at sea, to be implemented before 2019 (FHL, 2013).

Animal by-products have a special regulation regarding their management, following especially several food crises. Animal co-streams are divided into three categories regarding their potential risk towards human health, animal health and the environment, and each category implies different treatments. Indeed, food processing includes cleaning and gutting steps, which involves co-streams that may pose a risk for infecting the environment, soil, water, crops, natural plants, wild and domestic animals, and human with disease or pests (Adler et al., 2014).

The first category comprises materials with the highest risk for human health, such as for example bovine brain or spinal cord. It also includes infected animals, materials likely to disseminate infectious agents. These materials should be collected and incinerated or put to landfill after treatment.

Category 2 comprises materials with lower risks of infectious disease, and includes for example fallen stock and digestive tract content. Category 2 materials can be incinerated, put to landfill after treatment or recycled for other uses than animal feed, such as production of biodiesel, biogas and biochemical products.

Category 3 materials are materials with no risk for health, including parts not intended for human consumption but whose hygienic quality could allow for human consumption. These materials can be used to produce animal feed after treatment. Examples of category 3 are bones and skin. Category 3 materials are the ones used for upgrade. According to FHL (2013), around 90% of fish rest raw materials are Category 3 products.

The EU's food hygiene legislation regulates the use of marine rest raw materials for human consumption, and thus controls the greatest potential for value creation (FHL, 2013).

4.2. Composition of fish rest raw materials

In order to align fish with market expectations, the seafood can undergo many processing steps (see Chapter 4.1.2), which generate different types of rest raw materials (Penven et al., 2013). Fish rest raw materials can be: heads, viscera including roe and liver, trimmings, fish bones or cartilage, hides, tails, tongues, eggs, oil, milt (Penven et al., 2013; Kristbergsson and Arason, 2007). The average proportions of each are described in the following figure, and the characteristics of each rest raw material are described later on.

The largest proportion of rest raw materials consists of heads. In 2013, this represented 36 per cent of all rest raw materials that originated from white fish in Norway. Liver and guts constituted respectively 15 and 18 per cent, while backs and trimmings including skins from processing accounted for 19 per cent. 12 per cent of all rest raw materials were estimated to be roes and milts (FHF, 2014).

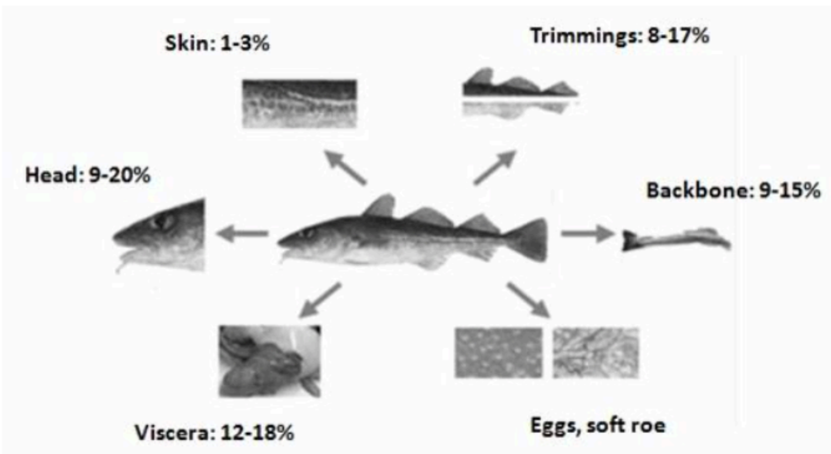


Figure 18 - Average proportion of fish rest raw materials (Penven et al., 2013)

4.2.1. Fish viscera

Viscera of fish include digestive tissues such as liver, roe, intestines or stomach, and constitute between 10 and 25% of the net weight of the fish depending on the maturity and season (Arason, 2003; Kristbergsson and Arason, 2007).

Most of the intestines are usually discarded at sea, although they contain large quantities of digestive enzymes (Arason, 2003). These enzymes can be used in several industries, such as for detergent production, leather processing, chemical modifications, natural skin care products, cosmetics, or food processing (Kristbergsson and Arason, 2007).

4.2.2. Fish roe

Fish roe products are extremely valuable, and have several applications, such as caviar for example, or salted and flavoured with sugar (Bledsoe et al., 2003; Arason, 2003). They can be blended with other ingredients, for examples herbs or cream cheese. On the other side, the availability of fish roes is highly seasonal as roes are collected during the spawning season of the fish (Kristbergsson and Arason, 2007).

The appearance, flavour and texture are all important sensory characters (Bledsoe et al., 2003). The quality is highly dependent on the maturity of the roes when harvested (Kristbergsson and Arason, 2007).

Japan is a major importer of fish roe products, like caviar and eggs. Europe is also an important player. In the Scandinavian countries, there is a high demand for salted and frozen cod roes for smoking or canning. Roes from haddock and saithe are also used similarly (Kristbergsson and Arason, 2007).

4.2.3. Fish liver and fish oil

Fish livers contain considerable quantities of oil, between 40 and 75% depending on the species (Alonso et al., 2010). The primary processing of fish oil is generally performed at the fishmeal plant; when the fish is cooked and pressed, the oil is separated. For example, cod liver corresponds to approximately 10% of the ungutted cod, and cod liver oil is processed for human consumption and consumed in capsules or liquid form (Kristbergsson and Arason, 2007). Alonso et al. (2010) stated however that although the cooking stage facilitates the separation of oily and water phases, it drastically reduces the oil quality. Depending on this quality, the oil can be stored to be used in the food or aquaculture industry, or can be processed in order to produce bio-fuel.

Kristbergsson and Arason (2007) stated that there is more demand for cod liver than the quantity supplied from ungutted fish brought ashore for processing; on the other side, there are large quantities of fish liver discarded at sea.

4.2.4. Trimmings and minced fish

After the filleting operations, considerable quantities of flesh may remain. Out of the total weight of mince from various parts of a cod, usually around 15 to 18% mince can be recovered (Kristbergsson and Arason, 2007). There are different technologies in order to do so, for example by using a high-pressure water jet, or mechanically by pressing the parts.

4.2.5. Fish skin, bones and fins

Fish skin is mostly composed of gelatine and scales (Kristbergsson and Arason, 2007). Scales from some species can be utilized as raw material for pearl essence, which is a substance used in cosmetics like lipsticks and eye shadows.

Skin, bones and fins represent around 30% of fish fillet processing waste, and represent a rich source of gelatine and collagen (Blanco et al., 2007).

Fish skin can be stored at refrigerated temperatures or frozen for a short period of time, without negative effects on the functional properties of the gelatine (Kristbergsson and Arason, 2007).

4.2.6. Fish heads

Fish heads contain relatively little meat and are often discarded. The parts with flesh can be seen in Figure 19.

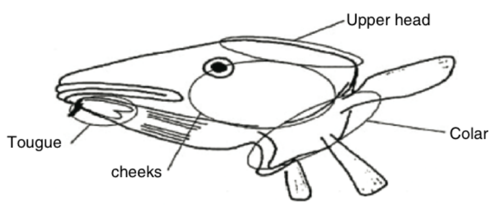


Figure 19 - Cod head indicating fleshy parts (Kristbergsson and Arason, 2007)

The tongue as well as the cheeks are demanded products due to their unique taste and texture (Kristbergsson and Arason, 2007). Removal of those parts can be done mechanically and the products are mostly salted and sold in Portugal and Spain.

The heads can also be dried and sold entire, which is more valuable than using it for fishmeal (Sævaldsson, n.d.). In 2011, Norway exported 3100 tonnes of dried cod heads to Africa for example (FAO, 2014b).

4.2.7. Other

In addition to the raw materials listed above, some liquid products are considered as waste like blood and wastewaters for example, while they could also be filtered to retrieve the nutrients they contain.

Rest raw materials also include whole fish that has been rejected from processing, or bycatch, which is fish that was caught unintentionally.

4.3. Applications for the rest raw materials

The rest raw materials listed in the precedent paragraph all have different properties and are thus basis for different ingredients and applications in diverse industrial sectors (Arason et al., 2010; Jayathilakan et al., 2012; Alonso et al., 2010). Several of these applications are sorted in two categories in the next paragraphs. The first one is mass upgrade, which uses important volumes and generates low-value products, and the second is high-value upgrade, which applies to low volumes of high quality rest raw materials and generates high value-added products.

4.3.1. Mass upgrade: utilisation for animal feed, agriculture or energy

<u>Animal feed</u>

- **Fishmeal and fish oil**

Fishmeal and oil can be marketed in different industries: for animal consumption, aquaculture or land-animal feed, and for human consumption, as fish-oil capsules or in pharmaceuticals (Shepherd and Jackson, 2013). In 2010, 73 per cent of the fishmeal produced was used by the aquaculture industry, and 71 per cent of the fish oil produced also goes for aquafeed (FAO, 2014b). Fishmeal represents also around 10 per cent of the diet of the pig and poultry industry. The main market for fishmeal and oil is thus animal feed, although there is a market in the food industry. For example, fish oil obtained from the manufacture of fishmeal is widely used in the manufacture of edible oils and fats such as margarine. Global demand and prices for fishmeal and fish oil have been increasing, which makes it less and less a low-value product (FAO, 2014b).

Fish meal is a relatively dry product composed of protein, minerals, fat and water, which can have different qualities regarding digestibility or palatability, depending on the raw material's type, nature and freshness and process used for its production (Blanco et al., 2007; Archer et al., 2001). Fish meal and fish oil can be produced from any type of whole fish or fish remains (FAO, 2014b; Archer et al., 2001). In 2012, about 35 per cent of the world's fishmeal production was obtained from fish residues (FAO, 2014b).

The traditional manufacture of fish meal and oil is a separation process in which the content of water, oil and solids of the fish are separated and the water removed by evaporation and drying (Nissen, 2003). It starts with a cooking step, in order to separate the oil from the rest of the material and to ensure that pathogenic organisms are destroyed. Usually, the minced fish is cooked for around 20 minutes at 95-100°C. The cooked material is then pressed to separate the solids from liquids containing oil and water. All solids are recombines and then dried in an evaporator, while the water is evaporated. The standard evaporator usually operates at 90-95°C, but some operate at 60-65°C (Gill, 2000).

Once made, fish meal is usually stored and transported in bags, and can be kept for several years in a cool dry storage without any change in its nutritional value.

It is perhaps the ultimate step for utilizing rest raw materials, since all raw materials that do not have another means of utilization can end up in a fishmeal plant (Kristbergsson and Arason, 2007).

The fish oils can be categorised in two types, which are the body oil contained in the muscles and the liver oil obtained from liver and viscera. Each oil type has different properties and value. The oil extracted in the process explained above is a mixture of the two. The demersal fish in focus, i.e. cod, haddock etc., contain a high quantity of oil in their liver, though the nutritional quality depends on the species, season, spawning and feeding habits (Archer et al., 2001). Fish freshness is a particular factor for oil production, as spoilage breaks down valuable components of the oil. The crude oil obtained from fishmeal production needs to be further processed. If it is intended for animal feed, it is generally washed and centrifuged. However, for human consumption, the process is more intensive, as seen in Figure 20. Alkaline refining is carried out to neutralise free fatty acids. It is followed by bleaching, which is achieved by mixing oil with natural clays and agitating to remove acids. Hydrogenation produces edible fat from the oil, and deoderization consists in the removal of small quantities of the more volatile compounds (Archer et al., 2001).

The conventional oil extraction described above uses high-temperature techniques that lead to the loss of proteins. In March 2015, SINTEF presented a new approach to get the two high-quality products, using a combined process they say can be profitable (SINTEF, 2015).

Prices for fishmeal have increased as demand continues to grow, with for example an increase of 206 per cent between January 2005 and January 2013. This is due especially to the growing demand from China and Asia where agriculture production has been increasing in the past decade. China remains the main market for fishmeal (FAO, 2014b).

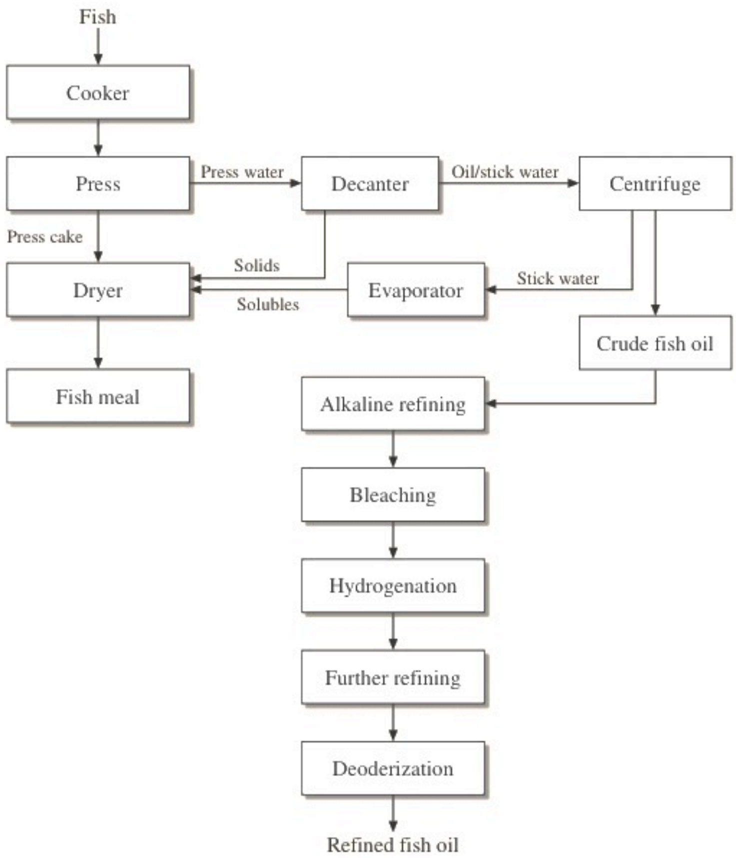


Figure 20 - Process steps for the manufacture of fish oil and meal (Menon and Lele, 2015)

- **Fish Protein Concentrate (FPC)**

FPC refers to any stable fish preparation intended for human consumption in which the protein is more concentrated than in the original fish. It can be used for example as ingredient in processing lines in order to boost protein content (Archer et al., 2001). There are different types of FPC according to its quality and degree of refinement.

The process is similar than for the production of fishmeal; the fish is minced and mixed with ethanol or propanol, and centrifugation is used to remove water, fat and fishy flavour and odours (Nissen, 2003; Archer et al., 2001). The raw materials for making FPC should receive the same care as fish for ordinary consumption.

- **Fish Protein Hydrolysate (FPH)**

FPH is a highly functional product similar to FPC, except water and oil have not been removed. It is supposed to contribute to whipping, gelling and texturing properties when used in food products. The favoured raw material to produce FPC is whole demersal fish or frames, which are mixed with water and enzymes to give FPH. FPH is however not yet used in products destined to human consumption in Europe, due to being more expensive than soya bean as a protein source, and negative perceptions of its odour and colour (Archer et al., 2001).

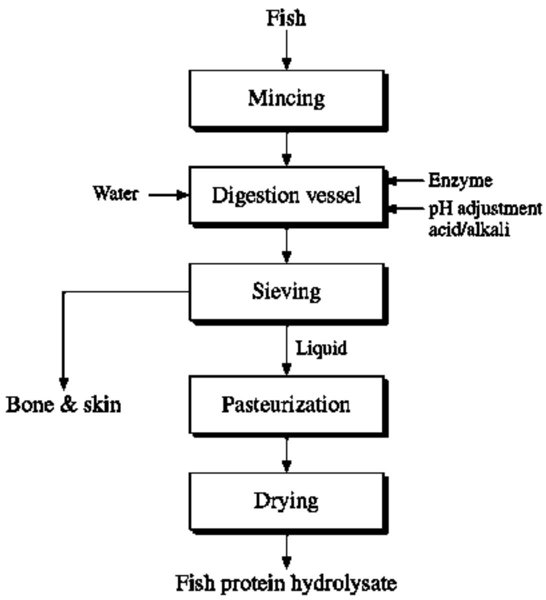


Figure 21 - Production of FPH (Menon and Lele, 2015)

- **Fish silage**

Fish silage is a liquid product made from whole fish or parts of fish, which are liquefied by the action of enzymes in the fish in the presence of an added acid (Tatterson and Windsor, 2001). Fish silage is used in the same way as fish meal in animal feed, and is most suited for pig farming, since it can be used in liquid feeding systems (Tatterson and Windsor, 2001; Archer et al., 2001). It is a widely established product in Scandinavia for use as pig feed (Archer et al., 2001).

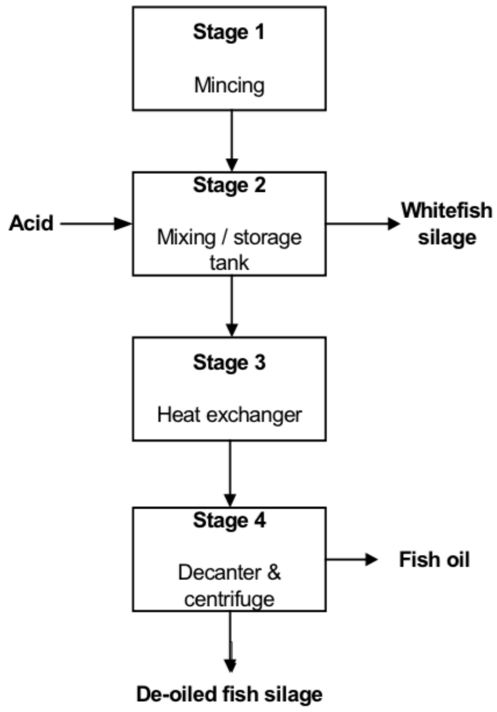


Figure 22 - Process steps for the manufacture of fish silage (Archer et al., 2001)

In order to produce fish silage, the raw materials are first minced through a grinder; immediately after, acids are added, and everything is mixed thoroughly so that all the fish comes into contact with the acid, while the pH of the mixture is controlled. The rate of liquefaction depends on the type of raw material, its freshness, and the temperature of the process (Tatterson and Windsor, 2001). Fresh fish liquefy more quickly than stale fish. The warmer the mixture, the faster the process. For example, silage elaborated from fresh white fish offal takes about two days to liquefy at 20°C, but takes 5-10 days at 10°C.

- **Pet food**

The market for pet food has been growing for several years, and as pets have more and more importance the families, there is an increased interest on the content of their food regarding nutrition, natural ingredients, etc. Requirements regarding quality are becoming almost as high as for human consumption (De Silva and Turchini, 2008).

Agriculture

- **Fertilizers**

The fish rest raw materials can be mixed together with sulphuric acid in order to produce liquid fish fertiliser, which has been a widely used fertiliser for a long time (Archer et al., 2001).

Another method is the anaerobic digestion of fish waste, which leads to the production of methane and sludge. The methane is recycled to generate electricity or heat, whereas the sludge is used as an organic fertilizer (Archer et al., 2001).

Compost is another product that can be obtained from fish rest raw materials and used as a soil enhancer to favour growing conditions. Fish rest raw materials are usually mixed with a rich source of carbon such as wood waste like sawdust or chippings, and is left to rest for four to six weeks (Archer et al., 2001). The process also generates heat.

These methods can be applied to different organic materials, not only fish waste but also plants and other animals. Those products are attractive regarding their natural origin and are widely used in agriculture, though there are many competitors and types of fertilizers.

Energy

- **Biodiesel and biogas**

Biodiesel fuel is a substitute for diesel fuel from petroleum and is usually obtained form oils and fats of vegetables and animals. The oil obtained from fish rest raw materials was found to have suitable properties for use in diesel engines, especially at low-temperature (Arvanitoyannis and Kassaveti, 2008).

Biogas is obtained from fish oil or from the rest raw materials directly and is usually produced by anaerobic digestion, which consists of organic materials decomposing with an additional substrate in an oxygen-free tank (Arvanitoyannis and Kassaveti, 2008).

4.3.2. High-value upgrade: utilisation for human consumption, supplements and pharmaceuticals

Human consumption

Products destined for human consumption are sometimes considered as relevant for mass upgrading, but as it is destined to human consumption, which has different requirements in terms of safety than energy or agriculture for example, it is classified here in the high-value upgrading parts.

- **Uses without further processing**

Some rest raw materials can be used as such for human consumption. For example, cod heads can be dried, salted and exported to Africa, or used in dishes in Iceland (Archer et al., 2001). Cod roes can be eaten after heat treatment, or canned and processed as sandwich spread. Livers can be canned or processed in liver oil, and consumed as such. Tongues and cheeks are retailed in some parts of Europe at similar prices to fillets, and the meat inside those parts can also be used for reformed products such as fishcakes or pies (Archer et al., 2001). Stomachs also have a possible market as such in Asian countries, requiring that they are frozen as soon as possible after capture or kept fresh on ice (Archer et al., 2001).

- **Fish mince**

Fish mince can be obtained from mechanical recovering from fish filleting waste. It can be obtained by passing fish frames through a bone separator, which consists of a perforated drum against which the raw materials are forced. The flesh goes through while the skin and bones are held back outside. Mince can also be recovered from trimmings, lugs, flaps and cheeks (Archer et al., 2001).

Mechanical recovery of fish flesh from frames must take place after filleting, using raw material free of guts. Quality requirements necessitate that the machinery used must be cleaned often, approximately every two hours, and the flesh must be frozen as quickly as possible or incorporated in a product intended for freezing (Archer et al., 2001). High quality mince can be used to make frozen products such as fish fingers and fishcakes, or used as a raw material for products like surimi, soups and sauce products.

A sorting step is also required, as all species do not have the same demand.

- **Enzymes**

An enzyme is a biological catalyst that can be used to speed up a chemical reaction. They can be extracted from the viscera of large fish, especially cod in Norway. For a higher quality and yield of enzymes, the process should be done quickly after removal of the viscera. The process consists in mincing the fish, repeated centrifugation and precipitation to remove solid materials and concentrate the enzyme. Enzymes can also be produced from pepsin recovered from the silage process. Fish enzymes can be used for different purposes including baking, meat tenderization, milk, leather production, fish sauce or fish processing applications to remove skin (Archer et al., 2001).

Nutraceuticals, cosmetics and health

As an introduction, the boundaries and market segments between the medical, nutrition and cosmetics industries are first depicted in Figure 23. Cosmeceuticals are cosmetics with health beneficial effects. Nutricosmetics usually refer to products that are eaten – pills, tablets, liquids, snack foods, but formulated for "beauty purposes". Nutraceuticals refer to food supplements, either for humans or animals that provide health or medical benefits (Wahren and Mehlin, 2011).

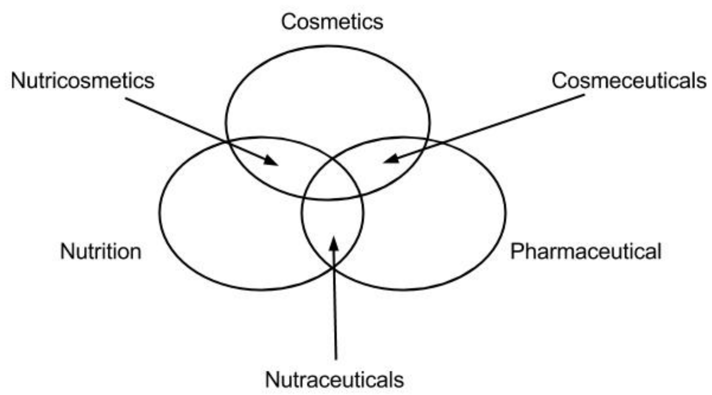


Figure 23 – Different market segments in 3 industries (adapted from Wahren and Mehlin, 2011)

The following paragraphs present some applications in the different markets segments.

- **Collagen and gelatine**

Fish skin and bones for example are a rich source for collagen, which has diverse applications in the meat processing industries and in the cosmetics, pharmaceutical and biomedical industries (Blanco et al., 2007; Archer et al., 2001). Collagen that is not denaturalised provides a natural source of amino acids which are biologically active, and stimulates collagen production in the human skin, responsible for a healthy and youthful skin and thus of interest for the cosmetic industry. The collagen structure can also be broken into peptide chains that can be used in food supplements or cosmetic applications (Mehlin and Weitkemper, 2012), for example ready-to-drink beverages or protein bars.

Gelatine is another product that can be produced from fish skin and bones. Among the different interests, fish gelatine could fulfil religious requirements from both the Jewish and Muslim markets in the food industry, as it has applications in halal and kosher foods. Its price tends to be 4 to 5 times higher than that of mammalian gelatine though (FAO, 2014b; Mehlin and Weitkemper, 2012).

However, fish gelatine has lower gelling and melting temperatures than mammalian gelatine, which means that it cannot be a substitute in many of the applications for mammalian gelatine. Also, the production is hampered by an inefficient supply of raw materials from specific species available on a regular basis (Olsen et al., 2014). Availability and stability in the supply of fish skin has so far been the major limiting factors for marine gelatine (Mehlin and Weitkemper, 2012). Seagarden (http://www.seagarden.no) in Norway is an example of company that produces collagen from demersal fish, as well as products for human nutrition.

The yield for collagen from fish skins is about 10 per cent, which means that to produce minimum 300 tonnes of collagen there is a need for about 3000 tonnes of fish skin, and there is no difference in process or quality for frozen or fresh skin (Mehlin and Weitkemper, 2012).

- **Nutraceuticals and bioactive ingredients**

In addition to the use of by-products directly as human food or for producing feed ingredients like fish meal, fish protein concentrates and fish oil, there has been a lot of focus on transforming rest raw materials into isolated functional or biologically active components, to be used as dietary ingredients, processing aids or pharmaceutical products (Olsen et al., 2014).

The term nutraceutical is defined as any substance that may be considered food or part of food and provides medical or health benefits including the prevention and treatment of diseases (Menon and Lele, 2015). Nutraceuticals from fishery sources include calcium, unsaturated oils, enzymes, proteins, nucleic acids and pharmaceuticals, etc. (Menon and Lele, 2015).

A number of nutritionally valuable proteins from fisheries rest raw materials has been reported, which have functional, antioxidative and other bioactive properties. For example, DNA can be extracted and purified from cod, herring or salmon milt for pharmaceutical use. This DNA can be further processed into a drug, AZT, which has been used in the treatment of HIV (Archer et al., 2001).

Table 4 summarizes the link between the rest raw materials generated from the different forms of processing with the different applications and uses presented above. Figure 24 shows the link between parts of fish and applications.

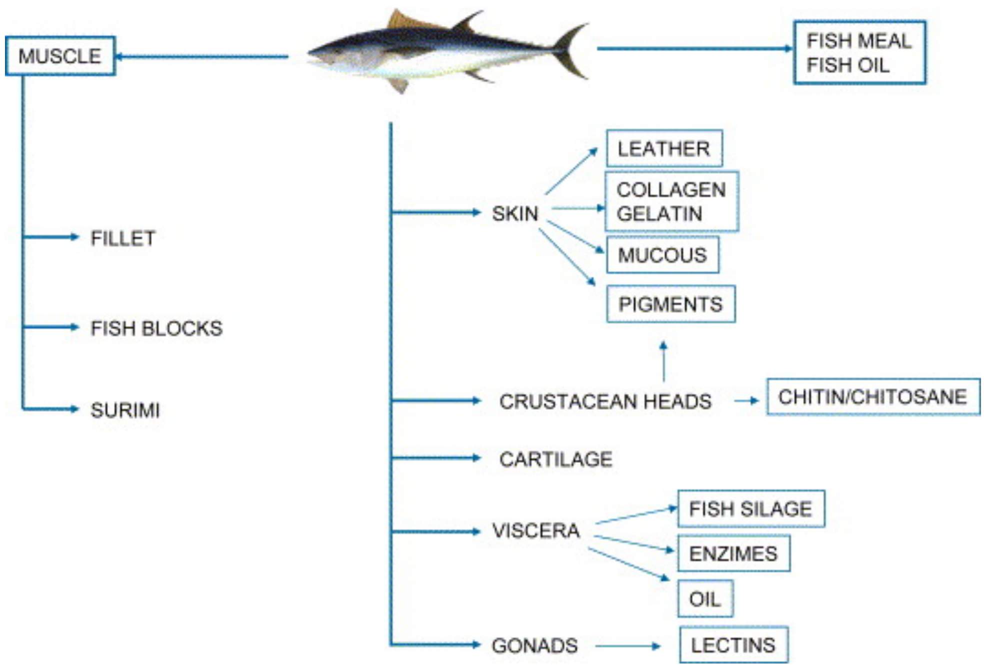


Figure 24 - Link between fish parts and applications (Blanco et al., 2007)

Table 4 - Rest raw materials (RRM) sorted by type of production

Process	RRM type	RRM	Applications	Market Industry
Filleting	Skin		Gelatine Collagen Leather Pet food	Medical Pharmaceutical Cosmetics Fashion Feed industry
	Trimmings	Bones	Collagen Organic fertilizers Salted and exported as such	Pharmaceutical Agriculture Food industry
		Meat	Food products (surimi, fishcakes, etc) Pet foods	Food/Feed industry
Heading	Fins		Fishmeal	Food/Feed industry
	Head	Gills Collar Chicks Tongue Bones Head Eyes	Human consumption (salted, dried, exported)	Food industry
Gutting	Viscera	Liver	Liver oil (omega 3, capsules, creams) Canned products	Medical Pharmaceutical Food industry
		Roe	Human consumption (salted, smoking, canning)	Food industry
		Stomach	Enzymes	Cosmetics Medical/Pharmaceutical
		Intestines	Enzymes	Cosmetics Medical
		Rest	Enzymes, Fishmeal	Medical Feed ingredients

4.4. Status and current use

As presented before, the rest raw materials have different applications. Figure 25 presents different possible applications utilising rest raw materials, by taking into account the market absorption capacity and the unitary profit that can be obtained from the finished products. The possibilties of upgrading rest raw materials differ in the capacity of absorption by the market, and the profit that can be achieved for those who proceed value-adding activities. The top of the pyramid corresponds to small volume exploitation for high value addition, but is more constraining in terms of quality, requiring rigorous sorting, low temperatures and intensive traceability implementation (Penven et al., 2013). On the bottom of the pyramid, fewer cosntraints apply, as sorting is not necessary ans specifications are more flexible (Penven et al., 2013).

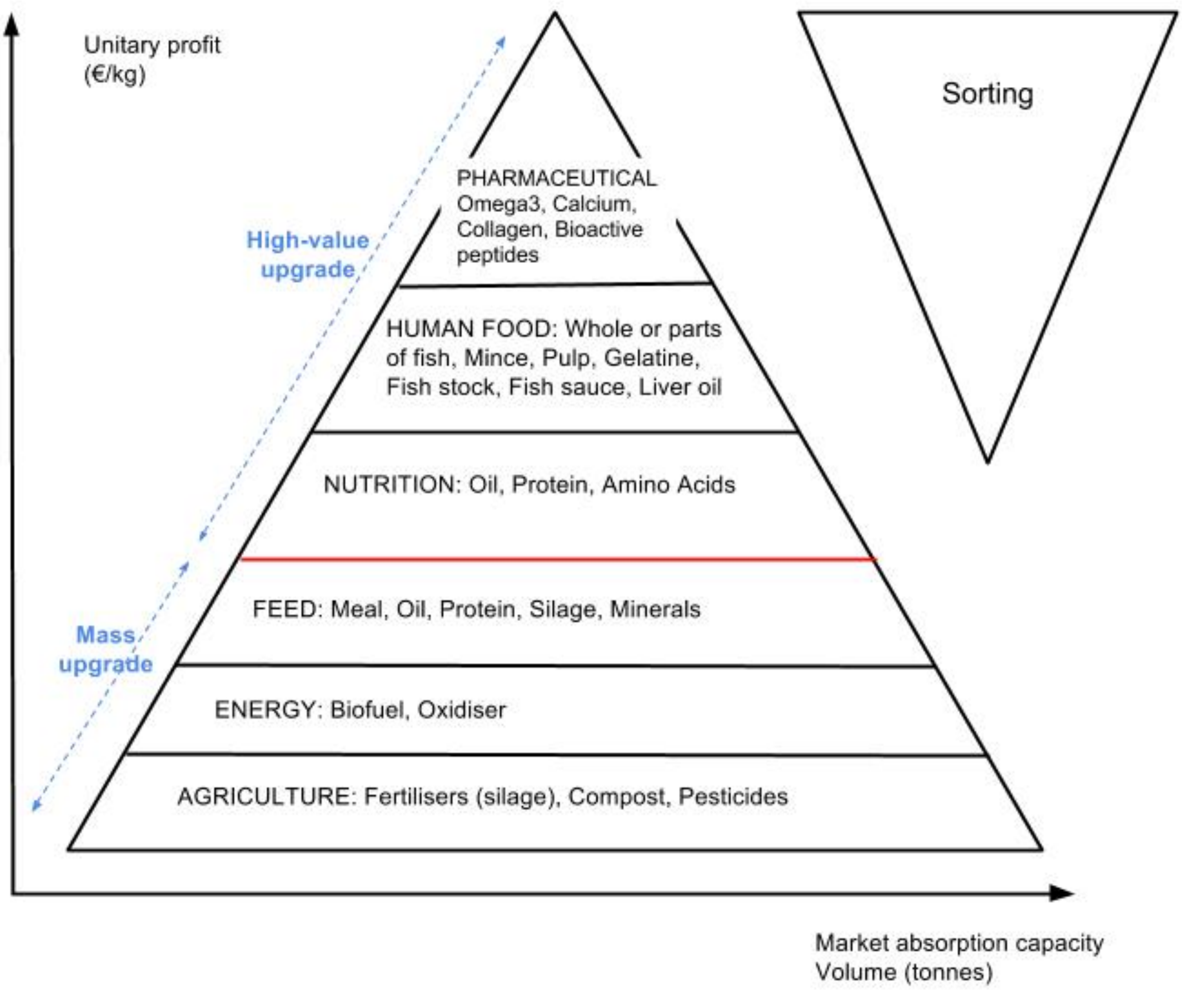


Figure 25 - Market pyramid for different value adding applications (adapted from Penven et al., 2013)

The notion of sorting is crucial in the upgrading of the applications. Profits obtained from the end products are tightly linked to the stringent selection of raw materials before production.

The two types of upgrading activities that were presented in Chapter 4.3 are also depicted in this figure. Mass upgrading is situated at the bottom of the pyramid and uses high volumes of rest raw materials for low-value end products, whereas high-value applications are situated on the top and use low volumes of high quality raw materials.

As for today, mass upgrading represents the highest share of utilisation of rest raw materials. Indeed, the Norwegian Seafood Federation published an environmental report in 2013 where an estimation of the rest raw material utilisation in 2012 is presented (FHL, 2013). FPC, which is high quality fishmeal intended for human consumption, represents the largest share, followed by feed-fertilizers and oils. Those results are presented in Figure 26. FPC, feed for fur industry, energy and fertilizers, and oils represent the majority of the rest raw material utilisation.

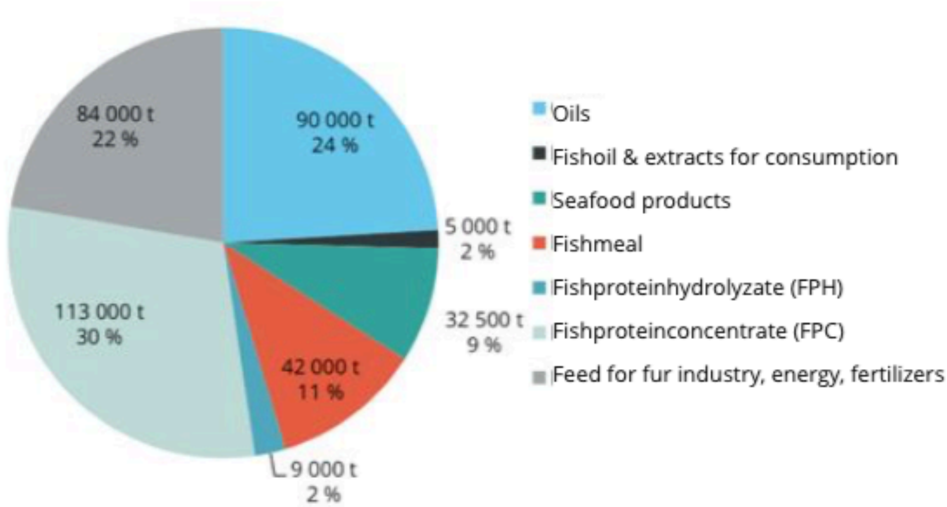


Figure 26 - Overview of the degree of rest raw materials utilisation by sector in 2012 (FHL, 2013)

Olafsen et al. (2014) presented results for year 2013 that can be seen in Figure 27. 40 per cent of the total rest raw materials is transformed in silage and reprocessed into oils and FPC. Fishmeal and fish oil are the second most important application in terms of volume, although around 12 per cent only is intended for human consumption. According to the FAO Globefish report (2015a), the total fishmeal world production for the first three quarters of 2014 was slightly more than the same period in the pas two years, but production in Norway and Denmark increased significantly by 32 per cent (FAO Globefish report, 2015a).

The results of Olafsen et al. (2014) and the Norwegian Seafood Federation differ a little, though they are not representating the same year. Despite, it follows the world's trend: the three most common methods for utilisation of the rest raw materials are the manufacture of fishmeal and oil and the production of silage destined to feed applications, and the manufacture of organic fertilisers (Arvanitoyannis and Kassaveti, 2008; Gill, 2000). This is mostly due to the fact that there is little or no requirements for sorting before the production step, and the processes are relatively simple.

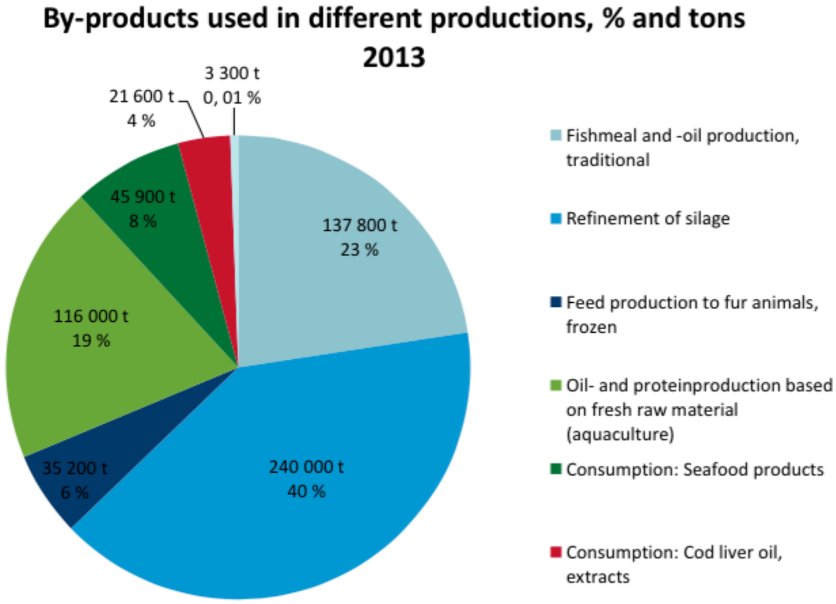


Figure 27 - Overview of rest raw materials utilisation in different productions in 2013 (Olafsen et al., 2014)

It should be noticed, as stated in Chapter 4.1.2, that there are few factory ships in Norway that produce fillets onboard. This restricts the types of raw materials generated from onboard processing and thus the applications that can be pursued. Most of the Norwegian vessels that have onboard processing just carry the heading and gutting steps. The Gadus Poseidon, which can be seen in Appendix 1: Gadus Poseidon, is an example of those vessels, built in 2013 and property of Havfisk AS. This ship is equipped with a fishmeal and oil factory, which utilises viscera and heads from cods, herrings, and saithe. The livers and roes are sold as such. The ship's maximum production capacity is of 80 tonnes of frozen fish per day. According to the Norwegian Seafood Research Fund (FHF, 2014), heads and viscera of white fish species can represent 30 to 50 per cent of the ungutted weight. Then, it could be assumed that the heading and gutting operations already produce a consequent amount of rest raw materials that has potential for several applications. In 2013 around 230,000 tonnes of rest raw materials from the whitefish sector were still dumped at sea, mostly generated by the heading and gutting processes onboard of freezer trawlers (Digre et al., 2014). As described in the preceding chapters, there are very diverse applications for the utilisation of rest raw materials, and some have higher added value than others (RUBIN, 2012; Sandbakk, 2002).

The rest raw materials could be upgraded to other products of higher value, for instance biologically active, or bioactive, components to be used as dietary supplements, processing aids or pharmaceutical products. The industry thus has to move towards the production of more value-added products, such as those described in Figure 25 (Penven et al., 2013; Olafsen et al., 2012; Rustad et al., 2011; Blanco et al., 2007; Nges et al., 2012). Some companies have already entered the higher-value upgrading field. The marine ingredient industry represents an annual turnover of approximately 8 billion NOK. Around one third of this is based on Norwegian rest raw materials from the seafood industry, but there is still a large potential to increase the utilisation of rest raw materials (Digre et al., 2014). Both fishermen and processors have become more interested in making marketable products from raw materials previously used for fish meal or discarded as waste (Arason et al., 2010; Digre et al., 2014). Sales for the industries that utilize rest raw materials have grown 49% in the last 5 years (FHL, 2013).

Figure 28 for example shows all the different products that can be made from cod, which is one of the main groundfish species. In the Icelandic fisheries conference held in 2014, Sigfusson said that fillet and liver from cod were the only parts usually sold and the rest was discarded; but if all the parts were utilised as shown in Figure 28, the average value of a 5kg cod could raise from \$15 to \$50-60.

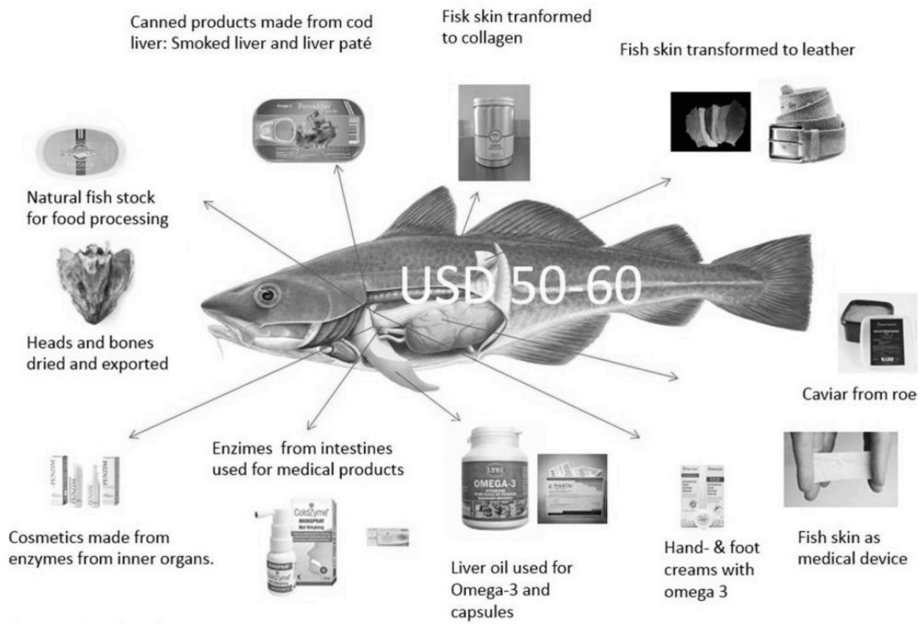


Figure 28 - Products that can be made from cod (Sigfusson, 2014)

Even though an important part of the rest raw materials are taken ashore and processed in a worthwhile manner, there is still considerable potential for improvement (FHL, 2013), as demonstrated in Figure 29.

Indeed, Olafsen et al. (2014) estimated that out of the total available volumes from live weight watch and farming in 2013 in Norway, 28 per cent remains available by-products. However, when the focus is on demersal fish, the share of available by-products is 44 per cent.

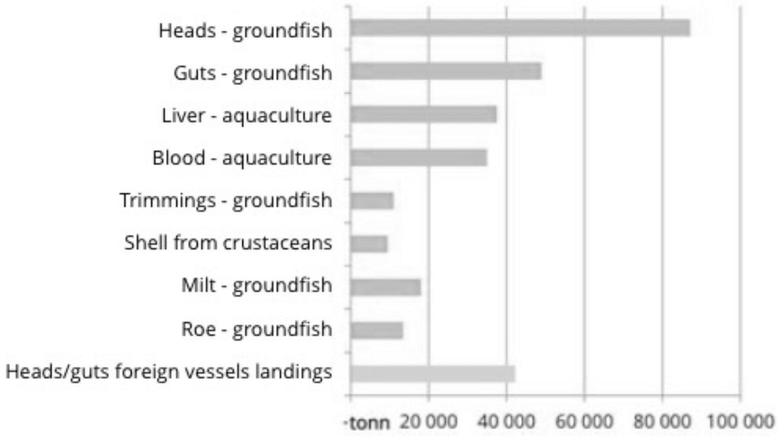


Figure 29 - Overview of yet unutilised rest raw materials in 2012 (FHL, 2013)

Therefore, the Norwegian fishing industry needs to both increase the utilisation of rest raw materials from processing, and upgrade the applications that are made from those rest raw materials. In Figure 27, the possible applications for the rest raw materials generated by both HG-processing vessels and fillet-processing vessels are classified. Sorting and classifying the rest raw materials onboard before they are brought ashore for further processing is a key step if the value added to the rest raw materials is to be higher.

According to Digre et al. (2014), the most obvious solution for reduced waste and increased value of marine rest raw materials from the groundfish sector is to develop a technology for automatic separation of the raw materials when they are generated, and to develop a compact and automated process technology for the production of more high-value products and semi-finished products. Several parts of the fish can also be used directly as food for human consumption, as food habits differ in different societies. “What is considered low-value in one part of the world can be considered as a delicacy elsewhere” (Gildberg, 2002), which requires a thorough market study to determine how to make the most out of the rest raw materials. The production yield of each possible application should also be determined to estimate the volume that can be produced from the available rest raw materials.

Ismond (2002) already stated thirteen years ago that in order to get a better profitability in the seafood industry, there would be a need for a shift to a more market-driven strategy, and giving more attention to the quality of rest raw materials would increase the costs of upgrading the rest raw materials, but would also allow to market the products in more profitable segments.

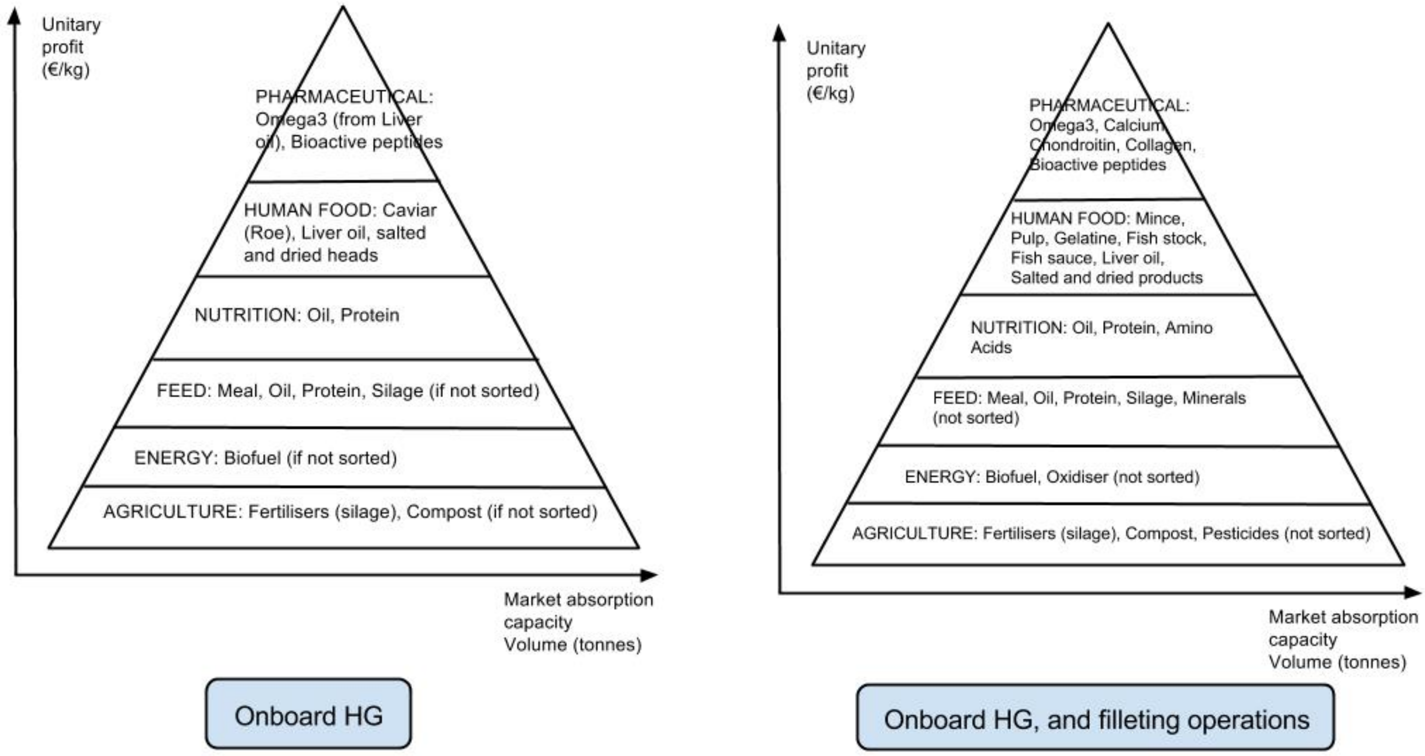


Figure 30 - Classification by value of the rest raw materials applications considering the types of processing operations

However, despite extensive research and development, very few high-value products based on fish rest raw materials have become established on the market and sold in larger quantities for now. This is mostly due to (FAO, 2014b; Olsen et al., 2014; Olafsen et al., 2014):

- The lack of existing markets
- The fact that the amounts of high-quality by-products are not available on a regular basis
- High costs of isolating small specific components
- Requirements in documentation
- The lack of technical solutions
- The lack of perceived economic incentives to bring rest raw materials ashore

In addition, the EU's food hygiene legislation regulates the use of marine rest raw materials for human consumption and thus the greatest potential for value creation (FHL, 2013).

4.5. Summary of the empirical background

In this chapter, the fisheries sector and its components were described. It was based on a literature study and used secondary empirical data such as public statistics and different reports from both scholarly journals and reports from projects and industries.

The types of ships, regulations and fish species were presented. RQ1 and RQ2 were answered as the different rest raw materials available onboard fishing vessels and the different applications that can be pursued from their utilisation were presented. Finally, an analysis of the current utilisation routes in Norway and the other potential applications was conducted and presented. It was highlighted that there are numerous applications that can be conducted from rest raw materials' utilisation, and they can be sorted by value and volume requirements, as seen in Figure 25. For now, most upgrading activities can be placed in the base of the pyramid, showing that more value can be generated out of this utilisation. In addition, this chapter outlines the potential resources available onboard fishing vessels.

Based upon this background, the following chapter builds a conceptual solution for bringing the rest raw materials from their source, the fishing vessels, to the upgrading facility onshore and discusses the logistics issues raised by this concept. The following chapter therefore aims to answer RQ3.

5. PROPOSED CONCEPT

In this section, a solution to the problem statement of this thesis is developed, that is to say a means to bring the rest raw materials generated by onboard production to the onshore processing facility so that they are processed into value-added products. This solution is based upon a core concept, which is first presented. The new supply chain is then depicted, as well as each of its actors and their roles, business opportunities and main logistics challenges, before looking more deeply into the material flow, the underlying requirements of the different processes, and the information flow. Finally, a paragraph is dedicated to financial background, with information regarding underlying costs and potential profits. The solution presented here is discussed in Chapter 6 in relation to feasibility and credibility especially.

5.1. Core concept

It has been showed that an opportunity to improve the sustainability and the resource use of fisheries lies in the onboard-generated raw materials. The concept proposed in this chapter for adding value to those onboard rest raw materials is based upon a ship collecting rest raw materials from the fishing vessels and bringing them ashore so that they are processed into valuable end products instead of being thrown away into the sea. A new stream is thus created in the fish supply chain starting from the fishing vessels to new end products for other industries. This concept is based on the approach of reverse logistics described in Chapter 3.2, which considers the collection, sorting, transportation and treatment as typical processes to recapture value from products considered as 'waste', and places itself in the second level of the waste management hierarchy in Figure 9.

There might be other options that could be looked at, for example a mobile processing facility for rest raw materials upgrading, based on the model of a mother ship described in Chapter 4.1.2. The processing facility could also stand on an at-sea platform. However, as one of the objectives is to upgrade the utilisation of the rest raw materials to higher-value products, the equipment and technology required for those products might not be suitable for an onboard or at-sea facility. As most of the targeted markets are situated abroad, it should also be as practical as possible to export the end products. An onshore facility is therefore the most realistic and easy-to-implement solution, and it implies that there is a need for logistic means to bring the rest raw materials from ships to the coast.

Processing facilities utilising rest raw materials already exist onshore, and they take their supply in filleting facilities or auctions in ports. The proposed concept builds on these existing facilities and discusses the logistics challenges and issues of bringing the available raw materials from at-sea ships to the onshore processing facilities. Logistics issues include amongst others the separation of the different rest raw materials - as they are intended for different treatments and industries when upgraded to high-value products -, the sorting and storage onboard both the fishing vessels and the collector ship, and the at-sea transfer between the two boats.

This solution relies partly on the establishment of a “zero-waste” policy that would require the fishing vessels to land their rest raw materials, as it would be the only incentive that would force all of them to do so. Less restrictive, the policy could charge the boats for discharging waste in the sea. As the European Commission is gradually putting in place a landing obligation of bycatch and unwanted species for all commercial fisheries in European waters (European Commission, 2015), and the scientific literature reports more and more on rest raw materials generation onboard fishing vessels and the underlying lost potential, it is not irrational to suspect that there can be soon a law against the discards of rest raw materials. If so, a logistic solution enabling the fishing vessels to allocate only a minimum space onboard to store rest raw materials until they are collected by another boat could be a good trade-off for fishermen.

The perspective of having to store rest raw materials leads to consider different alternatives, such as:

- Keeping the same capacity holds, and allocate existing space to the storage of rest raw materials
- Design modification of the vessels
- Allocate intermediate or partial storage onboard, and use special vessels to collect the rest raw materials generated by the fishing fleet

Design modification of the vessels should be considered for the ships to be built in the next future. As for now, the setting up of a ship that would collect and deliver the rest raw materials to the processing facility could be the best alternative for fishermen. Indeed, from a certain perspective that would implicate that the fishermen have more space for their main products; if they had to store all the rest raw materials onboard, the ship would be full faster and they would have to come unload to port more often. The collector boat could bring supplies to the fishing vessels in addition to transhipping the rest raw materials, such as fuel, provisions, fishing gears, mail or other items, following the tenders’ model described in Section 4.1.2. The law could for instance also allow the fishing vessels to dispose of one batch at sea, so that after being emptied by the collector boat one or several times, the ship could come back with full capacity on main products. Fishermen would also save the cost of disposal and instead could make an income out of it.

Until such a law is passed, other incentives for fishermen to preserve their rest raw materials could be higher yearly quotas or more fishing days allowed. Some fishing companies have already started taking measures to utilise the full catch; for instance, several vessels have a fishmeal and oil plant onboard to process the rest raw materials generated by the main processing line. This is an important step demonstrating willingness to make use of all the raw materials available, although it also hampers the possibilities to upgrade the rest raw materials to higher-value end products.

5.2. A new supply chain

Figure 31 depicts the new supply chain, representing the new stream utilising rest raw materials form onboard processing. Some onboard processes have dotted lines because they are dependent on both the boat's operations possibilities. As for the processing operations at the upgrading facility, they are dependent on the wanted end products.

The primary mission of the new supply chain is to exploit the potential value of the rest raw materials generated onboard fishing vessels, where lies the major opportunity of utilisation (FHL, 2013), and potentially from onshore filleting facilities in order to bring enough volume for the production to be cost-efficient. This follows the principles of reverse logistics, aiming to move goods from their typical final destination to another point, for the purpose of capturing value otherwise unavailable.

The objective is also to set up a production and sales company that is producing value-added products based on rest raw materials from the fish industry, destined to higher-value industries than agriculture or feed ingredients. Hence, Norway could use its experience and knowledge to gain a competitive edge in a high-value sector, as many new processing companies from Asian or African countries are entering the low-value market (Wahren and Mehlin, 2011).

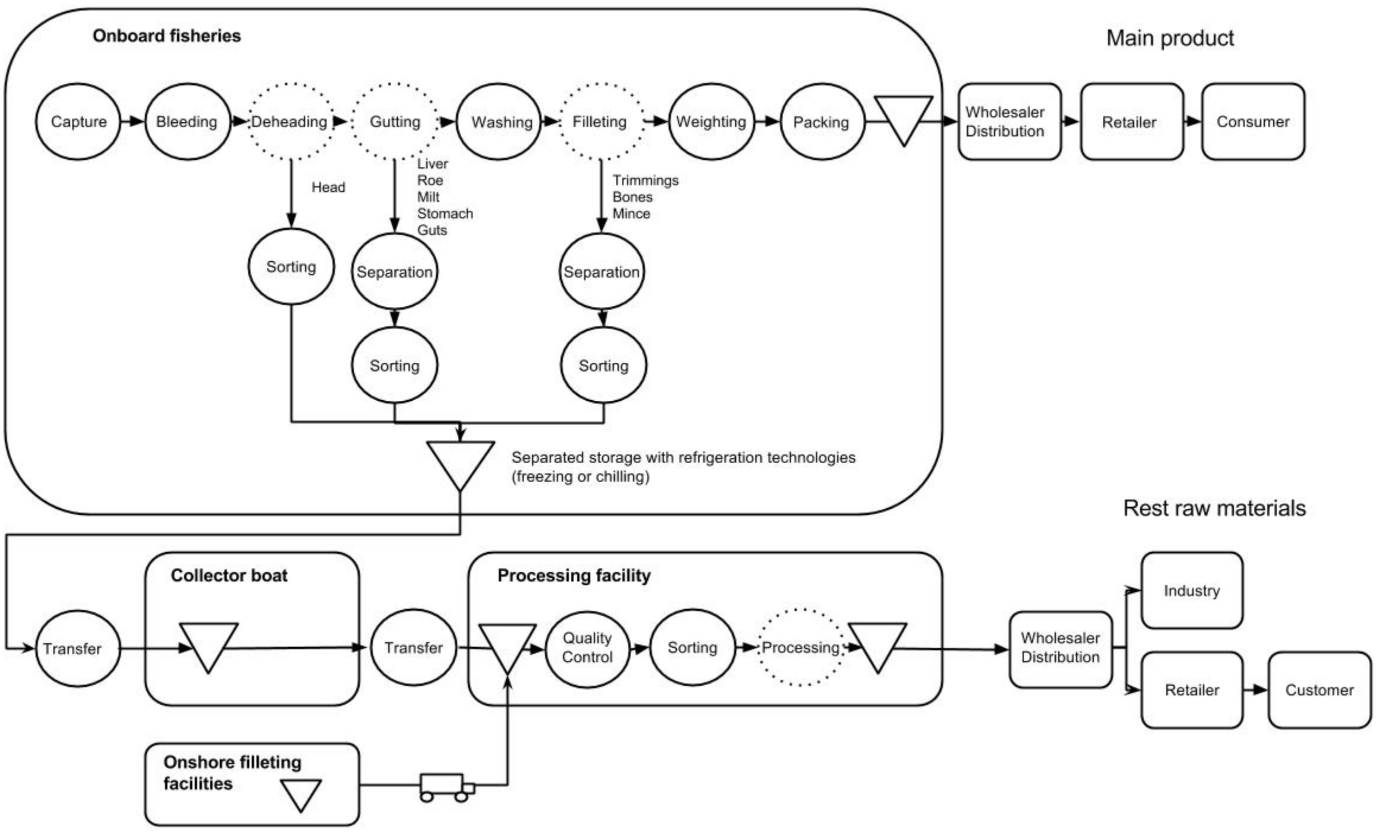


Figure 31 - New supply chain model to bring the rest raw materials ashore for upgrading

As in all kinds of production, the transformation of rest raw materials into commercial products should consider the possible markets and demand. The demand for fish products is expected to increase as the population is growing, getting wealthier and asking for healthier products. New markets are arising in developing countries as the population's interest in healthy products is increasing. The FAO Groundfish market report stated that there is a possibility that the Norwegian cod will reach the high-quality, high-priced market in China in the years to come (FAO Globefish report, 2015b). April 2015 was a record in codfish exports, an increase of 33% compared to 2014 (Undercurrentnews.com, 2015).

Regarding products produced from rest raw materials, there are several companies that already are in operations and utilise the rest raw materials from the onshore processing facilities, showing that there is already a demand. However, precise numbers with regard to sales or exports of high-value products were not found to support this statement, except for fishmeal and fish oil whose market is well established. Penven et al. (2013) studied two by-products processors in France, Copalis (http://www.copalis.fr) and Bioceval (http://www.saria.fr/en/srfr/company-profile/saria-industries/bioceval/), operating with different strategies. Copalis produces a wider range of products than

Bioceval, which reaches human and animal nutrition, nutraceutical, functional food and cosmetics industries, while Bioceval produces fishmeal and oil for aquaculture. With less and closer suppliers, Copalis has a higher turnover than Bioceval, and 75 per cent comes from exports. In Norway, Hermes AS (http://www.hermes-as.no/en/) took initiatives to bring back the most valuable rest raw materials to shore, for instance cod liver, cod roe or saithe roe. Companies like Scanbio (http://scanbio.com/en) already utilise rest raw materials from fisheries and aquaculture. Successful upgrading of rest raw materials from the fish industry therefore already exists. Now, those processing companies should include a new branch that collects and utilises the rest raw materials generated onboard the fishing vessels. In order to do so, there is a need for new logistics solutions to bring the rest raw materials from the fishing vessels to the processing plant, while maintaining their quality and safety. The aim of this section is therefore to define the major logistic issues that arise and discuss the possible alternatives.

The supply of rest raw materials is limited, just as fisheries, by fishing quotas established by governments aiming to maintain the sustainability of the fisheries. The FAO Groundfish market report expects slightly tighter supplies of groundfish in 2015, with about a 100,000-tonne reduction in the quota in the Barents Sea (FAO Globefish report, 2015b). Olafsen et al. (2014) estimated quantities of available by-products considering seasonal landings figures, showing that the supply can be year round, with the highest season in the first part of the year, as seen in Figure 32.

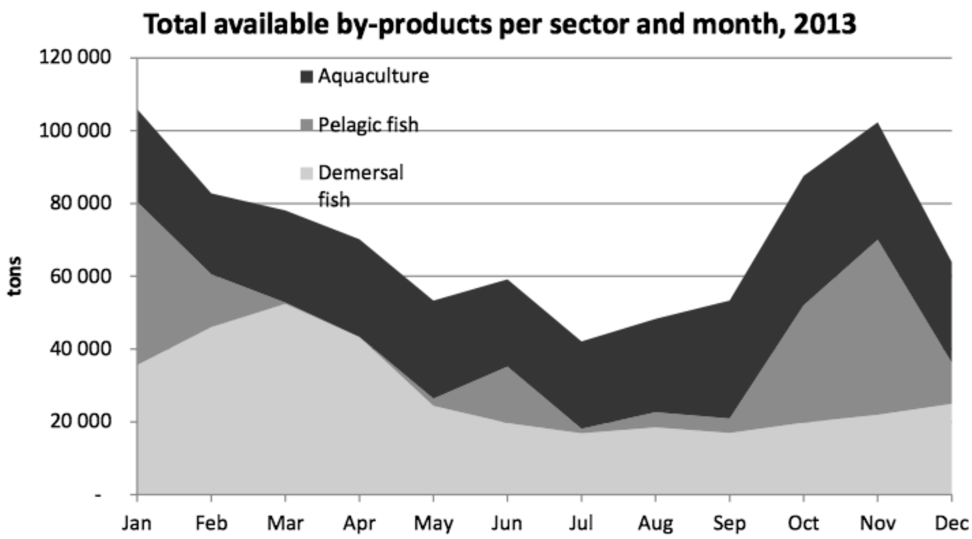


Figure 32 - Estimation of the total available by-products per sector and month in Norway in 2013 (Olafsen et al., 2014)

The onshore processing facility that upgrades the rest raw materials is most likely going to sell its products to companies operating in different fields. Trade-offs need to be studied between the cost of isolation of certain components and their prices and demand on the market, so that the company can evaluate which products to make and what volume of rest raw materials to use for these purposes. There seems to be many known different market opportunities, which need to be studied in order to establish their profitability, considering for instance the cost of collection, production and transportation. Also, some parts can be sold without further processing in regions of the world with different culinary habits; for instance, Nigeria is an important market for dried fish and dried products such as drier heads and backs (Norwegian Seafood Council (NSC), n.d.). In addition, Figure 32 showed that there are at least 20,000 tonnes of rest raw materials available during the whole year, but the yields for the different products need to be determined to estimate if the supply from onboard processing is enough or if the processing facility should also take resources from onshore filleting facilities.

The following paragraphs present each actor of the supply chain depicted in Figure 31 and the main challenges they have to face.

5.3. Actors

In this chapter, each actor the new supply chain is described regarding its role, business opportunities and logistics challenges that would arise if the solution is to be implemented. The description follows the material flow, and starts with the fishing vessels, then the collector ships and upgrading facility, to finish with distribution and customers.

5.3.1. Fishing vessels

Olafsen et al. (2014) estimated from the landings statistics in Norway that there were 325,000 tonnes of rest raw materials available from processing vessels. There were 37 cod trawl licences in 2014, and of which 3 are filleting vessels (FiskeriDirektoratet, 2015; Digre et al., 2014). However trawler vessels can vary from small open boats to large factory trawlers with onboard processing; there is a need for further information from industries and companies to determine the total number of catcher-processor ships and the number at sea at the same time. Larsen and Dreyer (2012) stated that there were

27 freezer trawlers that land round frozen fish – whole fish, as captured and ungutted - and 7 factory trawlers in 2010. It could then be assumed that the 325,000 tonnes of rest raw materials estimated by Olafsen et al. (2014) could have been produced by less than 7 vessels, which gives an idea of the scale of the solution needed.

Role

The focus of the thesis is directed towards onboard processing, where lies the most potential for rest raw materials' utilisation according to the scientific literature. The fishing vessels that provide semi-processed or processed fish are thus considered as the producers of physical products, so the suppliers of raw materials in the new supply chain. Usually those vessels are more than 28 meters long and have at least heading and gutting operations onboard. Such vessels are commonly owned by a few companies such as Havfisk AS (http://www.havfisk.no) or Norwegian frozen at sea (http://www.norwegianfrozenatsea.no/?menu=19).

They are responsible for different actions:

- Input procurement, for example machinery, fuel, food, nets, ships, etc.
- Fishing
- Classify caught fish
- Separate, classify and sort the rest raw materials as well as the main products – headed and gutted fish or fillets
- Store the main products and rest raw materials
- Negotiate the price with the collecting company
- Receive payment

In order to set up the path and frequency of collection, the fishing vessels also need to communicate information such as the status of their onboard inventory or the types and volumes of rest raw materials available.

Potential business opportunities

In order to have the vessels stop discarding rest raw materials, there is a need for incentives. It could be to give more fishing days to the vessels that stop discarding, or higher quotas for fishing. Keeping rest raw materials onboard means losing the allocated space; this space is then not used for the main products, and the ships should unload their content more frequently. Keeping rest raw materials onboard therefore corresponds to lost fishing days and thus lost revenue. Increasing the number of fishing days could then offset this loss.

Some fishing companies have already started to take measures to utilise the full catch; for instance, several vessels have a fishmeal and oil plant onboard to process the rest raw materials generated by the main processing line. This is an important step demonstrating willingness to make use of all the raw materials available, although it also hampers the possibilities to upgrade the rest raw materials to higher-value end products. In order to increase the revenues obtained from the upgrade of rest raw materials, there is a need to focus on reducing costs associated to storage capacity and transportation to shore.

The most efficient possibility would be a policy or law passed by governments or the European Commission that forbids the fishing vessels to discard their rest raw materials into the sea. If a "zero-waste policy" is one day implemented, the fishing vessels would have to take back to shore both discards and 'waste' and the industry would be subjected to important changes. Less restrictive, the law could make the fishermen pay to discard at sea, similarly to what onshore companies have to do to dispose of their waste.

For now, the available space on fishing vessels is fully allocated to edible commercial fishery products, as storage capacity is an expensive asset. A non-discard policy will not only increase the volume of raw materials to be stored on board, but also the energy and space requirements (Alonso et al., 2010) thus requiring a change in the cost-benefit balance. In anticipation of the implementation of such a policy, the fishing companies starting to implement a model such as the one described above could have a considerable competitive advantage in the future.

As said before, from a certain perspective, if discards of rest raw materials were forbidden, the solution would allow fishermen to gain space for their main products. If they had to store all the rest raw materials onboard, the ship would be full faster and they would have to come unload to port more often. The law could for instance also allow the fishing vessels to dispose of one batch at sea, so that, after being emptied by the collector boat one or several times, the ship could come back with full capacity on main products. Fishermen would also save the cost of disposal and instead could make an income out of it. The collector boat could bring supplies to the fishing vessels in addition to transhipping the rest raw materials, such as fuel, provisions, fishing gears, mail or other items.

The vessels, or their owners, would be trading with the processing company, and they would discuss prices and onboard procedures guidelines based on different factors such as the volumes of rest raw materials to collect, their nature, the position and route of the boat. For example the more consequent the volume of rest raw materials available is, the more amortized the costs of transport can be.

Logistics challenges and issues

The fishing vessels with onboard processing facilities need to report their position and content to their head quarters that will deal with the collector company. Knowing the exact number of boats at sea and their loads, the route and location for unloading can be decided. All the ships are not at sea at the same time during the year, and at the same locations; this is why collaboration and information sharing between the fishermen and the collector are crucial for the solution to succeed.

As for now, most of the vessels consider the raw materials generated by onboard processing as waste, and treat it accordingly, which in most cases means throwing it back to the sea. This is due to the fact that those parts have less value than the main product, to which the priority is thus given regarding storage and logistics (Gildberg, 2002).

The preservation of rest raw materials as ingredients for high-value products would imply that the vessels invest in processes to separate, sort and store the rest raw materials onboard. Turning the rest raw materials into higher-value end products will be a challenge for fishing vessels, as it will demand more advanced equipment on board, more competence from the workers handling the rest raw materials and equipment, and it will require that fishermen allocate some space to store the rest raw materials, thus reducing the one dedicated to the main product. The need for additional workers should also be evaluated. A case study should be executed together with the fishing companies first, to estimate if the fishing vessels have spare capacity at some time of the year, which usually happen considering the seasonal distribution of fish supply, and then to estimate what storage capacity should be allocated onboard. Considering the seasonality of the supply, there might be a need for more frequent collection in the peak season – January to April, while the boats might have spare capacity in the other months.

The precise definition of procedures for onboard handling of rest raw materials depends on several factors, such as the specific vessel features – length, width, hold size, fishing deck type -, or the ultimate utilisation of the raw materials and requirements established by the processor regarding form or quality. For instance, it could be needed in some cases to separate and store separately the different fish parts, and not in other cases. It is therefore difficult to establish procedures valid for all cases; the processes to have onboard, the quality and packing requirements and the handling procedures are to be determined with regard to the end products. A more precise study of the requirements and decisions to make for onboard handling of the rest raw materials is done in Chapter 5.4.1.

5.3.2. Collector ship

The collector boat would probably be a reefer ship. A reefer ship is a refrigerated cargo ship, typically used to transport perishable commodities that require temperature-controlled transportation, such as fruits and vegetables, fish or meat.

Role

The collector ship is the physical distributor of the unprocessed rest raw materials. Its role is to receive the rest raw materials from the fishing vessels, sort and store them onboard, transport and unload them on docks. The collector ship would deliver its load in designated ports, where appropriated storage facilities should be in order to store the raw materials until another carrier takes it to the processing facility.

Potential business opportunities

There is a need for logistics means to bring the rest raw materials available from onboard production to the processing facilities onshore. A solution to this problem would be to set up a collector ship that is able to transfer the frozen and sorted rest raw materials to its own hold, while at sea and without interrupting the cold chain. The collecting and transporting activities could be either integrated with the processing company or executed by a third-party logistics provider, depending on the profitability of the new products and the possibility to set up a profitable business for the carrier. The location of the processing facility, the number of collector ships and the need for inland transportation are to be determined considering the number of ships at sea at the same time, and their location and route, that is to say considering the total volumes available at sea and their location.

Logistics challenges

As for the collector principle more generally, there is a need to decide several parameters:

- Number of ships that are to be at sea and collect the rest raw materials
- Ship inventory capacity and power, depending on the fishing vessels and how long the collectors should stay at sea
- Frequency of picking
- Locations for transhipping
- Ship design

- Vertical integration with processor or third party logistics

The main challenge for the collector ship and the fishing ship is the transfer of materials at sea, although there have been some cases that show it is possible to do a transfer between a fishing vessel and a reefer ship while at sea. Several issues arise regarding the material flow:

- Physical difficulties of the transfer between vessels
- Maintaining the cold chain to preserve the quality of the products
- Rough weather making it difficult and unpredictable
- Catching vessels and collecting vessels need to locate each other at sea
- Vessel design to make the transfer possible.

In addition to the transfer, the collector ship has to face onboard issues, as it should sort and store the different rest raw materials' containers in a proper way, just as the fishing vessel had to do before it.

Regarding the information flow, the major issue relates to traceability and transparency. Information should be passed as well as the products, so that the origin of rest raw materials once in the processing facility is still clear.

The challenges are further discussed in Chapter 5.4.2.

5.3.3. Processing/Receiving facility

Role

The facility onshore carries the processing step of the new supply chain. It receives rest raw materials from the carrying boat or inland transporters and sorts them regarding quality standards. The processor is responsible for the transformation of rest raw materials into valuable products following hygiene and safety rules, and negotiates prices with its suppliers, the fishing vessels and possibly the onshore filleting facilities, and with either the exporter or the industries that are buying the products.

Potential business opportunities

The processing facility aims to reduce waste and convert otherwise unused fish raw materials into valuable ingredients destined to a sector to be determined. The rest raw materials processors have multiple choices as for the market they wish to target, such as functional food, cosmetics and animal nutrition markets. Many possible applications for different parts of fish have been mentioned in Chapter 4.3. There is a need to evaluate the different costs involved in the production and transportation of the different products in relation to their market prices. Once the processors have chosen which markets they want to enter, they need to define precisely the special features of the rest raw materials for their suppliers – form, preservation means, etc. -, so that the products arrive at the processing facility in the highest possible quality and can be processed according to the customers requirements.

The company owning the processing facility should also probably be the one that collects the parts from the fishing boats. Indeed, if they were two separate entities, the value creation for the collector is uncertain. The companies currently upgrading rest raw materials – Copalis, Bioceval, Scanbio - seem to be using their own means to collect the rest raw materials and bring them back to the processing facility.

Logistics challenges

The processing facility has to face different types of challenges, regarding for example the choice of its location, size or design and kinds of equipment needed, or the procedures high-value upgrade of rest raw materials requires. It should also be determined if the upgrading company vertically integrates the collector ships and also possibly trucks needed to bring the rest raw materials from the fishing ships to the facility.

- ***Product choice***

The first decision the processing company needs to make is the products they are going to produce. For that the different markets must be studied and profitable opportunities highlighted. Once chosen, the upgrading company should establish guidelines and requirements for the rest raw materials' quality and share it with their suppliers.

A strategy could be, if the volume is sufficient, to establish both mass upgrading activities and high-value production. The highest quality rest raw materials would then first be treated for high-value upgrading, and the rest raw materials of these processes would be used as source for mass upgrading with the remaining volume, as can be seen in Figure 33.

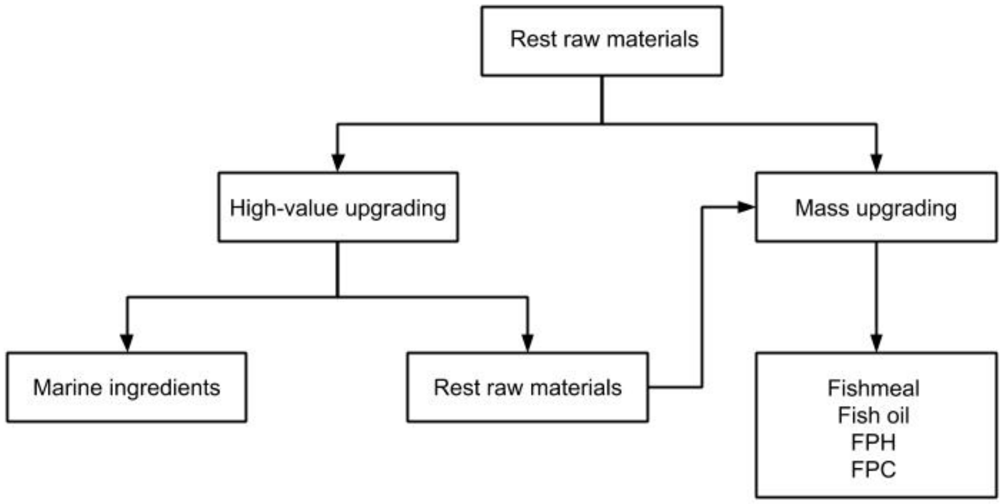


Figure 33 - Mix of high-value and mass upgrading

- ***Number and location***

The number of facilities and their location are to be decided. Facility location is interrelated with SCM and can be defined as the taking of simultaneous decisions regarding design, management, and control of a generic distribution network. It should take into account the set of demand points corresponding to existing customer locations, demand flows allocated to available suppliers, and the configuration of the transportation network (Manzini, 2012).

One strategy would be to locate processing facilities close to ports where the collector ships will unload their content, as it is the case for most fish filleting facilities, in order to reduce transportation costs as much as possible. It could be interested to take filleting processing plants into account when deciding on the location, as the rest raw materials from those plants could also be redirected to the upgrading facility to provide more materials supply. The upgrading company needs to establish if a sourcing strategy with only onboard processing is enough, considering the products they want to make and their yields of production.

Olafsen et al. (2014) evaluated the amount of available rest raw materials by region, as can be seen in Figure 34.

Considering the availability of rest raw materials from groundfish species depicted in Figure 34, the processing facility should be placed so as to optimise the distance to the main ports of the regions Finnmark, Troms, Nordland or Møre & Romsdal. A Nofima report from 2012 named “Kartlegging av marint restråstoff i Troms” cited Tromsø as a hub for fish processed onboard (Larsen and Pleym, 2012). As those regions spread over one thousand kilometres, inland transportation can be required from the ports to the upgrading processor, which has an impact on costs and quality. As Nordland, Finnmark and Troms are adjacent, it might be interesting to prioritise this area for the location of the processing facility.

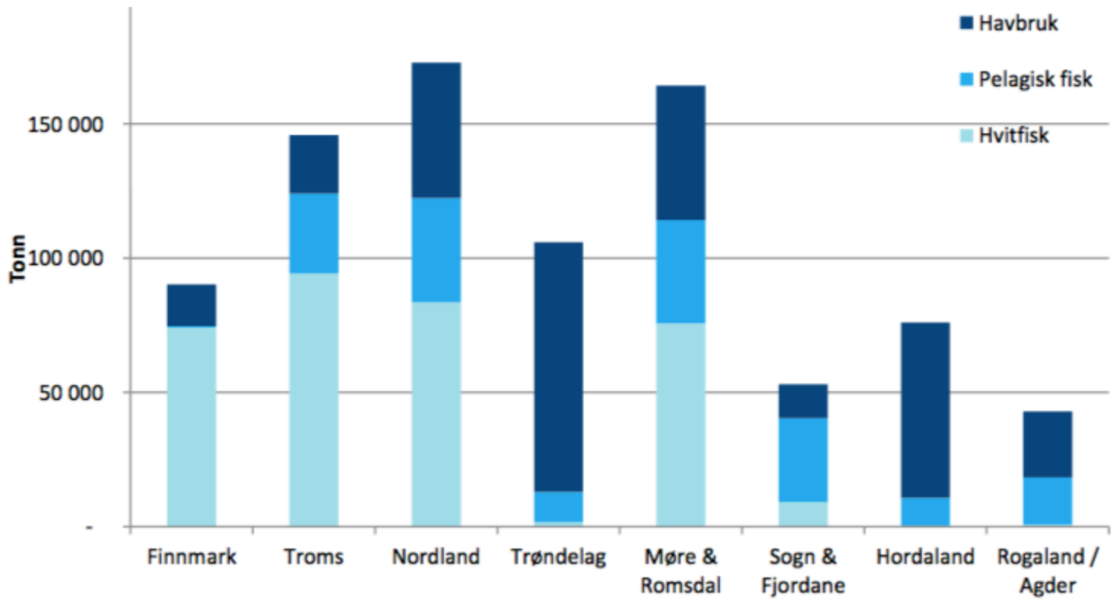


Figure 34 - Total available rest raw materials by region and sector in 2013 (Olafsen et al., 2014)

- ***Equipment needs***

The investments and equipment needed by the processor company depend naturally on the market segment they choose to enter and the products they wish to produce.

Though, as the means of preserving the rest raw materials from onboard processing to the processing facility is likely to be by freezing, one necessary step is going to be the thawing of the materials. The report from the project "Fryst hvitfisk restråstoff: Fra havfiskeflåten til marine ingredienser" (Sigurdsson et al., 2014) drew the results of test productions of frozen unsorted rest raw materials conducted at different processing plants. Some of their results were that the thawing of raw materials was a major challenge, and if a production based on frozen products is to be established, it will require the development of facilities for controlled thawing to avoid the deterioration of raw materials.

- ***Handling, safety and quality***

The processing facility for rest raw materials should have a system to monitor the quality and safety of the products at all time, especially if the products are intended to human consumption. Most fish processing facilities abide to the HACCP programme described in Chapter 4.1.3. A similar system should also be applied to rest raw materials processing facilities. Regulations should also be checked with governments and governing entities to guaranty the product's safety and quality.

- ***Supply and Demand***

In order to be able to establish a successful business out of rest raw materials utilisation, there is a need for a quite stable supply of raw materials. Landings of fish often show strong seasonal fluctuations, which create discontinuities in supply of raw materials for the processing industry (Hermansen et al., 2012). The seasons may be determined by the behaviour of the fish itself or may be the result of public decision-making (Trondsen, 1997). For Northeast-Arctic cod for example, the fishing effort is concentrated in the winter season, from January to April, when the mature part of the stock migrates from the Barents Sea to the Lofoten area (Hermansen et al., 2012). Though, Olafsen et al. (2014) estimated that a stable basis amount of rest raw materials is available all year round, as seen in Figure 32. Penven et al. (2013) stated that upgrading activities, whether mass or high-value level, have important raw materials quantities requirements. However, Figure 32 shows that on average, 20,000 tonnes of rest raw materials are available per month, for a total of approximately 230,000 tonnes per year dumped at sea (Olafsen et al., 2014). For comparison, the French company Bioceval that produces fishmeal and oil utilises 60,000 tonnes per year, and Copalis utilises 23,000 tonnes. Consequently, the available amounts of rest raw materials onboard are substantial. It could even be interesting to have a sourcing strategy that includes the filleting companies onshore and the aquaculture sector as well, although precautions might need to be taken regarding the species and quality differences between all products, in order to minimise the potential cross-contamination (Arason et al., 2010).

On the other hand, while some markets have demand fluctuations synchronous with the fisheries, other markets have demand peaks in other seasons than landings, or have a stable demand during the year (Hermansen et al., 2012). The demand pattern for the products made from rest raw materials or for the rest raw materials themselves need to be determined.

5.3.4. Wholesale/Distribution

Role

The distributor picks up the end products at the processing facility and carries the transportation to the customers. It receives products, packs them according to their characteristics and needs, performs export procedures and dispatch, and also negotiates prices with importer and processor.

Potential business opportunities

Considering Figure 25, higher value end products have lower market capacity, and thus it can be economically more suitable for the processor to outsource the delivery and have an external distributor that can work on economies of scale with other products. It could also be interesting for the distributor to be a third-party logistics that includes warehousing, distribution, order fulfilment and inbound and outbound freights management. The market for higher-value products is likely situated abroad, which implies global transportation and underlying obstacles, like tolls or customs for instance.

Logistics challenges

Once the rest raw materials have been upgraded into value-added products, they must be sent to the targeted market. The markets depend of the types of products the processing facility has chosen to produce, and are further presented in the following paragraph.

The distributor has to consider the different characteristics of the end products: adequate packaging, remaining shelf life, quality and safety issues, and choose the appropriate means and frequency of transportation regarding those characteristics.

5.3.5. Customers

The customers vary depending on the types of products the processor company choose to make based on the rest raw materials. Customers can be other industries or retail companies. They negotiate prices with the exporter considering the market prices or their internal operations. Most likely, the upgrading company will have to export its products to foreign markets, where there seems to be demand for higher-value products: Asia, the U.S., or in Europe. Each market segment has peculiar particularities and it should be taken into account in the development of the business. As presented in Figure 30, there are different possible markets for fish rest raw materials. The following paragraphs present some information about each market.

- ***Agriculture***

The lowest-value market is agriculture with products like fertilizers and compost. There are often used locally since the production is cheap and transportation accounts for most of the costs. Demand for fish fertilizers is however increasing, especially through an increased interest in organic gardening.

Table 5 gives a SWOT analysis for fertilisers produced from fish rest raw materials.

Table 5 - SWOT analysis for agriculture products from fish rest raw materials (adapted from Penven, 2014)

Strengths	Weaknesses
▪ Solution for important volumes ▪ Simple and known techniques ▪ Eco-friendly image ▪ No need for sorting ▪ Can use Category 2 rest raw materials	▪ Regulations for different grounds ▪ Long production time ▪ Varying compositions ▪ Low value ▪ Strong odours
Opportunities	**Threats**
▪ Natural origin of products ▪ Important market in agriculture	▪ High number of competitors ▪ Competition with other types of fertilisers ▪ Changing prices in accordance with catch levels

- ***Feed***

The utilisation of fish rest raw materials as feed represents the most important market today. In the feed industry, rest raw materials can be used to produce fishmeal, fish oil, fish silage or FPC and FPH (see Chapter 4.3). Fish silage is used commercially in Scandinavia and Poland (Arason, 1994). FPH and FPC can be used as pig feed, and half of the market is situated in the US (Wahren and Mehlin, 2011). The fishmeal and oil market intended to fish feed is also significant. Most of the rest raw materials from aquaculture, demersal and pelagic fish goes to fish feed in the form of protein concentrate and oil. The shortage of marine raw materials in aquaculture represents an opportunity of utilisation for the rest raw materials from the fish industry. Norwegian companies have secured a significant market position for fish feed in the Mediterranean countries (Wahren and Mehlin, 2011).

The pet food market is also part of the feed industry. The consumption of marine ingredients is growing, though the growth and sales of pet food is 70 per cent higher in North America than in Europe. The use of residues and homemade food is still dominating but the growth is expected to continue, especially in Asian markets (Wahren and Mehlin, 2011).

Table 4 gives a SWOT analysis for feed products obtained from fish rest raw materials.

Table 6 - SWOT analysis for feed products from fish rest raw materials (adapted from Penven, 2014)

Strengths	Weaknesses
▪ Solution for important volumes ▪ Simple and known techniques ▪ Clear regulations ▪ No need for sorting	▪ Restricting regulations ▪ Lower quality of products from RRM than from full fish ▪ High investments in machinery ▪ Poor quality image ▪ Low value ▪ Need high volumes to be profitable
Opportunities	**Threats**
▪ Important market in aquaculture, pet food and feed ▪ Eco-friendly image	▪ Linked to high demand in Asia ▪ Competitors using full catch for production ▪ Changing prices in accordance with catch levels

- ***Nutrition***

The food and beverage industry is a market segment that has good opportunities for ingredients containing omega-3 (Wahren and Mehlin, 2011). Omega-3 additives in food was the fastest growing market in the US in 2011, as well as functional food, for example with omega-3 enriched eggs, which represented one fourth of the egg market in the US in 2011. In Europe, the UK and Spain are the biggest markets, with dairy as the largest segments. Fish oil represents the largest share of food supplements. The US constitutes an important market, although the consumption per capita is higher in Scandinavia and the UK (Wahren and Mehlin, 2011).

Sigurdsson et al. (2014) stated that the biggest market opportunity lies in human nutrition, and expect two to three years of intensive product testing and market development in order to verify this assumption.

- ***Pharmaceutical and cosmetics***

In Asia, collagen is used in functional food application for skin care beauty, and the market is growing strongly globally (Mehlin and Weitkemper, 2012). For the food industry, nutricosmetic and nutraceutical manufacturers are mainly situated in Japan, the US, France and Malaysia. For the cosmetic industry, Poland, France, Japan and Germany are the leaders in the manufacture of cosmetic products from fish collagen (Biotecmar, 2011).

The nutricosmetics market (see Figure 23) is driven by urbanisation, increased purchasing power and increased desire to look young and attractive through safe and natural methods, aiming traditionally women over forty, but now also younger women and men. Asia is the largest geographical market, followed by Europe and North America. Oral ingestion of fish collagen and hydrolysed fish collagen is claimed to improve skin appearance and is supported by clinical studies; products based on marine collagen are commodities especially in Japan and increasingly in Europe and the US (Wahren and Mehlin, 2011).

The cosmeceutical market includes cosmetics with health positive effects. The largest application is the ‘anti-wrinkle’ segment, and others include products helping fighting acne, eczema or dermatitis (Wahren and Mehlin, 2011).

Regarding the pharmaceutical industry, some drugs like high concentrated marine omega-3 oils have been developed and have helped with diseases like diabetes, heart diseases or obesity (Wahren and Mehlin, 2011). BASF for instance (http://omega3.basf.com/web/global/omega3/en_GB/) has an international business producing high content omega-3 products for pharmaceuticals, consumer health and clinical nutrition, of which one production site is situated in Norway.

Table 7 gives a SWOT analysis for marine ingredients for nutrition or pharmaceuticals and cosmetics products produced from fish rest raw materials.

Table 7 - SWOT analysis for marine ingredients (adapted from Penven, 2014)

Strengths	Weaknesses
▪ Brand image ▪ High-value production ▪ High interest in marine ingredients	▪ Strict regulations ▪ Complicated processes ▪ Seasonality of supply ▪ Need for sorting ▪ Need for high range of products to be profitable ▪ High costs in R&D ▪ Low yields
Opportunities	**Threats**
▪ R&D ▪ International market	▪ Varying quality for different suppliers ▪ Changing prices ▪ New markets to develop ▪ International competitors

5.3.6. Governments and regulating authorities

This solution needs the support of the state and regulating authorities to establish quotas and incentives for fishermen through a policy against discards of rest raw materials. Transhipping procedures and licenses should also be defined and monitored. In addition, guidelines and regulations for rest raw materials should be settled especially to regulate the safety and quality requirements when it is intended for human consumption.

5.3.7. Summary

The different actors and their key logistics issues are summarised in Figure 35.

In the following section, the material flow is described as well as the processes the flow goes through, and the logistics requirements and issues met by the different actors.

Supply chain stage	Logistic issues	Information required
Fishing vessels	- Storage capacity allocated to RRM - Separation and sorting protocols - Design modification, new equipment	- Requirements regarding sorting and storage of RRM - Number of vessels with onboard processing (total and at sea) - Transhipment procedures and regulations - Frequency of collection of RRM by collector ships
Transhipment at sea	- Execute a legal and safe transfer - Maintaining the cold chain	- Number possible per journey - Legislation - Authorised transhipment zones - Procedures for safe and legal transhipment
Collector ships	- Design allowing transfer at sea and cold storage - Frequency of collection - Maximum journey length - Number of ships - Storage capacity	- Storage allocated to RRM by fishing boats - Location of processing facility - RRM shelf life
Transhipment at port	- Port selection - Intermediate storage in port or direct inland transportation	- Location of processing facilities
Processing facility	- Location & number of facilities - Equipment - Choice of product(s) to make - Establish quality charter for suppliers	- Sourcing strategy, availability of RRM and location - Demand and thorough market analysis
Wholesaler Distribution to markets	- Transportation means - Warehouses locations	- Market location, thorough market analysis - Product shelf life
Governments & Authorities	- Transhipping license/regulations - Establish RRM safety and quality rules - Law against discharge of RRM or fees - Identification of transhipping zones	

Figure 35 - Summary of the main logistics issues faced by each actor and the pieces of information they would need to go further

5.4. Material flow

The material flow is depicted in Figure 36.

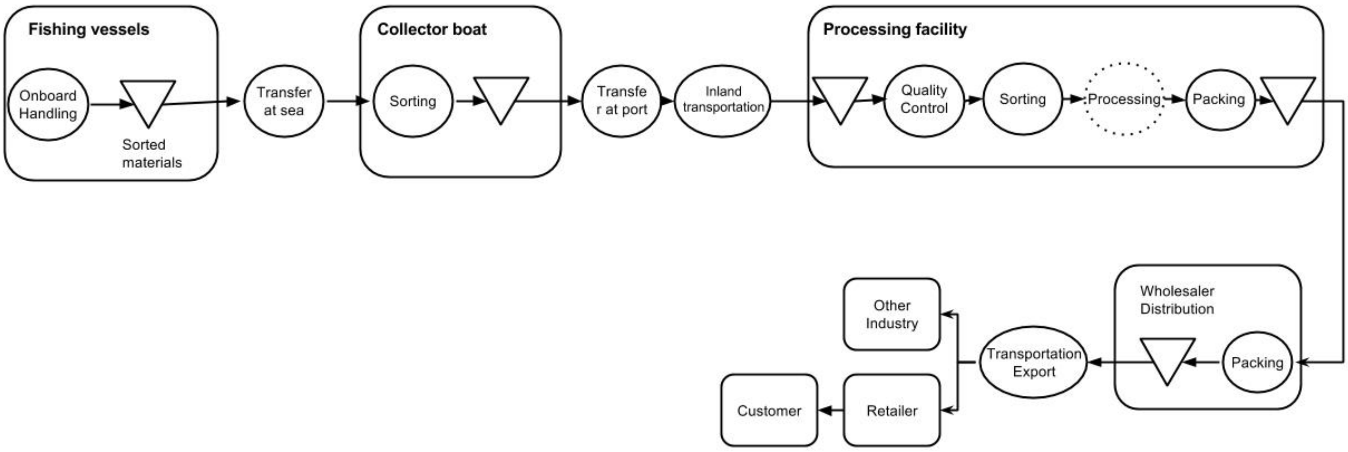


Figure 36 - Material flow from fishing vessel to customer

In the following paragraphs, the different processes are described, together with the different logistic issues and requirements to fulfil in order to be able to implement the solution.

5.4.1. On-board handling in the fishing vessels

All rest raw materials generated in value-added processing can be used in food production; it requires however that at all levels rest raw materials are handled in accordance with the hygiene regulations for food products (FHL, 2013), and should be processed as soon as possible or conserved by freezing, chilling, or by adding necessary substances (Sandbakk, 2002; FAO, 2014b).

The fishing companies should also be in contact with the rest raw materials processing companies to determine the specific quality and preservation parameters they wish to have, so that both can make the highest price out of those raw materials. The precise definition of procedures for onboard handling of rest raw materials depends on several factors, such as the specific vessel features – length, width, hold size, fishing deck type, or the ultimate utilisation of the raw materials and requirements established by the processor regarding form or quality.

Separating/Classification/Sorting

As shown in Figure 31, different processing steps generate different rest raw materials. To allow high-value upgrading, there should be a process for receiving, separating, classifying and store the rest raw materials onboard of the fishing vessels. Waste management onboard, including separation, classification, storage and pre-treatment is a key factor of success, as the sectors which process rest raw materials use specific molecules contained in specific components (Penven et al., 2013), but it also aims to prevent as much as possible the deterioration of what is going to become raw materials for the valorisation process.

There is a need for different installations onboard so that the different parts are retrieved and treated according to the products' needs. This can be done in several ways. For instance, vacuum systems can be used to transport offal directly to storage containers (COWI Consulting Engineers and Planners et al., 2000). Another solution could be to re-engineer the conveyor belt, or to install another conveyor underneath the main processing line to retain the 'waste' from each process step – de-heading, gutting, filleting and skinning. Wastewaters flowing away can be filtered through the conveyor belt, while the solid offal is retained on the belt and can be transported to a collection area. Sorting is for now a manual operation, and there is a strong need for more efficient and automated solutions (Falch et al., 2007), as it is impossible to do onboard of the biggest ships considering the volumes of fish that are harvested. It would mean an excessively large increase of staff and of the production area. Increasing the personnel onboard is first both costly and difficult considering the limited space for the crew. Second, manual sorting is time-consuming, which reduces the overall productivity. The automatic process should:

- Gently remove the viscera, thus enabling the preservation of each fraction undamaged
- Recognise and automatically separate the specific fractions
- Automatically sort the separated fractions.

These improvements and required installations are likely to increase the fishing costs. They are also limited by the vessel size and storage capacity, which determine the processing equipment that can be installed on-board and under which conditions classification protocols could be carried out. The additional processing equipment should be compact and efficient, as the possibilities depend on available space but also weight, as the needed machinery brings a considerable weight to the vessel.

In addition, the separation protocols are dependent on the end products wanted by the processing company. It could be needed in some cases to separate and sort the different fish parts, for instance for collagen extraction, and not in other cases, for example for the production of fishmeal and oil. It could be separated and sorted in four categories (BE-FAIR Report, 2007):

- Fraction currently kept as edible products
- Fraction considered as edible but discarded because of different reasons, for instance illegal size or low commercial value
- Fraction for use in fishmeal, oil or hydrosilates production
- Fraction for use in specific productions, for instance fish skins, cartilages, viscera.

There is also a need to study what the market is expecting in order to determine how products should be separated, sorted, stored and processed. Another question that the market should answer is whether the raw materials should be sorted by species; for instance, should the cod backbones and haddock backbones be separated or can they be stored together? Sorting by species and rest raw materials types will further complicate the operations.

Quality control

Quality control could be an important step to set up onboard the fishing vessels, as the quality of frozen products when they are thawed out at the processing plant cannot be better than it was at the time of freezing. The quality of marine rest raw materials is dependent on several factors such as species, size, freshness, season, location of catching and onboard handling procedures (Arason et al., 2010). As criteria for poor quality have been defined for the main fish products, regarding appearance, odour or flavour, they remain to be defined for the different parts constituting the rest raw materials. Then, quality could be another sorting criteria, the low-quality products reserved to mass upgrading whereas the highest quality should be kept for high-value upgrading.

Fish rest raw materials, especially when containing viscera, deteriorate very quickly, and it is important they are preserved as soon as possible after being produced (Olsen et al., 2014), as their quality has an impact on consumer’s safety, as shown in Figure 37.

Figure 37 underlines the importance of proper storage, process and preservation of the rest raw materials in order to retain the product quality. When performing the upgrade of rest raw materials, the interest has for now lied on low capital and operating costs instead of product quality, which resulted in variable margins and profitability (Ismond, 2002).

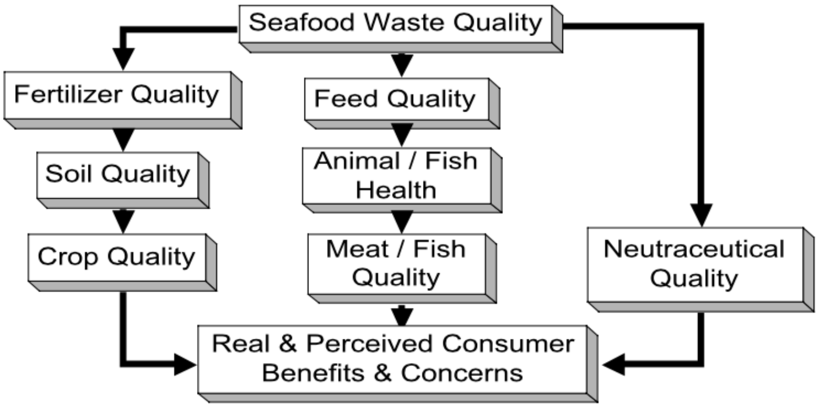


Figure 37 - Path from "waste" to consumer (Ismond, 2002)

Packing and storage

The question of how the rest raw materials should be stored and preserved is one of the main challenges that researchers seem to be facing. Some state that there is no current and cost-effective method for stabilising small volume of high-value fishery processing waste. There are two methods to preserve them in order to make low-value fishmeal or animal feed. The first one is to produce liquid silage by reducing the pH to lower than 4 by formic acid and storing it at ambient temperature. The second is a fermentation process after adding fermentable carbohydrates (Olsen et al., 2014).

Others state that freezing is a good conservation method for most sorted by-products, such as liver, roe, stomach, skin, head. In addition, big fishery trawlers can have a fishmeal plant on board, or for silage production (Sandbakk, 2002). Although freezing can be a good solution for some fractions, the temperature varies for the different parts. For example, there have been studies that showed that cod liver should be stored at minus 45 degrees or under in order to prevent its degradation. Then, as the freezer is powered by the boat's engine, the horsepower of the engine determines the limitation for the possibility to produce refrigeration capacity (Falch et al., 2007).

Arason et al. (2010) studied the effects of storage condition and packaging on rest raw materials from cod and saithe stored for 2 and 4 months. They recommended that the rest raw materials should be stored at minus 24°C to minimize negative changes in cut-offs and liver.

Frozen fishery products are not completely stable in the frozen state and are still deteriorating over time, which can be seen in changes in their texture, odour and flavour for instance. The rate at which fishery products deteriorate during frozen storage depends on two main factors: the temperature and the exposure to air. The lower the temperature is, the slower the product deteriorates. Therefore, the storage time before further processing should be as short as possible, and packing methods should limit access of oxygen selected (Arason et al., 2010). To avoid an increase of temperature in the freezing storage, the products can go through a freezing tunnel first and once frozen be stored in the hold (BE-FAIR Report, 2006). Exposure to air should be particularly monitored when the load is transferred from the fishing vessel to the collector ship. The shelf life of the frozen rest raw materials is to be determined and will influence the frequency of collection from the collector vessel.

The different boxes containing the sorted rest raw materials should be stored in a freezing room labelled with at least the following information:

- Fishing vessel identification
- Date and place of catch
- Content, type of rest raw materials, and weight
- Date and time of processing

The fishing vessel should allocate a storage place for the frozen rest raw materials. It should be evaluated if rest raw materials and main products can be stored in the same space, or if they should be separated. The size and capacity of the storage are to be determined in accordance with the collector company, as both actors can discuss the trade-offs between inventory capacity for both fishing vessel and collector ship, and determine the frequency of collecting. In addition, it is essential that the allocated storage facility onboard the fishing vessels is accessible for transhipment at sea, meaning that it should be reachable by opening of the deck. Transhipment is explained more precisely in the next paragraph, although there seems to be a lack of documentation on the subject and regarding the practical requirements.

Summary of main arising issues:

- Need for automated processes for separation of materials and sorting onboard
- Investment and installation of equipment onboard
- Sorting protocols
- Preservation protocols
- Storage capacity allocation

5.4.2. Transfer between the fishing vessel and collector

Transhipment is defined as "the unloading of all or any of the fish onboard a fishing vessel to another fishing vessel either at sea or in port" (McCoy, 2007). Transhipment has been used for several years; for example, the Russian fishing vessels are said to land their catches to the continent via transport vessels (FiskeriDirektoratet, 2009). However, there seems to be a lack of documentation on the subject and regarding the practical requirements.

There is an important debate on the regulation of transhipment, especially in the developing countries as it is often used to carry illegal fish catch and sell it onshore. These practices raise several concerns, regarding for instance traceability and transparency. Maintaining the transparency is essential to establish the degree to which the marine resources are exploited. It is important thus than the information flow runs smoothly between the fishing vessel, the collector ship and company, as well as the authorities. The collector ship should have a transhipment license stating all the necessities to make a quick and safe transfer at sea that preserve the raw materials' quality and storage conditions. In order to avoid illegal transhipment, governments or ruling administrations could define transhipping zones in accordance with collecting and fishing companies, which would also consider safety and practicality.

If such a method for the transfer of rest raw materials is used, the fishing vessels would have to allocate an intermediate inventory for rest raw materials onboard, which would be unloaded by collector boats once or several times during their journey. Transhipment at sea gives rise to a number of requirements for logistics and for maintaining the cold chain and quality and safety of the rest raw materials:

- Transhipment should be rapid so that the increase of the products' temperature is kept to a minimum during the transfer.
- Transhipment is also subjected to weather conditions, as it should be avoided in hot weather, rain and particularly windy conditions.
- The frequency of transhipment should be defined between the fishing company and the collector company. It depends on factors such as the storage capacity the fishing vessels are willing to allocate to rest raw materials, the collector's storage capacity, the shelf life of the frozen materials and optimization regarding volumes to make the journey economically worthy.

Summary of main arising issues:

- Physical transfer maintaining the cold chain
- Information sharing, traceability
- Regulations
- Inventory location for enabling transfer at sea
- Frequency of occurence

5.4.3. On-board collector boat

The collector company also has to define the number of boats they wish to have operating. In order to do that, there is a need to evaluate the quantity of fish processors vessels at sea during the same period, and the needed frequency for collecting the rest raw materials. Trade-offs should be studied between a large number of small boats and a small number of bigger boats, which depend mostly on the shelf life of rest raw materials to retain the highest quality, which defines the maximal length of the journey at sea.

Regarding design, the size and characteristics of the collector ship are linked to the capability of executing a licensed transhipment at sea, but also should have a freezing storage to maintain the cold chain and quality of the raw materials. It should if possible be compartmentalised, correspondingly to the different types of rest raw materials that have been sorted by the fishing vessels and transported.

The ship should be aware of all requirements regarding the materials' shelf life and handling particularities, and adjust the length of its journey accordingly. It should be also investigated whether one boat can carry out several transhipments at sea without damaging consequences on the products, for example rising cold storage temperature. This results in important differences in strategies. If it is possible to perform several transhipments, the reefer ships collecting rest raw materials can have higher storage capacity and a longer journey at sea. An optimised route should be calculated for the collector boat to collect the rest raw materials. On the other hand, if only one transhipment is possible to maintain the rest raw materials' quality, the ships' storage capacity can be smaller, though depending on the volume of rest raw materials allowed by the fishing vessels' allocated storage. Then, the different fishing vessels should agree to allocate approximately the same space so that the collector's company can decide of an appropriate size for its ships.

Summary of main arising issues:

- Number, design, size of collector boats
- Transhipment requirements
- Handling procedures
- Vertically integrated or third party logistics

5.4.4. Transfer to ports and processing site

The collector ship will have to unload its content at a port, before it is moved to the processing facility. This causes several concerns:

- How often should the ship unload its content?
- In which port should it unload?
- Should the load be stored at the port in a refrigerated storage until it is picked up, or should the load be moved directly from the boat to a truck and transported to the processing facility?

It is likely that storage and transport facilities will be required in the port where the rest raw materials are landed. Storage facilities will enable the aggregation of sufficient quantities of material in order to make the inland transport and treatment afterwards cost-effective.

The length of the inland journey depends on the location of the processing facility, or the processing facilities if there are to be more than one.

Summary of main arising issues:

- Location, frequency of unloading
- Intermediate storage at port

5.4.5. Processing site

The first facility should be placed optimally knowing the ports where the collector ships can unload their content. Figure 34 showed that rest raw materials from groundfish are available in 4 main regions: Møre og Romsdak, Nordland, Troms and Finnmark.

From Bodø to Hammerfest, there are 530 kilometres in a straight line, but more than 950 by the road. Ålesund is situated another 1000km by road in the south of Bodø. That implies substantial transportation if there is to be one facility, and thus its location should be properly studied.

The rest raw materials should be unloaded at the processing facility with respect to the cold chain, and need to be checked, so that their quality is evaluated and the products sorted regarding their possibilities of upgrading. The thawing step is crucial according to Sigurdsson et al. (2014), and needs to be carefully monitored.

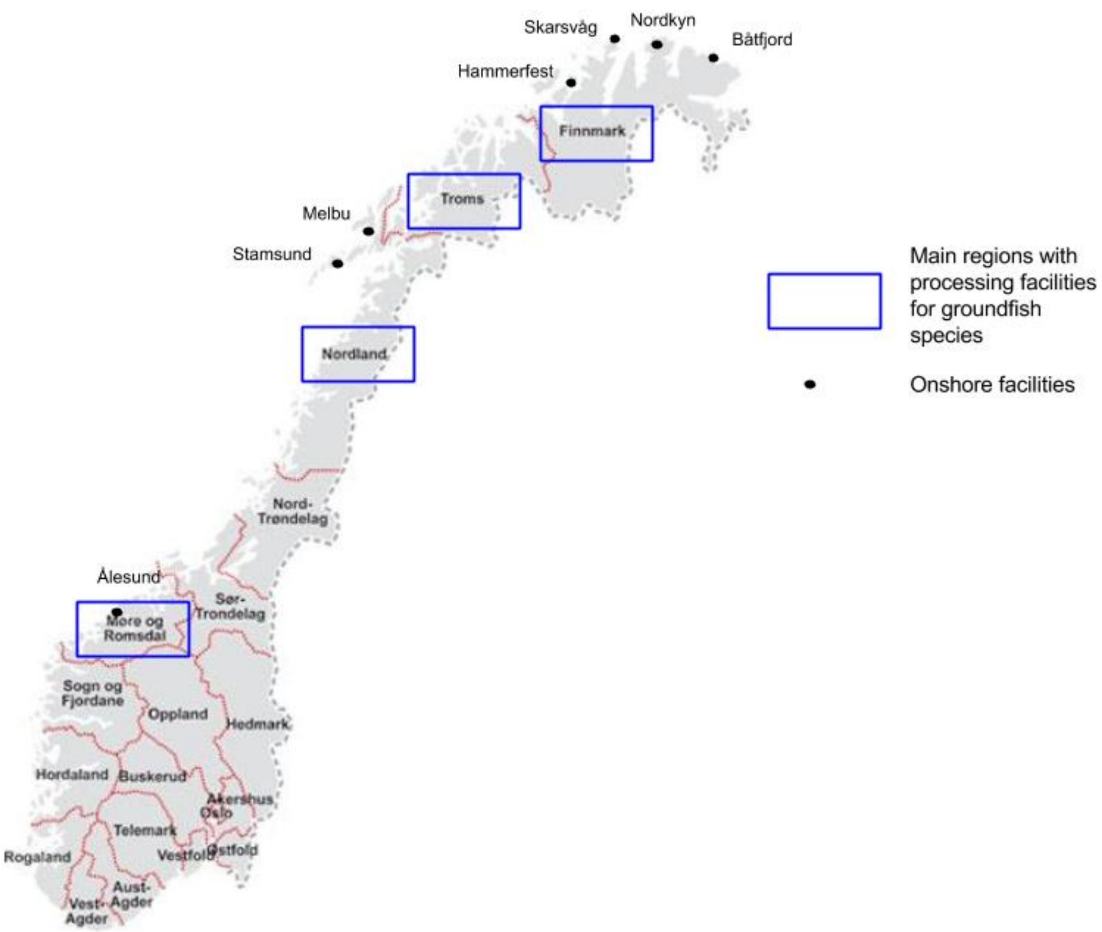


Figure 38 - Location for onshore processing facilities and main regions exploiting whitefish

The company processing the rest raw materials should first consider the market, legislation and environmental aspects of the different utilisation opportunities, as well as the costs of production and transportation. Once they have established which products they wish to produce, the processing facility to clearly define handling and quality requirements for the rest raw materials and communicate with both the collector boats and the fishing companies to make sure they are enforced.

Summary of main arising issues:

- Location and number of processing facilities
- Choice of products
- Processing equipment
- Maintain cold chain and monitor thawing
- Define requirements for suppliers regarding handling, quality, form

5.5. Information flow and information sharing

The LIFE project called FAROS, conducted between 2010 and 2013, aimed to contribute to the implementation of an efficient discard management network between the different stakeholders involved in the fishing industry, by optimising the synergies between them. The project used tools based on geographical information systems in order to obtain accurate information on the volumes, situation and seasonality of the discards (FAROS Project, 2013). As part of the FAROS project, a technology was developed called BEOS (Biomass Estimator Optical System), which integrates images captured by a camera placed on the conveyor belt of the fishing hold, processing optic information and extracting characteristics from the individuals in each image, so it could recognize the species. The data of each catch was then sent to shore, thus allowing real-time online submission of data obtained when fishing. The central system could make the database generated available for end users. The final objective of the FAROS project was to develop a virtual network capable of including all stakeholders of the fishing sector: fleets, ports, auctions, recovery and transformation industries, end buyers. The industries onshore can know in real time the availability of raw material to supply their production lines, which allows the production to be based on up-to-date information and can help for logistics programming of goods transport as industries receiving landing port information (FAROS Project, 2013). This type of thinking and collaborative network could be utilised to promote the availability of rest raw materials onboard of fishing vessels, so that the onshore company that is going to upgrade the rest raw materials can now the availability of supply in real time and organise the logistics of collector boats.

On a more practical level, several pieces of information that should be shared by the different actors are listed in the following paragraphs, although this list is not exhaustive.

Fishing vessel

The fishing vessels need to provide the following information parameters:

- Vessel identification and certification, route, landing information
- Capacity, Inventory level, tonnage
- Trip dates, start and end
- Product information: targeted species, catch location, date, gear type, volume, net weight
- Rest raw materials information: species, type, volume, catch date, methods used for sorting

Collector boat

- Vessel name, company, certification, position
- Inventory levels, capacity
- Product information: species, types, volume
- Prior requirements for transhipment
- Transhipment declaration to send before and after

Processing facility for rest raw materials upgrading

- Capacity
- Byproducts production types
- Requirements for the rest raw materials' format: this point is critical, since the company will most likely have to deal with several suppliers and needs the quality and form of the rest raw materials to be similar if they are to regroup and process them into relatively standardized products
- Product description: ingredients, additives, process, packaging, conditions for storage and transportation, shelf life, instructions for use
- To the distributor:
    - Information on volumes involved
    - Logistics tasks to be performed
    - Level of performance required

Processing facility for filleting operations

- Availability of rest raw materials, types, date of processing, means used for preservation

Distributor of end products to markets

- Services, technologies
- Warehouse space, capacity, personnel
- Geographical locations
- Flexibility

In addition, the transhipment operation needs to be monitored and controlled so that the information flow and traceability are maintained. In order to have enough volume to upgrade rest raw materials into valuable products, the processing facility might have to combine different catch from different boats and different species, thus making it difficult to carry on the traceability of the product. Transhipment requires notifications and reporting requirements before, during and after the transfer at sea, of information such as vessel name and identification, carrier vessel, tonnage of products, date and location of transhipment. Standards should be defined regarding the collection, verification, exchange and reporting of data. An example of transhipment information sheet can be seen in Appendix 2: Transhipment log sheet, retrieved from conference proceedings from a meeting of the South Pacific Regional Fisheries Management Organisations in January 2015. The location of transhipment is also important for regulations, since if the fishing vessels are far from ports in international waters, or if the rest raw materials are collected from foreign fishing ships, the load might need to be considered as imports. Then authorities should also be informed.

The Norwegian boats are already equipped with GPS, making it possible to follow their journey. This can be used by the collector company together with the inventory level to be able to establish an optimised route for their collector boats depending of all the boats' positions. Many algorithms already exist to find the shortest route, like Dijkstra's algorithm for example.

If the processor chooses to produce high-value products from the rest raw materials, it is essential that their quality is retained efficiently. For that, the processor has to convince the industry to respect a quality charter, which requires exchanges and trust relationships. The number of companies to federate and the locations of the deposits and the company might not facilitate this task. Therefore, the upgrading processors might need to work first with a limited number of suppliers with whom a long-term agreement can be made to ensure the highest quality of rest raw materials.

The information should be precise and shared efficiently, as the fishing companies will have to deal with both streams for the main products as well as for the rest raw materials; the rest raw materials' processing companies will have multiple fishing vessels as suppliers and many customers in different industry areas. The need for collaboration can also be necessary between different supply chains. For example, the collector could be in relation with both capture fisheries and aquaculture in order to have enough volume to process the rest raw materials.

5.6. Overview of costs and prices

Norway has around 300,000 metric tonnes of demersal raw materials that is being thrown away into the sea and not being utilised. The heads of groundfish species are the parts leading the wasted potential. Referring to Codland CEO Erla Osk Petursdottir's estimation, Norway is losing a potential $540 million, that being around 4 billion NOK (Ramsden, 2014).

5.6.1. Costs implications for the fishermen

Fishing vessels incur a range of operating costs such as fuel and oil, boxes, food and stores, sales commissions, landing fees, labour costs, travel costs, quota leasing, purchase of days at sea (Mangi and Catchpole, 2012).

Sigurdsson et al. (2014) conducted an analysis and concluded that the costs associated with onboard freezing of byproducts lies between NOK 3.01 and 3.57 per kg. This provides a basis for estimating that the product price for the byproducts must be at least NOK 4 to 5 per kg to provide enough incentive for the vessels to take care of this material. These calculations did not include contribution to fixed costs or profits for the vessel. The investment costs in a new production line's for byproducts and issues regarding increased capacity in freezing and storage were however not investigated. In addition, they stated that increasing staffing on the vessels is not economically viable. Their case ship could then take care of under one third of the theoretical annual volume of byproducts without increasing the staff.

Additional costs will come from:

- Investment costs in automated systems to separate and sort the rest raw materials. Automation is essential to make the upgrading profitable, especially regarding Norwegian high wages and the difficulty to increase staff onboard due to limited space

- Inventory costs for the storage allocated to the rest raw materials
- Lost value since loss of space for main products

5.6.2. Collector boat

There will be investment costs in the collector ships, and the extent will depend on the number of ships, their capacity and features.

The cost of transhipping is to be defined as well. Transhipping can be expensive, but the costs can be offset by the increased fishing days that it affords.

5.6.3. Inland storage and transportation

The rest raw materials would be unloaded at port, and either the processing facility is directly reachable, either there is a need for inland transportation, which implies storage facilities at the port and transportation costs.

When the rest raw materials come from an inland filleting facility, the storage of rest raw materials before pick up brings also an additional cost, as well as inland transportation to the upgrading facility.

5.6.4. Processing facility

The facility will face investment costs for the different processes required by the end products of their choice. Automated processes would bring an advantage, as in Norway the low energy costs will be an advantage if the processes of rest raw materials are fully automated. Especially, the thawing process should be automated and carefully monitored, as it is crucial to maintain the quality of the rest raw materials.

The sorting and cold storage needed for any high-value upgrading represent significant costs for industries, which must be offset by compensation. Penven et al. (2013) described two different strategies. Copalis' facility is situated close to the producers of rest raw materials. However, Bioceval has many suppliers situated up to 600km, and most of the time makes them pay to have their rest raw materials collected. The cost is fixed by Bioceval and depends on the nature and volume of the materials and the distance to treatment site. Even if the costs of production exceed prices, the rest raw materials producers might still pay if the losses are less than the cost of waste disposal, if governments mandate the production or if the governments subsidise the production. The two strategies of Bioceval and Copalis are depicted in Figure 39.

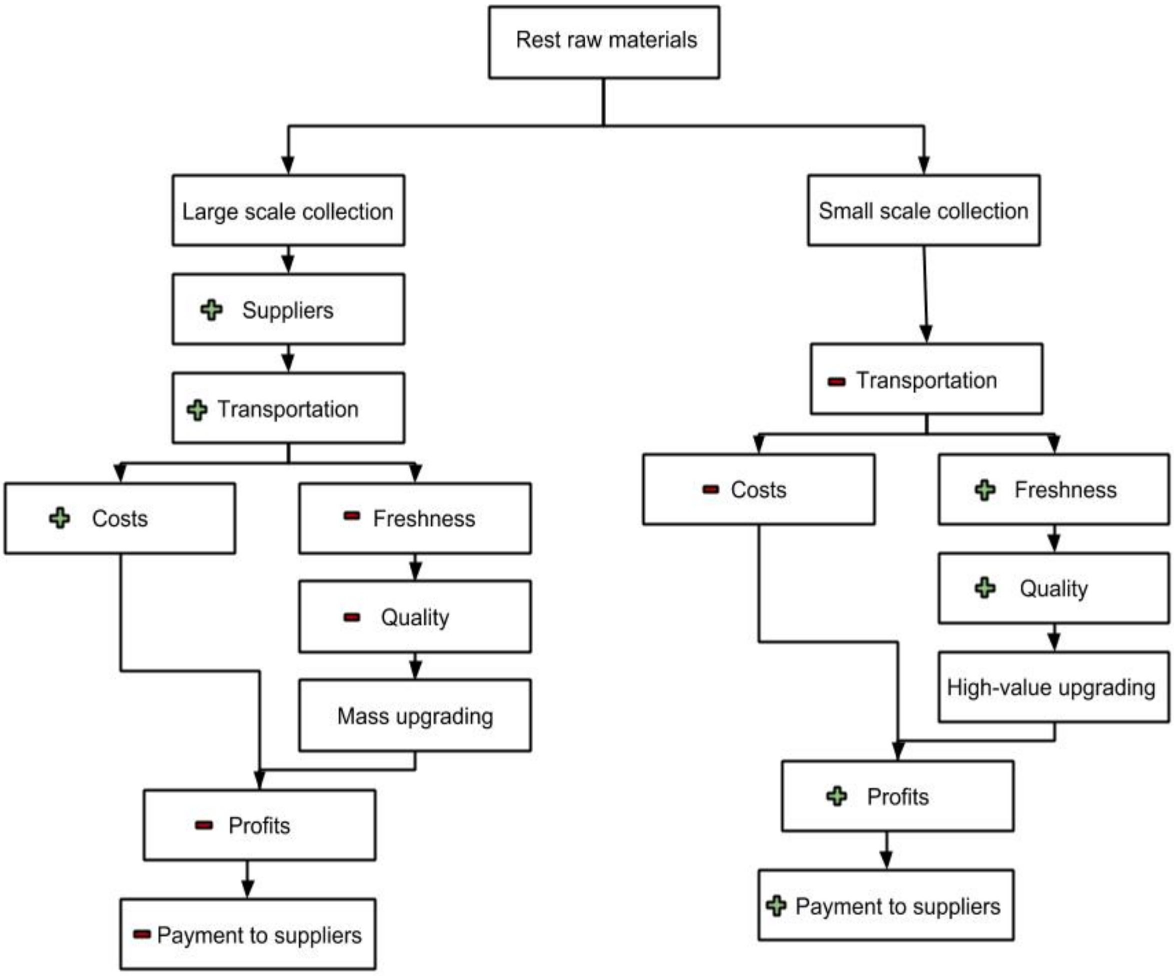


Figure 39 - Influence of large- or small-scale collection on prices paid to suppliers of rest raw materials (adapted from Penven (2014))

In this research, the scale of collection is rather large as rest raw materials are onboard the fishing boats at sea. Therefore the costs for transportation are likely to be high, all the more if inland transportation costs are added. However considering the proposed concept, the rest raw materials would be frozen onboard, thus preserving their quality compared to the model in Figure 39. Then there is a need for a precise cost evaluation to determine if the prices can offset the costs and estimate the suppliers' pay, which could be another incentive for the fishermen to keep the rest raw materials onboard.

5.6.5. Exporter

Since for high-value upgrading, most markets are situated abroad, the tolls for exporting products should be taken into account. The means of transportation should also be chosen considering the shelf life and markets.

5.6.6. Prices

The costs of the logistic solution might be disproportionately high compared to the value of the raw materials. Hence the need to integrate the collector with the upgrading processors and make substantial efforts in terms of product development, testing and market development. Sigurdsson et al. (2014) estimated price ranges for the different kinds of end products, as can be seen in Table 8. They concluded their study by the fact that there is potential for a profitable exploitation of rest raw materials from whitefish species.

Table 8 - Type of end products from rest raw materials and price range (Sigurdsson et al., 2014)

Type	Price range (kr/kg)
Feed or feed ingredients	1-12
Pet food	9-25
Human Nutrition	25-120
Pharmaceutical	Over 100

Those results, compared the statement that the costs associated with onboard freezing of rest raw materials are between 3 and 4 kr/kg, confirm that there is indeed profitable opportunities in the utilisation of rest raw materials from onboard processing, although the investment costs, inventory and transportation costs need to be established to assert the logistic solution presented in this chapter.

5.7. Summary of Section 5

Section 5 presented the proposed concept to bring the available resources from fishing vessels to the onshore processing facility, which consists of a collector ship acting as a shuttle between fishing vessels and the upgrading factory. This solution was depicted as a new supply chain and each of its actors were described, together with their roles, potential business opportunities and main logistic issues. This was summarised in Figure 35. The processes were then described in each of the stages, highlighting that several processes need further research and development in order to be implemented, such as especially the automated separation and sorting of rest raw materials onboard.

The implementation of this solution will also require good collaboration between the different actors as it needs transparency regarding inventory levels and product types in particular in order to be established in a cost-efficient manner and be a profitable operation for all actors in the supply chain. It is also important that information is passed in order to maintain the traceability of all the parts.

This concept is also highly dependent on external factors, and they are depicted in Figure 40 together with the different supply chain stages on which they have an impact.

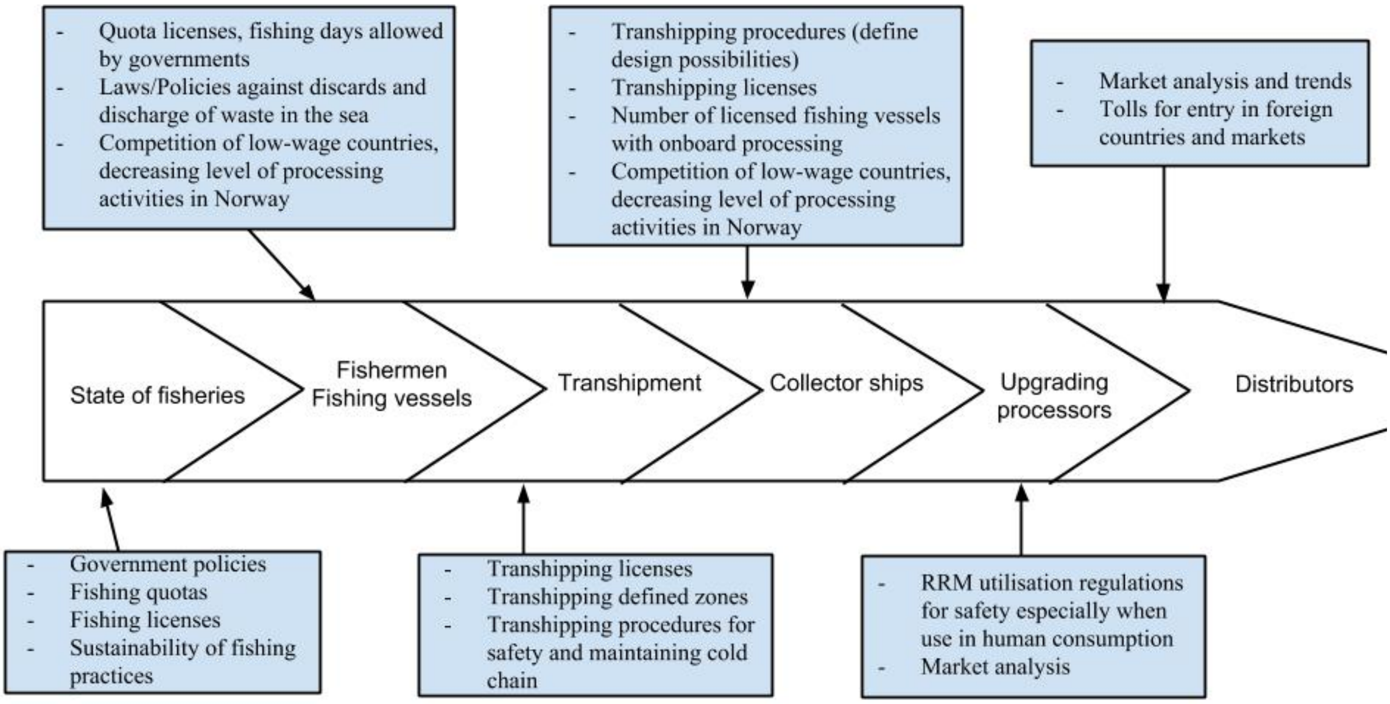


Figure 40 – External influences on each actor of the SC

In the following section, the proposed concept is discussed regarding realism, potential opportunities and barriers, limitations and need for further research investigations.

6. DISCUSSION

A conceptual solution was presented in the preceding chapter, and logistics issues were outlined and discussed. In this chapter, the findings of this research are discussed and potential errors and limitations are outlined. The section starts with a reminder of the drivers behind the study, followed by a discussion regarding the realism of the proposed solution concept and its limitations. Then, the needs for further investigations are presented.

Reminder of the importance of utilising rest raw materials

The increased awareness of sustainability issues and growing concern with the environment have led most industries to pay attention to their waste, especially when they exploit natural resources. This has been the base for the development of processes such as reverse logistics, which focus on the flow backwards the supply chain and adding value to 'waste'. The utilisation of rest raw materials from onboard processing operations follows on from those processes.

In addition, Norway is one of the world's leading nations regarding the production of marine fisheries and aquaculture, and benefits from a brand image of natural and quality products. However, Norway is losing value-adding activities as more and more whole frozen fish are exported to China to be processed there and sent back to Europe, especially due to the low production costs in China. It represents not only a value loss for Norway, but also a breach of sustainable goals as transportation, fuel use, emissions and 'food miles' greatly increase.

Apart from commitment to sustainable development, there are great opportunities in using all resources from the catch, which contains ingredients and proteins that are demanded by several other industries. Today's society is more and more preoccupied with appearance, youth and health, and this preoccupation triggers market developments in healthy and functional foods and cosmetics in particular.

The drivers leading to full utilisation of marine catch are summarised in the causal link depicted in Figure 41.

The scientific research shows that the highest potential for untapped resources lies in onboard processing rest raw materials that are for now wasted. At the same time, existing onshore facilities convert their rest raw materials into low-value products, mainly fishmeal and oil intended to aquaculture feed. Both these untapped resources and inland used materials could be utilised to produce higher-value products.

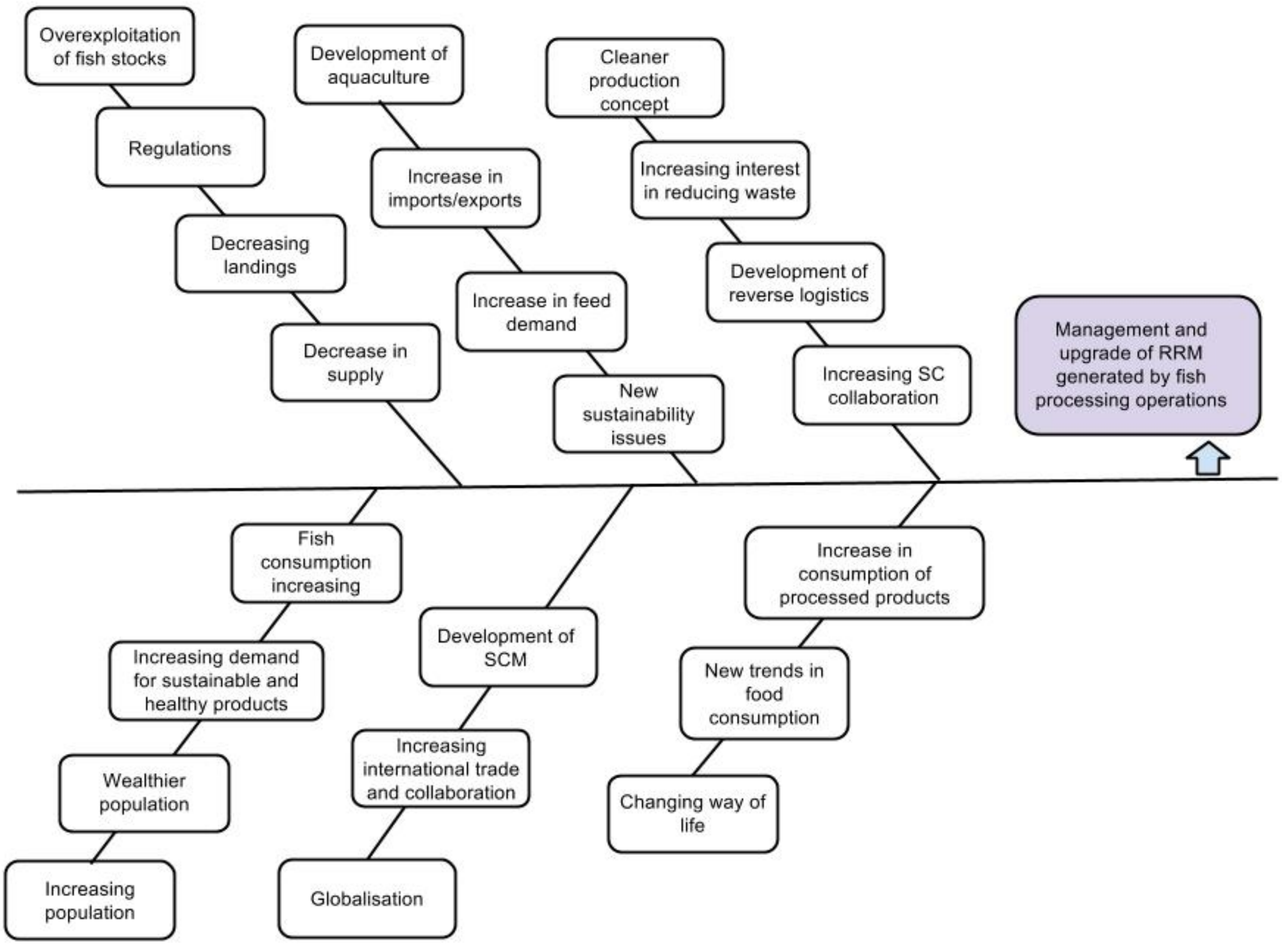


Figure 41 - Causal link between theoretical concepts and rest raw materials utilisation

The solution concept presented in Chapter 5 could be used as a means to retrieve value-adding activities to Norway. By using automated processes to sort and preserve the rest raw materials onboard, the onboard workforce does not need to increase, while more workers can be used in the facilities that upgrade rest raw materials onshore. Norway has a long experience in most of the mass upgrading activities and should use it to build a competitive advantage in higher-value industries and arising markets, while more competitors enter the mass-upgrading activities.

A realistic concept?

The concept presented in Chapter 5 aims to regain value from rest raw materials considered for now as waste and disposed of as such. This concept is based on a literature study executed beforehand, which established the context for its development.

The study of secondary empirical data highlighted for example that rest raw materials were available onboard processing fishing vessels, that reefer ships can execute transhipments at sea and transport perishable foods, and that high-value upgrade is possible and there is some demand as several companies are already exploited the inland resources. The process underlying the solution development is depicted in Figure 42.

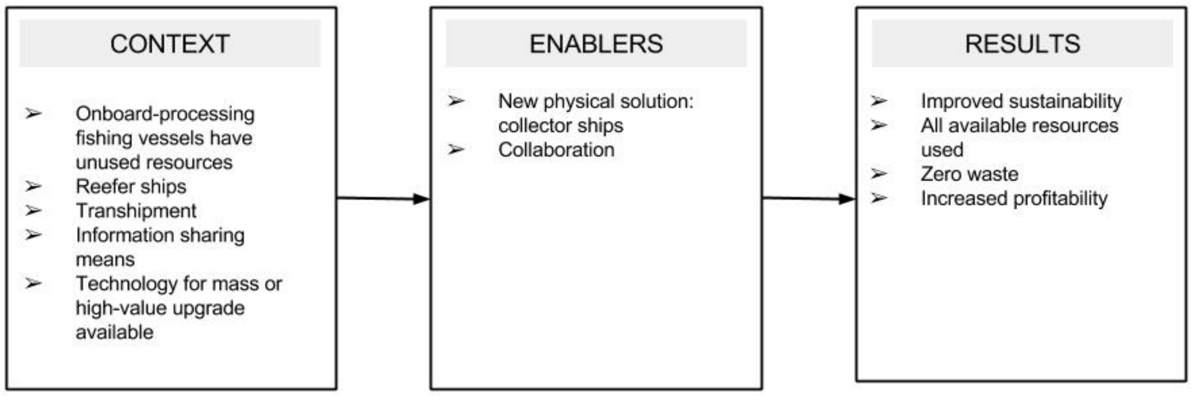


Figure 42 - Logic behind the building of the conceptual solution

The scientific literature has been talking about the opportunity that lies in onboard processing rest raw materials for more than a decade, but no solution has yet been implemented. This is depicted in Appendix 3: Authors and themes, where it can be seen that there are few case studies on rest raw materials utilisations and many studies regarding rest raw materials properties. As the market for higher-value products is developing and the exploitation of rest raw materials can be profitable according to several authors, there is a need for cost-effective logistics solutions to bring the available resources to the processing facility onshore.

Different factors influence the utilisation of rest raw materials:

- **Economic**: Large volumes are required to achieve economies of scale, especially in the case of low-value added products, while there are high investment costs for high-value products.
- **Technical**: Expertise is required to use advanced technology in the production of high-value products, including selection, documentation and proper treatment of the rest raw materials
- **Technological**: Need for automated solutions to fulfil sorting requirements onboard fishing vessels.
- **Social**: The use of fish rest raw materials should not be a threat to human health

- **Policy**: Supportive regulations and legislation are required to facilitate private sector investments.

Several authors argue that the upgrade of rest raw materials to high-value products is not realistic at the moment. The report from the FAO (2014b) states that “the use of by-products for the isolation of high-value bioactive compounds is not realistic in many cases”, due especially to the lack of markets, the lack of regular supply of high-quality by-products and the high costs of extracting very small amounts of ingredients. The most realistic uses lie in food and feed applications for now. Olsen et al. (2014) reinforced this statement, saying that the extraction of enzymes or collagen is not likely to succeed on a commercial scale in most cases because the rest raw materials are of variable quality and most often available in small volumes. Several companies cited in Chapter 5 were though upgrading rest raw materials to high-value products used in functional food and cosmetic and pharmaceutical industries, thus proving that the extraction is possible and can be profitable.

The objective to upgrade rest raw materials to high-value products can be seen therefore as realistic. However, the problem lies in the realism of the logistic solution to bring the available resource onboard to the coast. Many gaps were highlighted when searching through secondary empirical data. First, details regarding transhipment procedures, possibilities, or regarding the maintaining of the cold chain were not found in public databases and reports. Second, there is a need for a thorough financial evaluation regarding costs – collector boat, equipment, transhipment, investments, and profits to establish whether the proposed solution can be profitable. In addition, from the literature findings it could be concluded that no commercialised onboard-automated processes exist at the moment to separate and sort the rest raw materials. This point is crucial, as manual sorting is not possible for large vessels with automated processing lines. Until a prototype is made and can be tested, the solution might not be feasible. The gaps and their implications are summarised in Table 9.

Table 9 - Gaps in literature and databases and implications

Topic	Gaps	Implications	Decisive information
Transhipment	Procedures Cold chain	Feasibility of solution Quality maintenance	✓
Cost evaluation	Collector boat: fuel, number Transhipment costs Equipment Investments	Not possible to establish cost range	
Fishing boats	Number of onboard processing boats	Hard to estimate extent of the collection needs	
Automated processes	Existing machinery	Cannot do the sorting step if do no exist	✓
Market analysis	Current level, sales prices	Unclear requirements for separation and sorting Prices willing to pay Missing locations, estimations of future development	

Potential Barriers to the solution development

One potential barrier relates to the objective of upgrading rest raw materials to products for human consumption, especially nutricosmetics and nutraceuticals described in paragraph 4.3.2. Any product intended for human consumption with special health claim has to be approved by authorities such as the Food and Drug Administration in the United States or the European Food Safety Authority. To obtain such approvals, there is need for positive results from studies on humans, which are really expensive.

Another barrier lies in the inability to produce high-value products. One reason could be that the quality of frozen rest raw materials might not be high enough to be used in high-value upgrading. Another assumes that no automated solution for separating and sorting rest raw materials is compact enough to be placed onboard fishing ships. One major obstacle is also to solve whether transhipment can be performed between a fishing vessel and a reefer ship without comprising the cold chain or decreasing the quality of rest raw materials.

Regarding incentives, a barrier arises if there is no support from authorities and governing bodies. FHL (2013) stated that “the unexploited raw materials in the cod sector can readily be dealt with, but to do so we are dependent of adjustment in regulations”. In addition, the increasing aquaculture production could encourage the upgrade of rest raw materials to low-value feed products.

The possibility of shortage due to the reduction of fishing activity can also jeopardise the supply quantities, which can hamper the development of some applications with low yields of production. From 2013 to 2014, the world fish market registered a drop of 1.2 per cent for feed products and 6 per cent for other uses (FAO Globefish Data Series, 2015).

Limitations

Several pieces of information were not found in the literature or secondary empirical data. They are summarised in Table 9. It was not possible to go deeper in the definition of several parameters because of those missing pieces. For example, it is possible to access the number of vessels over 28 meters, but it is not mentioned if they have processing facilities onboard, and if so, of which type. Those missing parameters impacts on several areas, as for instance the scale of the solution needed; an approximation of the number of collector ships required is not possible, as well as the number and optimal locations of processing facilities. Some missing parameters are also crucial for the solution to be realistic. Especially, precise information regarding transhipment was not found and the solution is dependent on whether it is possible.

In this study, the scope restricted the fish species to demersal species, as these are the ones concerned by onboard processing and the highest potential for utilisation. Fish species are numerous however, and there are other high-value products that can be produced from other species, for instance chitin from crustaceans. The upgrading facility could consider diversifying its production to several species types, not only demersal species. If it can get high profits from close suppliers – and thus lower transportation costs-, it could maybe offset the transportation costs for the collector ships. These opportunities are to take into account in the financial evaluation.

The solution presented and discussed in Chapter 5 considered a collector boat picking up the rest raw materials from fishing vessels and bringing it to the facility on shore. Other solutions could also be examined. For example, the processing facility could be established on an at-sea platform, which could be strategically placed if the fishing vessels have a defined route for their fishing season. Then the fishing vessels could alter this route to unload their rest raw materials inventory at the platform and thus there would not need collector boats or at-sea transhipment.

As one of the bases for the motivation of this study is to increase the sustainability of fisheries, a study on the environmental implications of the solution, such as life cycle analysis (LCA), should be conducted to assure that the solution is indeed increasing sustainability. This study should consider energy and water consumption, emissions and other considerations cited in Chapter 3.1.

Need for further investigation

Although the research community has been working with the subject of rest raw materials' utilisation for several years, there are still many issues left to be addressed. They are described in the following paragraphs.

- *State support*

Governments and governing bodies are the initiators of any potential rest raw materials' utilisation. They can make fishermen keep their materials, through incentives like additional fishing days or policies forbidding or taxing discards.

Authorities also control the transhipment process, through the establishment of safety procedures and licenses for companies. As they did for the main fish products, quality and safety guidelines and rules should also be introduced for handling and preserving rest raw materials, which possibly depend on the end products.

- *Further research on markets, supply, and solution development*

There is a need to investigate each utilisation opportunity and write precise documentation on:

- Potential capacity
- Raw materials requirements
- Cost / Income
- Infrastructure and equipment needs
- Safety and legal requirements

Further research should be conducted together with fishing companies to determine precisely what is available at sea at the same time, onboard handling procedures and willingness to allocate partial inventory.

The solution should be also be subjected to an environmental study, for example life cycle analysis, to compare the benefits of reducing waste to the environmental costs of collecting it.

- *Development of equipment*

There is a need to develop automated equipment to sort, separate and classify the rest raw materials onboard without damaging them.

- *Testing of equipment on selected vessels and onshore facilities*

A fourth step in the implementation of the concept would be to select a small number of vessels that produce what the market wants, and adapt the equipment developed beforehand to them. Equipment for processing facilities already exists and is commercialised as several companies currently perform in the market.

Once these points are defined, a precise and realistic logistic solution can be established to collect and upgrade the rest raw materials from onboard processing in a profitable manner.

Implications for theory and practice

This research aimed to highlight that there are potential business opportunities in the utilisation of rest raw materials from the fish processing industry. It first presented the difference drivers that are pushing towards better waste management practices and reuse of wasted parts. Then, the background for this utilisation opportunity was established, outlining what materials were available and where, as well as the different applications that can be pursued.

A concept enabling the transport of those materials from the source to the upgrading facility was built upon this background, and the underlying logistics requirements discussed. This research places itself on a general level, hence secondary empirical data was used, and needs further research to be adapted and precised with the use of case studies and companies' involvement.

This research sets the base for the development of a logistic solution that is needed to utilise onboard-generated rest raw materials. It summarises the knowledge on different applications for different parts in the case of groundfish species, and rates them according to unit profit and volumes needed. This can be used by upgrading processors to evaluate which products can bring them the most value regarding their supply volumes. Already existing facilities can evaluate where they stand, and maybe consider building a branch to collect rest raw materials form onboard processing and increase their resources.

The processing industry for onboard frozen white fish needs to be revitalised, as value is lost towards low-cost producers in other countries. This should be done considering those principles, as the proposed concept underlines:

- Market-led production: Supply of high cost products to well-paying and rapidly growing markets for seafood products
- Better quality raw materials: Different handling, automatic slaughtering lines to enhance quality of fish and rest raw materials
- Automated processing plants.

7. CONCLUSIONS

7.1. Summary by key insights

The theoretical background presented the concepts motivating the study. Sustainability concerns urge to reduce waste and require both more efficient processing of the primary product and increased recovery of processing waste. In the meantime, human consumption of healthy seafood is increasing and is coupled with flat or decreasing seafood landings and production.

The scientific research shows that the highest potential for untapped resources lies in onboard processing materials that are for now wasted. In addition, the resources that are used from onshore facilities are turned into low value-added products that do not present incentives high enough to make the vessels keep their rest raw materials. Both untapped and utilised resources could be upgraded to higher-value products, which could eventually offset the costs of keeping the rest raw materials.

A literature study highlighted the different parts that are generated by onboard processing and their possible utilisations. This was summarised in Table 4 and Figure 24. These opportunities for upgrading rest raw materials were sorted according to value creation and volume of resources needed, which was depicted in Figure 25.

The current situation of the Norwegian industry was then diagnosed, which demonstrated that most of the current applications are situated at the base of the pyramid and bring low value for the producers.

Considering these highlights, a conceptual solution was proposed, consisting of a collector boat that plays the role of a shuttle between the fishing ships and the processing facility onshore. This solution was not considered in the literature research beforehand, although the research has been on-going for several years. In order to be cost-efficient, this solution would need an upgrade in rest raw materials' utilisation. Upgrading the utilisation of rest raw materials leads to stricter logistics requirements that were discussed in Chapter 5. Key steps to focus on are sorting operations at the source and high-quality maintenance. High uncertainties aroused in the discussion on logistics requirements, in particular with regards to onboard automated processes and transhipment procedures.

Those uncertainties were due to missing information in the secondary empirical data and require further research in collaboration with both fishing and processing companies.

7.2. Summary of contributions and achievement of objectives

- *RQ1*

The first objective of the study was to describe the different types of materials that are generated by the fish processing industry and was addressed through RQ1.

The different types of rest raw materials were described in Section 4.2 and were linked to the type of production processes that are onboard fishing vessels. The description took the scope into account and sorted the literature accordingly, knowing that far more rest raw materials can be produced from other species of fish or seafood like crustaceans especially.

- *RQ2*

The potential uses for the different rest raw materials were described in Section 4.3. They were also linked to the scope and the species in focus, and do not comprise applications from other types of fish or seafood.

- *RQ3*

Based upon the answers to RQ1 and RQ2, a concept was proposed to increase the utilisation of rest raw materials from onboard processing. The different actors of the new stream were described, together with their roles, potential business opportunities and logistics challenges. The materials flow was then studied more precisely and logistics issues were highlighted and discussed.

The thesis has answered the primary objectives that were stated in the pre-study report (see Appendix 4: Pre-study report). The types of rest raw materials for the fisheries in focus were presented, as well as their possible application opportunities. A conceptual solution was proposed in order to use those potential resources and the underlying logistics requirements were discussed. Therefore a new way of looking at a known problem was presented and discussed.

There has been much research in the past decades with regard to possible applications for rest raw materials, but there is work left on logistics solutions to bring resources to the processing facility. Several gaps and uncertainties were raised, and require further research in collaboration with the industry in order to be answered.

7.3. Suggestions for further research

The need for further research has been mentioned in Chapter 6. As said before, this thesis lays the foundations for further empirical research. A conceptual solution to a practical problem is proposed and issues are raised and discussed. Additional research in collaboration with companies from both fisheries and processing industries should provide more material to develop and evaluate the solution in relation with different subjects, among them:

- Develop automated processes for onboard separation and sorting of rest raw materials
- Describe transhipment procedures maintaining the cold chain and quality of rest raw materials
- Evaluate the costs and profits involved in the solution
- Evaluate investment costs for processors especially, as technological feasibility does not necessarily translate to economic feasibility
- Evaluate the environmental impact of the co-stream

7.4. Concluding remarks

Upgrading the utilisation of rest raw materials and increasing the utilisation efficiency of the processing waste could bring back value-adding activities in Norway, activities that are currently lost as exports of frozen whole fish are increasing towards low-cost production in foreign countries. In addition, the nutritional value of Norwegian fish products is recognised and its brand image should be further used. Exports of codfish have reached a peak in this first quarter of 2015, demonstrating this influence.

In addition, it is likely that the legislation related to returning discards to the sea will be much more restrictive in the mean term, and will force fishing vessels to unload those discards in ports. In this context, the implementation of logistics means to allow high-value upgrading, which aim to reduce costs and produce benefits, should be particularly attractive.

It is important that rest raw materials from fish processing are recognised for their own value and interesting properties, and can be upgraded in various industries with differing added value, from agriculture to biotechnologies. The future of fish rest raw materials does not constitute however the priority for processors and fishermen. The fishing industry has to deal with high structural changes, which impacts on volumes and management of rest raw materials. Landings are decreasing but production volumes are increasing; international trade is increasing as well, and processors are not necessarily situated close to primary production.

The upgrade of rest raw materials from the fish industry was studied in this thesis. However, other opportunities related to different food sectors were not looked at. There might be opportunities for processors to combine the upgrading of different sources in the food industry, and not entirely the fishing sector. That might allow focusing on a more local scale and reducing the environmental impact of both waste and transportation.

Considering the trends of sustainable development, food waste reduction and material recycling and recovery, it is likely that the theme of this research will remain important in the years to come.

8. REFERENCES

Adler, S., Honkapää, K., Saarela, M., Slizyte, R., Sterten, H., Vikman, M. & Løes, A.-K. 2014. Utilisation of co-streams in the Norwegian food processing industry - A multiple case study. The Research Council of Norway.

Alonso, A. A., Antelo, L. T., Otero-Muras, I. & Pérez-Gálvez, R. 2010. Contributing to fisheries sustainability by making the best possible use of their resources: the BEFAIR initiative. *Trends in food science & technology,* 21**,** 569-578.

Anica-Popa, I. 2012. Food Traceability Systems and Information Sharing in Food Supply Chain. *Natural Resources Defense Council Issue Paper,* 7**,** 749-758.

Arason, S. 1994. *Production of fish silage*, Springer.

Arason, S. 2003. Utilization of fish byproducts in Iceland. *Advances in seafood byproducts***,** 47-66.

Arason, S., Karlsdottir, M., Valsdottir, T., Slizyte, R., Rustad, T., Falch, E., Eysturskard, J. & Jakobsen, G. 2010. Maximum resource utilisation-value added fish by-products.

Archer, M., Watson, R. & Denton, J. W. 2001. Fish waste production in the UK Sea Fish Industry Authority. *Seafish report No***,** 1-55.

Arvanitoyannis, I. S. & Kassaveti, A. 2008. Fish industry waste: treatments, environmental impacts, current and potential uses. *International Journal of Food Science & Technology,* 43**,** 726-745.

Arvanitoyannis, I. S. & Tserkezou, P. 2014. Fish Waste Management. *Seafood Processing.* John Wiley & Sons, Ltd.

Baldwin, C. 2009. Introduction. *Sustainability in the Food Industry.* A John Wiley & Sons, Ltd.

BE-FAIR Project. 2006. Good practice manual for recovery, handling and classification of discards and by-products on fishing fleets and fish auctions.

BE-FAIR Report. 2006. Good practice manual for recovery, handling and classification of discards and by-products on fishing fleets and fish auctions. Instituto de Investigaciones Marinas.

BE-FAIR Report. 2007. Report on the alternative management procedures of storage and pre-treatment for discards and by-products on board.

Biotecmar. Technical and economic feasibility of a marine by-products value chain: fish collagen and hydrolysates. *In:* CETMAR, ed., October 14th, 2011 2011 Plouzané.

Blanco, M., Sotelo, C. G., Chapela, M. J. & Pérez-Martín, R. I. 2007. Towards sustainable and efficient use of fishery resources: present and future trends. *Trends in Food Science & Technology,* 18**,** 29-36.

Bledsoe, G. E., Bledsoe, C. D. & Rasco, B. 2003. Caviars and Fish Roe Products. *Critical Reviews in Food Science and Nutrition,* 43**,** 317-356.

Bluhm, B. A. & Bechtel, P. J. The potential fate and effects of seafood processing wastes dumped at sea: a review. In Advances in Seafood Byproducts 2002, Conference Proceedings. University of Alaska Sea Grant College Program (publisher), Fairbanks, Alaska, 2003. 121-140.

Borderías, A. J. & Sánchez Alonso, I. 2011. First processing steps and the quality of wild and farmed fish. *Journal of food science,* 76**,** R1-R5.

Bosona, T. & Gebresenbet, G. 2013. Food traceability as an integral part of logistics management in food and agricultural supply chain. *Food Control,* 33**,** 32-48.

Cato, J. C. 1998. Seafood Safety - Economics of Hazard Analysis and Critical Control Point (HACCP) programmes. *FAO Fisheries Technical Paper 381*.

Cherrett, T., Maynard, S., McLeod, F. & Hickford, A. 2010. Reverse logistics for the management of waste. *Green Logistics: Improving the Environmental Sustainability of Logistics.* Kogan Page Limited London.

Christopher, M. 2011. *Logistics & supply chain management,* London, Financial Times Prentice Hall.

COWI Consulting Engineers and Planners, UNEP & Danish Environmental Protection Agency. 2000. Cleaner production assessment in fish processing. Paris: United Nations Environment Programme (UNEP). Available: http://www.unep.fr/shared/publications/pdf/2481-CPfish.pdf [Accessed March 24, 2015].

De Brito, M. P. & Dekker, R. 2003. A framework for reverse logistics. Rotterdam: Erasmus University Rotterdam. Available: http://papers.ssrn.com/sol3/Papers.cfm?abstract_id=423654 [Accessed March 11, 2015].

De Silva, S. S. & Turchini, G. M. 2008. Towards understanding the impacts of the pet food industry on world fish and seafood supplies. *Journal of agricultural and environmental ethics,* 21**,** 459-467.

Digre, H. Automatic fish handling system onboard. *In:* SINTEF FISHERIES AND AQUACULTURE, N., ed. French-Norwegian Marine Seminar, 2013 Bergen.

Digre, H., Skjøndal Bar, E. M., Mathiassen, J. R., Standal, D., Grimsmo, L., Henriksen, K., Romsdal, A. & Asche, F. 2014. Lønnsom foredling av sjømat i Norge. Med fokus på teknologiutvikling og økt automatisering (Profitable processing of seafood in Norway. Focusing on developing technology and increased automation). Trondheim: SINTEF Fiskeri og havbruk AS. Available: https://http://www.regjeringen.no/contentassets/00b7a7a3ebc141fdb9d62fbdf2ca9ea6/rapport_sintef_nou.pdf [Accessed April 14, 2015].

Dijkema, G. P. J., Reuter, M. A. & Verhoef, E. V. 2000. A new paradigm for waste management. *Waste management,* 20**,** 633-638.

Donnelly, K. A. M. & Olsen, P. 2012. Catch to landing traceability and the effects of implementation – A case study from the Norwegian white fish sector. *Food Control,* 27**,** 228-233.

Engelseth, P. 2009. Food product traceability and supply network integration. *J. Bus. Ind. Mark.,* 24**,** 421-430.

European Commission. 2015. *Discarding and the landing obligation* [Online]. Available: http://ec.europa.eu/fisheries/cfp/fishing_rules/discards/index_en.htm [Accessed April 27, 2015].

Falch, E., Sandbakk, M., Aursand, M. & Shahidi, F. 2007. On-board handling of marine by-products to prevent microbial spoilage, enzymatic reactions and lipid oxidation. *Maximising the value of marine by-products*, 47-64.

FAO. *Fisheries Glossary* [Online]. Available: http://www.fao.org/fi/glossary/default.asp [Accessed February 22, 2015].

FAO. 2001. *Fishing Vessel types* [Online]. Rome: FAO Fisheries and Aquaculture Department. Available: http://www.fao.org/fishery/vesseltype/search/en [Accessed March 23, 2015].

FAO. 2011. *Fishery and Aquaculture Country Profiles. Norway (2011). Country Profile Fact Sheets.* [Online]. Rome. Available: http://www.fao.org/fishery/facp/NOR/en - CountrySector-Statistics [Accessed 12 February 2015].

FAO. 2014a. *Food and Agriculture Organization of the United Nations* [Online]. Available: http://www.fao.org/fishery/topic/736/en [Accessed 6. Nov. 2014.

FAO. 2014b. The State of World Fisheries and Aquaculture. Opportunities and Challenges. Rome: Food and Agriculture Organisation of the United Nations. Available: http://www.fao.org/3/a-i3720e.pdf [Accessed March 11, 2015].

FAO Globefish Data Series 2015. World Fish Market at a Glance. April 16, 2015 ed.

FAO Globefish report. 2015a. Fishmeal and Fish Oil Market Report - March 2015. FAO. Available: http://www.globefish.org/ffff.html [Accessed April 17, 2015].

FAO Globefish report. 2015b. Groundfish Market report - April 2015. FAO. Available: http://www.globefish.org/groundfish-march-2015.html [Accessed April 17, 2015].

Farmery, A., Gardner, C., Green, B. S. & Jennings, S. 2014. Managing fisheries for environmental performance: the effects of marine resource decision-making on the footprint of seafood. *Journal of Cleaner Production,* 64**,** 368-376.

FAROS Project. 2013. LIFE Environment Project FAROS. LAYMAN'S REPORT. LIFE. Available: http://ec.europa.eu/environment/life/project/Projects/index.cfm?fuseaction=home.showFile&rep=file&fil=LIFE08_ENV_E_000119_LAYMAN.pdf [Accessed April 15, 2015].

FHF. 2014. Sluttrapport. Råstoffbehandling og kvalitet for marin ingrediensindustri: Forprosjekt (Rest raw materials handling and quality for marien ingredients industry: Pilot project). Available: http://www.fhf.no/prosjektdetaljer/?projectNumber=900949 [Accessed April 14, 2015].

FHF, Volda University College, Møre og Romsdal Fiskarlag, Surofi, Møreforsking, Ålesund videregåended skole & VRI 2013. Korrekt fangstbehandling om bord i fiskefartøy (Correct catch handling on board fishing vessels). Møreforsking AS.

FHL. 2013. Environmental report. Norwegian Seafood Industry. Emphasizing facts and figures from 2012 up to July 2013. Oslo: FHL - Norwegian Seafood Federation. Available: http://fhl.no/wp-content/uploads/2014/04/Environmental_report_2013_EN.pdf.

fisheries.no. 2014. Responsibilities in seafood safety. Available: http://www.fisheries.no/safe_healty_seafood/Ensuring_seafood_safety/Responsibilities-in-seafood-safety/ - .VU8xI2ChI1y [Accessed Mai 10, 2015].

FiskeriDirektoratet. 2009. Status report for 2008: Russian catches of North East artic cod and haddock. Available: http://www.fiskeridir.no/english/fisheries/reports/russian-cod-fishing-transhipment-at-sea [Accessed Mai 30, 2015].

FiskeriDirektoratet. 2014. Økonomiske og biologiske nøkkeltal frå dei norske fiskeria - 2013 / Economic and biological figures from Norwegian fisheries - 2013. Bergen: FiskeriDirektoratet. Available: http://www.fiskeridir.no/english/statistics/norwegian-fisheries/economic-and-biological-key-figures [Accessed February 21, 2015].

FiskeriDirektoratet. 2015. Fiskefartøy og fiskarar, konsesjonar og årlege detakaradgangar 2014

Norwegian fishing vessels, fishermen and licences 2014. Bergen: FiskeriDirektoratet. Available: http://www.fiskeridir.no/english/statistics/norwegian-fisheries/norwegian-fishing-vessels-fishermen-and-licenses [Accessed Mai 11, 2015].

Frederiksen, M. 2002. Quality chain management in fish processing. *Safety and Quality in Fish processing. Cambridge: Woodhead Publishing Ltd*, 289-307.

Garmendia, E., Prellezo, R., Murillas, A., Escapa, M. & Gallastegui, M. 2010. Weak and strong sustainability assessment in fisheries. *Ecological Economics,* 70**,** 96-106.

Gildberg, A. 2002. Enhancing returns from greater utilization. *In:* BREMNER, H. A. (ed.) *Safety and quality issues in fish processing.* Cambridge: Woodhead Publishing Limited and CRC Press LLC.

Gill, T. A. 2000. *Waste from Processing Aquatic Animals and Animal Products: Implications on Aquatic Animal Pathogen Transfer* [Online]. FAO. Available: http://www.fao.org/docrep/003/X9199E/X9199E00.HTM [Accessed February 17, 2015].

Grant, D. B., Trautrims, A. & Wong, C. Y. 2013. Sustainable Logistics and Supply Chain Management: principles and practices for sustainable operations and management. London, UK: Kogan Page.

Gullestad, P., Blom, G., Bakke, G. & Bogstad, B. 2015. The "Discard Ban Package": Experiences in efforts to improve the exploitation patterns in Norwegian fisheries. *Marine Policy,* 54**,** 1-9.

Gustavsson, J., Cederberg, C., Sonesson, U., Van Otterdijk, R. & Meybeck, A. 2011. *Global food losses and food waste: extent, causes and prevention*, FAO Rome.

Hall, G. M. 2010. Introduction: Challenges to the Fish-Processing Industry in a Resource-Starved World. *Fish Processing.* Wiley-Blackwell.

Hall, G. M. & Köse, S. 2013. Fish Processing Installations: Sustainable Operation. *Seafood Processing: Technology, Quality and Safety***,** 311-342.

Hermansen, Ø., Isaksen, J. R. & Dreyer, B. 2012. Challenging spatial and seasonal distribution of fish landings—Experiences from vertically integrated trawlers and delivery obligations in Norway. *Marine Policy,* 36**,** 206-213.

Huang, G. Q., Lau, J. S. K. & Mak, K. L. 2003. The impacts of sharing production information on supply chain dynamics: a review of the literature. *International Journal of Production Research,* 41**,** 1483-1517.

Hyman, M. 2013. Guidelines for National Waste Management Strategies. Moving from Challenges to Opportunities. UNITAR. Available: http://www.unep.org/ietc/Portals/136/Publications/Waste Management/UNEP NWMS English.pdf [Accessed Mai 30, 2015].

I Thorarinsdottir, R., Jokumsen, A., Thrandur Björnsson, B. & Torrissen, O. 2011. Local raw materials for production of fish feed for aquaculture. Copenhagen: Copenhagen: Nordic Council of Ministers.

Institute of Marine Research. 2014. *The Barents Sea Ecosystem* [Online]. Available: http://www.imr.no/temasider/havomrader_og_okosystem/barentshavet/en [Accessed March 9, 2015].

Ismond, A. 2002. The Impact of Food Safety and Competitive Markets on Byproduct Recovery Strategies. *In:* BECHTEL, P. J. (ed.) *Advances in Seafood Byproducts: 2002 Conference Proceedings.* Fairbanks, Alaska, USA: Alaska Sea Grant College Program.

Jayathilakan, K., Sultana, K., Radhakrishna, K. & Bawa, A. S. 2012. Utilization of byproducts and waste materials from meat, poultry and fish processing industries: a review. *Journal of food science and technology,* 49**,** 278-293.

Kaipia, R., Dukovska-Popovska, I. & Loikkanen, L. 2013. Creating sustainable fresh food supply chains through waste reduction. *International Journal of Physical Distribution & Logistics Management,* 43**,** 262-276.

Kantor, L. S., Lipton, K., Manchester, A. & Oliveira, V. 1997. Estimating and addressing America's food losses. *Food Review,* 20**,** 2-12.

Karlsson, C. 2009. Researching operations management. *In:* KARLSSON, C. (ed.). New York: Routledge.

Kinobe, J. R., Gebresenbet, G. & Vinnerås, B. 2012. Reverse Logistics Related to Waste Management with Emphasis on Developing Countries-A Review Paper. *Journal of Environmental Science and Engineering B,* 1**,** 1104-1118.

Kose, S. 2010. On‐board Fish Processing. *Fish Processing: Sustainability and New Opportunities***,** 167-206.

Kristbergsson, K. & Arason, S. 2007. Utilization of by-products in the fish industry. *Utilization of by-products and treatment of waste in the food industry.* Springer.

Larsen, T. A. & Dreyer, B. 2012. Norske torsketrålere - Struktur og lønnsomhet (Norwegian cod trawlers - Stucture and profitability). Tromsø: Nofima. Available: http://www.nofima.no/filearchive/Rapport 12-2012.pdf [Accessed Mai 25, 2015].

Larsen, T. A. & Pleym, I. E. 2012. Kartlegging av marint restråstoff i Troms. Tromsø: NOFIMA. Available: http://www.nofima.no/filearchive/Rapport 22-2012.pdf.

Laufenberg, G., Kunz, B. & Nystroem, M. 2003. Transformation of vegetable waste into value added products: (A) the upgrading concept (B) practical implementations. *Bioresource Technology,* 87**,** 167-198.

Lee, H. L. & Whang, S. 2000. Information sharing in a supply chain. *International Journal of Manufacturing Technology and Management,* 1**,** 79-93.

Mangi, S. C. & Catchpole, T. L. 2012. Utilising discards not destined for human consumption in bulk uses. Lowestoft, UK: Centre for Environment, Fisheries and Aquaculture Science. Available: http://www.seafish.org/media/Publications/SR661_Utilising_Discards_bulk_uses.pdf.

Manzini, R. 2012. A top-down approach and a decision support system for the design and management of logistic networks. *Transportation Research Part E: Logistics and Transportation Review,* 48**,** 1185-1204.

Mazik, K., Burdon, D. & Elliott, M. 2005. Seafood-waste disposal at sea - a scientific review. Hull, UK: Institute of Estuarine & Coastal Studies. Available: http://www.seafish.org/media/Publications/FINAL_seafood_waste_disposal_at_sea_report.PDF [Accessed March 13, 2015].

McCoy, M. A. 2007. Regulation of transshipment by the Western and Central Pacific Fisheries Commission: issues and considerations for FFA member countries.

Mehlin, B. & Weitkemper, N. 2012. Kollagen fra fiskeskinn. Forretningsmuligheter innen næringsmidler, kosttilskudd og kosmetikk. (Collagen from fish skin. Business opportunities in foods, dietary supplements and cosmetics.). Trondheim: RUBIN.

Mena, C., Adenso-Diaz, B. & Yurt, O. 2011. The causes of food waste in the supplier–retailer interface: Evidences from the UK and Spain. *Resources, Conservation and Recycling,* 55**,** 648-658.

Menon, V. V. & Lele, S. S. 2015. Nutraceuticals and Bioactive Compounds from Seafood Processing Waste. *In:* KIM, S. K. (ed.) *Springer Handbook of Marine Biotechnology.* Busan, Korea: Springer.

Morrissey, M. & DeWitt, C. 2013. Value‐added Seafood. *Seafood Processing: Technology, Quality and Safety***,** 343-358.

Murugan, K., Chandrasekaran, S. V., Karthikeyan, P., Al-Sohaibani, S. & Chandrasekaran, M. 2013. *Current state of the art of food processing by products*, CRC Press: Boca Raton, FL.

Nges, I. A., Mbatia, B. & Björnsson, L. 2012. Improved utilization of fish waste by anaerobic digestion following omega-3 fatty acids extraction. *Journal of Environmental Management,* 110**,** 159-165.

Nikolaou, I. E., Evangelinos, K. I. & Allan, S. 2013. A reverse logistics social responsibility evaluation framework based on the triple bottom line approach. *Journal of Cleaner Production,* 56**,** 173-184.

Nissen, H. 2003. Trends in the utilization and production of seafood byproducts. *In:* BECHTEL, P. J. (ed.) *Advances in seafood byproducts 2002 Conference Proceedings.* Fairbanks, Alaska: Alaska Sea Grant College Program.

Norwegian Commercial and Service Enterprises, The Swedish Chambers of Commerce & Finpartnership. 2009. Market Report. Focus on the Nordic Market. Fresh Fruit and Vegetables. Available: http://www.virke.no/omvirke/aboutvirke/International-trade/Documents/MarketReportHSHDIPPSCCFreshFruitNordicMarket.pdf [Accessed November 26, 2014].

Norwegian Seafood Council (NSC). 2013. A report on sustainable Norwegian seafood. Tromsø: Norwegian Seafood Council. Available: http://viewer.zmags.com/publication/0e268868 - /0e268868/1 [Accessed March 22, 2015].

Norwegian Seafood Council (NSC). n.d. All time record for Norwegian codfish exports in 2014. Available: http://en.seafood.no/News-and-media/News-archive/Press-releases/All-time-record-for-Norwegian-codfish-exports-in-2014 [Accessed Mai 4, 2015].

Olafsen, T., Richardsen, R., Nystøyl, R., Strandheim, G. & Kosmo, J. P. 2014. Analysis of marine by-products 2013. Tromsø: SINTEF Fisheries and Aquaculture, Norway. Available: http://www.kontali.no/%5Cpublic_files%5Cdocs%5CAnalysis_of_marine_by-products_2013_Summary_English.pdf [Accessed March 3, 2015].

Olafsen, T., Winther, U., Olsen, Y. & Skjermo, J. 2012. Value created from productive oceans in 2050. SINTEF Fisheries and Aquaculture, Norway. Available: https://http://www.sintef.no/contentassets/f025260af6b8435394eced5e03939e11/value-created-from-productive-oceans-in-2050.pdf [Accessed March 24, 2015].

Olorunniwo, F. & Li, X. 2010. Information sharing and collaboration practices in reverse logistics. *Supply Chain Manag.,* 15**,** 454-462.

Olsen, J. A. 1990. *Noen samfunnsøkonomiske vurderinger av ombordproduksjon,* Tromsø, Fiskeriteknologisk forskningsinstitutt.

Olsen, R. L., Toppe, J. & Karunasagar, I. 2014. Challenges and realistic opportunities in the use of by-products from processing of fish and shellfish. *Trends in Food Science & Technology,* 36**,** 144-151.

Parfitt, J., Barthel, M. & Macnaughton, S. 2010. Food waste within food supply chains: quantification and potential for change to 2050. *Philosophical Transactions of the Royal Society B: Biological Sciences,* 365**,** 3065-3081.

Penven, A. 2014. *La gestion des ressources et des territoires: Application à la mise en oeuvre de projets de valorisation de sous-produits du poisson. (Management of resources and land: Application to the implementation of upgrading projects for fish by-products).* PhD degree, Université de Nantes.

Penven, A., Gálvez, R. P. & Bergé, J.-P. 2013. By-products from Fish Processing: Focus on French Industry. *Utilization of Fish Waste***,** 1.

Pierre, J. P., Abraham, E. R., Richard, Y., Cleal, J. & Middleton, D. A. J. 2012. Controlling trawler waste discharge to reduce seabird mortality. *Fisheries Research,* 131–133**,** 30-38.

Prajogo, D. & Olhager, J. 2012. Supply chain integration and performance: The effects of long-term relationships, information technology and sharing, and logistics integration. *International Journal of Production Economics,* 135**,** 514-522.

Rajasekar, S., Philominathan, P. & Chinnathambi, V. 2006. Research Methodology.

Ramsden, N. 2014. Norway's whitefish industry wasting potential $540m in by-products. *Undercurrentnews*.

Romsdal, A., Thomassen, M. K., Dreyer, H. C. & Strandhagen, J. O. Fresh food supply chains; characteristics and supply chain requirements. 18th International Annual EurOMA Conference. Cambridge University, Cambridge, 2011.

RUBIN. 2012. Available: http://rubin.no/index.php/en/ [Accessed February 28, 2015].

Rustad, T., Storrø, I. & Slizyte, R. 2011. Possibilities for the utilisation of marine by‐products. *International Journal of Food Science & Technology,* 46**,** 2001-2014.

Sævaldsson, H. n.d. *Markets: Africa. Information centre of the Icelandic Ministry of Fisheries and Agriculture.* [Online]. Reykjavík: Ministry of Fisheries and Agriculture. Available: http://www.fisheries.is/economy/markets/Africa/ [Accessed February 27, 2015].

Sandbakk, M. 2002. Handling of by-products from cod-fish - a state of the art report from selected countries. Trondheim: SINTEF Fisheries and Aquaculture. [Accessed February 28, 2015].

Sandberg, E. 2007. Logistics collaboration in supply chains: practice vs. theory. *The International Journal of Logistics Management,* 18**,** 274-293.

Searchinger, T., Hanson, C., Ranganathan, J., Lipinski, B., Waite, R., Winterbottom, R. & Dinshaw, A. 2013. Creating a Sustainable Food Future. World Resources Institute (WRI). Available: http://www.wri.org/sites/default/files/wri13_report_4c_wrr_online.pdf [Accessed March 29, 2015].

Shepherd, C. J. & Jackson, A. J. 2013. Global fishmeal and fish‐oil supply: inputs, outputs and marketsa. *Journal of fish biology,* 83**,** 1046-1066.

Sigfusson, T. Fish Waste for Profit. Icelandic Fisheries Conference, 2014 Kópavogur.

Sigholt, T., Erikson, U., Rustad, T., Johansen, S., Nordtvedt, T. S. & Seland, A. 1997. Handling Stress and Storage Temperature Affect Meat Quality of Farmed‐raised Atlantic Salmon (Salmo Salar). *Journal of Food Science,* 62**,** 898-905.

Sigurdsson, F., Pedersen, J., Blakstad, F., Gjerde, B. & Grønnevet, L. 2014. Fryst hvitfisk restråstoff: Fra havfiskeflåten til marine ingredienser (Frozen groundfish rest raw materials: From the fishing fleet to marine ingredients). Trondheim: FHF. Available: http://www.fhf.no/prosjektdetaljer/?projectNumber=900858 [Accessed April 14, 2015].

Simatupang, T. M. & Sridharan, R. 2002. The Collaborative Supply Chain. *The International Journal of Logistics Management,* 13**,** 15-30.

SINTEF. 2015. Extracting useful raw materials from fish and plant waste. *ScienceDaily*.

Søvik, S. L. 2005. *Characterisation of enzymatic activities in by-products from cod species. Effect of species, season and fishing ground.* Doktor Ingeniør Doctoral Thesis, NTNU.

SSB. 2015. *Fisheries, 2014, preliminary figures* [Online]. Available: http://ssb.no/en/jord-skog-jakt-og-fiskeri/statistikker/fiskeri [Accessed 12 February 2015].

Standal, D. 2008. The rise and fall of factory trawlers: An eclectic approach. *Marine Policy,* 32**,** 326-332.

Tatterson, I. N. & Windsor, M. L. 2001. *Fish Silage* [Online]. FAO. Available: http://www.fao.org/wairdocs/tan/x5937e/x5937e00.htm - Contents [Accessed February 17, 2015].

Trondsen, T. 1997. Value-added fresh seafood: Barriers to growth. *Journal of International Food and Agribusiness Marketing,* 8**,** 55-78.

Trondsen, T. 2012. Value chains, business conventions, and market adaptation: A comparative analysis of Norwegian and Icelandic fish exports. *The Canadian Geographer/Le Géographe canadien,* 56**,** 459-473.

Undercurrentnews.com. 2015. April a record high month for Norwegian codfish exports. Available: http://www.undercurrentnews.com/2015/05/06/april-a-record-high-month-for-norwegian-codfish-exports/ [Accessed May 6, 2015].

Vlachos, I. P. 2014. Reverse food logistics during the product life cycle. *International Journal of Integrated Supply Management,* 9**,** 49-83.

Wahren, R. & Mehlin, B. 2011. Internasjonal markeds- og industrianalyse for marine ingredienser. Oppdatering av november 2011. (International market and industry analysis for marine ingredients. Update from November 2011). Trondheim: RUBIN. Available: http://www.rubin.no/images/files/documents/4657-210_internasjonal_markedsanalyse.pdf [Accessed Mai 12, 2015].

Wognum, P. M. N., Bremmers, H., Trienekens, J. H., van der Vorst, J. G. A. J. & Bloemhof, J. M. 2011. Systems for sustainability and transparency of food supply chains–Current status and challenges. *Advanced Engineering Informatics,* 25**,** 65-76.

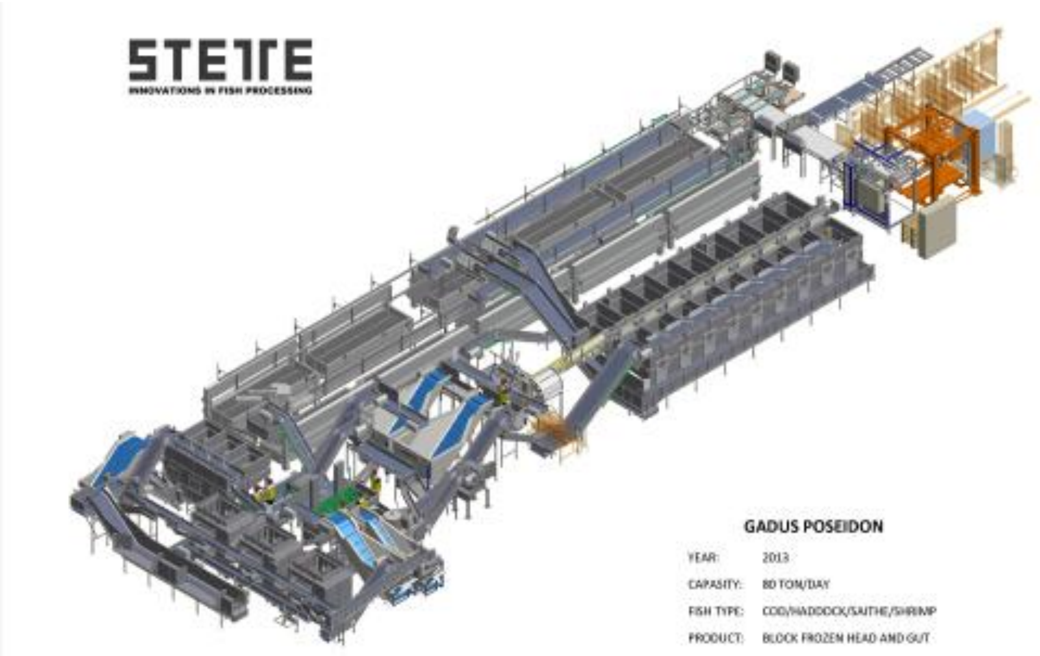
World Commission on Environment and Development 1987. *Our Common Future*, Oxford University Press.

Yin, R. K. 2003. Case study research design and methods third edition. *Applied social research methods series,* 5.

APPENDICES

Appendix 1: Gadus Poseidon

Online virtual visit: http://invisual.no/01stette/



Appendix 2: Transhipment log sheet

Transhipment Logsheet

FLAG STATE OF THE OFFLOADING FISHING VESSEL	
DATE OF THE AUTHORISATION ISSUED BY THE FLAG STATE OF THE OFFLOADING FISHING VESSEL	
DATE OF SUBMISSION OF AUTHORISATION TO THE SPRFMO EXECUTIVE SECRETARIAT	

FLAG STATE OF THE RECEIVING FISHING VESSEL	
DATE OF THE AUTHORISATION ISSUED BY THE FLAG STATE OF THE RECEIVING FISHING VESSEL	
DATE OF SUBMISSION OF AUTHORISATION TO THE SPRFMO EXECUTIVE SECRETARIAT	

PORT STATE (IF APPLICABLE)	
DATE OF THE AUTHORISATION ISSUED BY THE PORT STATE (IF APPLICABLE)	
DATE OF SUBMISSION OF AUTHORISATION TO THE SPRFMO EXECUTIVE SECRETARIAT (IF APPLICABLE)	

I. Details of the offloading fishing vessel

Name of vessel	
Registration number	
Radio call sign	
Vessel flag State	
IMO number / IHS Fairplay number (if allocated)	
Master of transhiping vessel	

II. Details of the receiving fishing vessel

Name of vessel	
Registration number	
Radio call sign	
Vessel flag State	
IMO number / IHS Fairplay number (if allocated)	
Master of transhiping vessel	

III. Transhipment operation

Date and time of commencement of transhipment (UTC)					
Date and time of completion of transhipment (UTC)					
If transhipment at sea: Position (nearest 1/10th degree) at commencement of transhipment If transhipment in port: Name and country of port					
If transhipment at sea: Position (nearest 1/10th degree) at completion of transhipment					
Description of product type by species (e.g. whole, frozen fish in 20 kg cartons)					
Species		Product type			
Species		Product type			
Species		Product type			
Species		Product type			
Species		Product type			
Species		Product type			
Number of cartons, net weight (kg) of product, by species.					
Species		Cartons		Net weight	
Species		Cartons		Net weight	
Species		Cartons		Net weight	
Species		Cartons		Net weight	
Species		Cartons		Net weight	
Species		Cartons		Net weight	
Total net weight of product transhipped (kg)					
Hold numbers in reefer vessel in which product is stowed					
Destination port and country of receiving fishing vessel					
Arrival date estimate					
Landing date estimate					

IV. Observations (if applicable)

V. Verification

Name of observer	
Authority	
Signature and stamp	

Appendix 3: Authors and themes

Authors	Sustainability	Reverse logistics	Traceability	Fish & RRM processing	Case study RRM utilisation	Research project	Particular properties of RRM
Adler et al. (2014)					✓		
Alonso et al. (2010)						✓	
Arason (2003)					✓		
Biotecmar (2011)							✓
Bledsoe et al. (2003)							
Arason et al. (2010)							✓
Archer et al. (2001)							✓
Arvanitoyannis et al. (2008)							✓
Blanco et al. (2007)							✓
Baldwin (2009)	✓						
Borderias et al. (2011)				✓			
Bosona et al. (2013)			✓				
Cherett et al. (2010)		✓					
De Brito et al. (2003)		✓					
Digre et al. (2014)				✓			
Donnelly et al. (2012)			✓				
Engelseth (2009)			✓				
Farmery et al. (2014)	✓						
FHF (2014)							✓
Frederiksen (2002)				✓			
Garmendia et al. (2010)	✓						

Authors	Sustainability	Reverse logistics	Traceability	Fish & RRM processing	Case study RRM utilisation	Research project	Particular properties of RRM
Gildberg (2002)				✓			
Hall (2010)				✓			
Kaipia et al. (2012)	✓						
Kinobe et al. (2012)		✓					
Kose (2010)				✓			
Mehlin et al. (2012)							✓
Menon et al. (2015)							✓
Murugan et al. (2013)				✓			
Nikolaou et al. (2013)		✓					
Olafsen et al. (2012)					✓		
Penven et al. (2013)					✓		
Pierre et al. (2012)	✓						
Rustad et al. (2011)							✓
Sandbakk (2002)					✓		
Searchinger et al. (2013)	✓						
Sigurdsson et al. (2014)					✓		
Vlachos (2014)		✓					
Wahren et al. (2011)					✓		
Wognum et al. (2011)	✓		✓				

Appendix 4: Pre-study report

Faculty of Engineering Science and Technology
Department of Production and Quality Engineering

Pre-study report

Utilisation of rest raw materials from the fish industry: business opportunities and logistics requirements

Laura Jouvenot

Responsible supervisors: Anita Romsdal
Heidi C. Dreyer

Spring 2015
Master thesis

NTNU
Norwegian University of Science and Technology

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Background

The increasing world population, getting both wealthier and urbanized, is putting pressure on natural resources and sustainable development. First expected to be 9 billion people on Earth in 2050, the new UN projection says than instead of levelling off, the world population will continue to grow beyond 2100. Therefore, food supply chains are facing a major challenge, considering that food is a human necessity and has important requirements of natural resources. Moreover, wealthier population requires more fresh food products, which is even more challenging considering the short shelf life of fresh products (Parfitt et al., 2010). There is therefore a need for efficient supply systems. Especially, waste, loss or spoilage of food has been gaining increased attention in the last decade. Over the whole supply chain, from production to the retail shelf and consumer's fridge, the average loss of food products is estimated to be 35 per cent (Parfitt et al., 2010; Gustavsson et al., 2011).

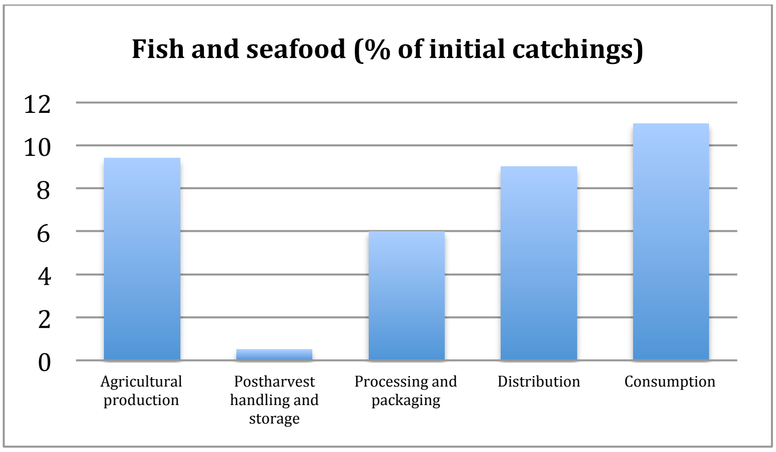
Moreover, the food industry is facing rising costs and often decreasing availability of raw materials together with environmental pollution concerns (Laufenberg et al., 2003). Consequently there is a considerable emphasis on the recycling, recovery and upgrading of parts that were considered as waste, but which often could be upgraded to higher value and useful products, or raw materials for other industries (Laufenberg et al., 2003; Penven et al., 2013). This products include livestock feeds, biodiesel (fuel made from vegetable oils and animal fat), adhesives and solvent derived from citrus oils, pharmaceuticals made from cow's and goat's milk, or juice products and vinegar made from apple peels (Kantor et al., 1997). Moreover, valuable components such as fish oil, proteins, collagen and gelatine, enzymes and minerals can be obtained from the rest raw materials of the fish industry.

Regarding terminology, although there is no agreed definition, the term "rest raw material" will be used to refer to parts that are not regarded as ordinary saleable products (fillet for example), but which can be recycled after treatment (Rustad et al., 2011). The term "by-product" can also used with the same meaning. Rest raw materials can be differentiated from waste, which refers to products that cannot be used for feed or value-added products (Rustad et al., 2011).

If we look at the fish industry in particular, considerable quantities of rest raw materials are generated by traditional fishing practices (FHL, 2013). Marine by-products usually refer to viscera, heads, bones, skin, bycatch and fish that are damaged or not suitable for human consumption (Rustad et al., 2011). Seafood processing discards and rest raw materials can account for up to approximately three quarters of the total weight of the catch, consequently raising economical and environmental issues (Rustad et al., 2011). Especially, an increasing number of vessels is processing captures on-board, thus generating important quantities of subproducts, such as heads, viscera, or skins. These subproducts are perishable and need to be stabilized quickly by freezing for example. However, only a few parts have enough commercial value to be sold on land, such as livers from monkfish; consequently, most of the by-products generated on-board is usually thrown back at sea (Rustad et al., 2011).

Problem description

A fresh food supply chain consists of some typical actors in a linear relationship: primary production for products such as meat, fish, fruits and vegetables, other suppliers for packaging material and equipment for example, then industrial production or processing unit, wholesaler and distributor, and retailers selling the products to consumers (Romsdal et al., 2011). At each stage in the supply chain, the food changes 'ownership' and value is added. On the other hand, different types of rest raw materials are generated along the different stages of food supply chains, from primary production via post-harvest handling and storage, to food processing, distribution, retail and consumption. Most of the rest raw materials are wasted whereas they represent a potential value for the industry.
For example, Gustavsson et al. (2011) estimated the following percentages for the lost products in the European fish supply chain:



Across the seafood industry, up to 66% of the product is discarded and is dumped at sea or goes to landfill, which moreover implies a cost for the company (Archer, 2011). Instead of being thrown away, discarded products could be used for other purposes, for example as inputs to new supply chains.
This is for instance already the case for most the rest raw materials generated from farmed fish; they are fully utilised, in contrast to ocean fisheries with on-board production, where a significant part of the by-products is dumped into the sea after processing (FHL, 2013; Adler et al., 2014; Olafsen et al., 2014). The recovery of by-products is challenging due to their rapid deterioration and they are often discarded into the sea due to inadequate processing facilities (Olsen et al., 2014). Estimations vary as for the quantity of by-products available, but generally agree that the amount of marine by-products is significant and there is a large potential for creating more value-added products.

For now, by-products from fish filleting operations have mostly been used for the production of low-value bulk products such as fishmeal or mince and silage, resulting in low profits for the fish industry. The utilization of such co-streams, for feed or technical applications for example, probably gives a lower rate of return than for food applications, but should still be more profitable than to treat the co-streams as waste. In addition, fish resources are limited, leading to the need to optimize utilization of the catch. Fish provide around 15% of the world's need for animal proteins (Rustad et al., 2011).

In order to successfully utilize fish by-products, retaining the quality of the raw materials is a key factor (Rustad et al, 2011). The methods to do so differ for each by-product, but generally imply that by-products are processed immediately after production in order to ensure a high quality. However, one of the major challenges is the limited space on board, especially for old vessels (Rustad et al., 2011).

Research questions and scope

The study will focus on the fish industry. Indeed, using fish rest raw materials is both challenging and interesting. Fish rest raw materials are constituted of many inedible parts, e.g. bones and skin, which cannot be directly used for human consumption (Adler et al., 2014). However, by-products from the fish industry are regarded as valuable, due to the content of protein with high biological value (Adler et al., 2014).

The study will firstly identify the different types of rest raw materials that arise in the different stages of the fish supply chain, and secondly outline some potential applications for the co-streams. Based on the findings from stage 1 and 2, the study will identify business opportunities associated with creating value from what is currently considered as waste, and discuss the logistics requirements related to the supply chains that are created.
Consequently, the following research questions will be answered:

RQ1: What types of rest raw materials are generated in the fish supply chain?
RQ2: What are the potential uses for the rest raw materials?
RQ3: What would be the logistics requirements to the new supply chains?

The key outcomes of the thesis are to estimate the business potential related to the use of rest raw materials from seagoing vessels, together with the identification of logistics solutions required to realise that potential. Finally, it will outline the needs for the sector to put the business in motion.

Since most of the rest raw materials generated in on-shore operations are already used (FHL, 2013; Olafsen et al., 2014), the thesis will focus particularly on fish processed on-board of the large fish vessels, where lies the largest potential for creating more value-added products, and thus will aim to provide conceptual solutions to increase the low utilization efficiency of the rest raw materials. The geographical area will be focused on Norway, and could be extended if data is missing or interesting work has been conducted in another region. However, since regulations vary from a region to another, the largest scope will probably remain in the European Union.

Regarding actors in the traditional fish supply chain, the focus will be on the producers, that is to say the catching and process stages. The utilisation of rest raw materials will then result in the creation of a new supply chain, of which the wholesale, retail and consumer stages will be look at in order for example to study of the customer's interest in rest raw materials, or study their roles and underlying logistics requirements.

In addition, as in all kinds of production, transformation of by-products into commercial products should be market-driven, with a realistic possibility of being sold with an economic margin within a reasonable time period (Olsen et al., 2014). Both regulatory status and future market potential need to be considered, insofar as data can be found.

Finally, regarding the logistics requirements underlying the possible business opportunities, the focus will lie in the appropriate treatment, storage and transport of the rest raw materials in order to retain the quality of the products and ensure safety and hygienic conditions. Thus, requirements for the physical logistics solutions will be investigated.

Methodology

The first part of the thesis will consist in a literature study, in order to appraise the current status of fish rest raw materials' utilisation and the other possible applications.

A primary literature study was conducted in order to investigate the problem and delineate the research scope. Further literature review will be conducted in the same manner. The databases ScienceDirect, ProQuest and Google Scholar will be used for searching literature. The search results will be limited to journal articles, reports, presentation papers, books and doctoral theses. Papers will be selected by relevance and interest considering the titles and the abstracts. After finding the first slot of papers, their references will be reviewed to find additional papers.

The review will be divided into several categories:

- General description of the fish industry, product characteristics for different species and different production methods (aquaculture, small and large fishing vessels, with focus on large trawlers)

- Fish rest raw materials: characteristics, market demand, equipment needed for processing
- Current utilization of by-products for the different production methods and opportunities
- Logistics, treatment, process, transportation: identify the requirements needed to retain quality of fish by-products
- Investigation of the financial potential

Scientific literature will then be used concurrently with empirical data in order to investigate the potential business opportunities and to suggest conceptual solutions related to the utilization of on-board fish rest raw materials. Secondary empirical data will be used from industry reports, from the FAO Fisheries website and the Norwegian website for statistics SSB as a start. This data will be used to support the development of conceptual solutions, as well as to illustrate the challenges raised by the industry. Depending on the development of the study, primary data may be used as well.

References

Adler, S., Honkapää, K., Saarela, M., & Slizyte, R. Utilization of co-streams in the Norwegian food processing industry.

Archer, M. (2001). *Fish waste production in the United Kingdom: the quantities produced and opportunities for better utilization*. Sea Fish Industry Authority.

Galvez, R. P., Berge, J.-P., eds. *Utilization of Fish Waste*. CRC Press, 2013.

Gustavsson, J., Cederberg, C., Sonesson, U., Van Otterdijk, R., & Meybeck, A. (2011). Global food losses and food waste. *Food and Agriculture Organization of the United Nations, Rom*.

Laufenberg, G., Kunz, B., & Nystroem, M. (2003). Transformation of vegetable waste into value added products::(A) the upgrading concept;(B) practical implementations. *Bioresource Technology*, *87*(2), 167-198.

Kantor, L. S., Lipton, K., Manchester, A., & Oliveira, V. (1997). Estimating and addressing America's food losses. *Food Review*, *20*(1), 2-12.

Norwegian Seafood Federation (FHL), 2013. Environmental Report. Norwegian Seafood Industry. Emphasizing facts and figures from 2012 up to July 2013.

Olsen, R.L., Toppe, J., Karunasagar, I. 2014. Trends in Food Science & Technology 36 (2014) pp 144-151. Available at: http://www.iffo.net/node/663 [Accessed 11.02.2015]

Parfitt, J., Barthel, M., & Macnaughton, S. (2010). Food waste within food supply chains: quantification and potential for change to 2050. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *365*(1554), 3065-3081.

Penven, A., Gálvez, R. P., & Bergé, J. P. (2013). By-products from Fish Processing: Focus on French Industry. *Utilization of Fish Waste*, 1.

Rustad, T., Storrø, I., & Slizyte, R. (2011). Possibilities for the utilisation of marine by‐products. *International Journal of Food Science & Technology*, *46*(10), 2001-2014.

Statistics from the Food and Agriculture Organization (FAO) about Norway: http://www.fao.org/fishery/facp/NOR/en#CountrySector-Statistics

Project plan

Tasks

The thesis will consist of five main tasks:

- Identify the different types of rest raw materials
- Outline some potential applications for the co-streams
- Identify potential business opportunities
- Discuss the requirements for the physical logistics solutions
- Develop and discuss a business concept for utilisation of rest raw materials
- Discuss the needs for the sector in order to put the business in motion

Major milestones

Main project milestones are presented in the following table:

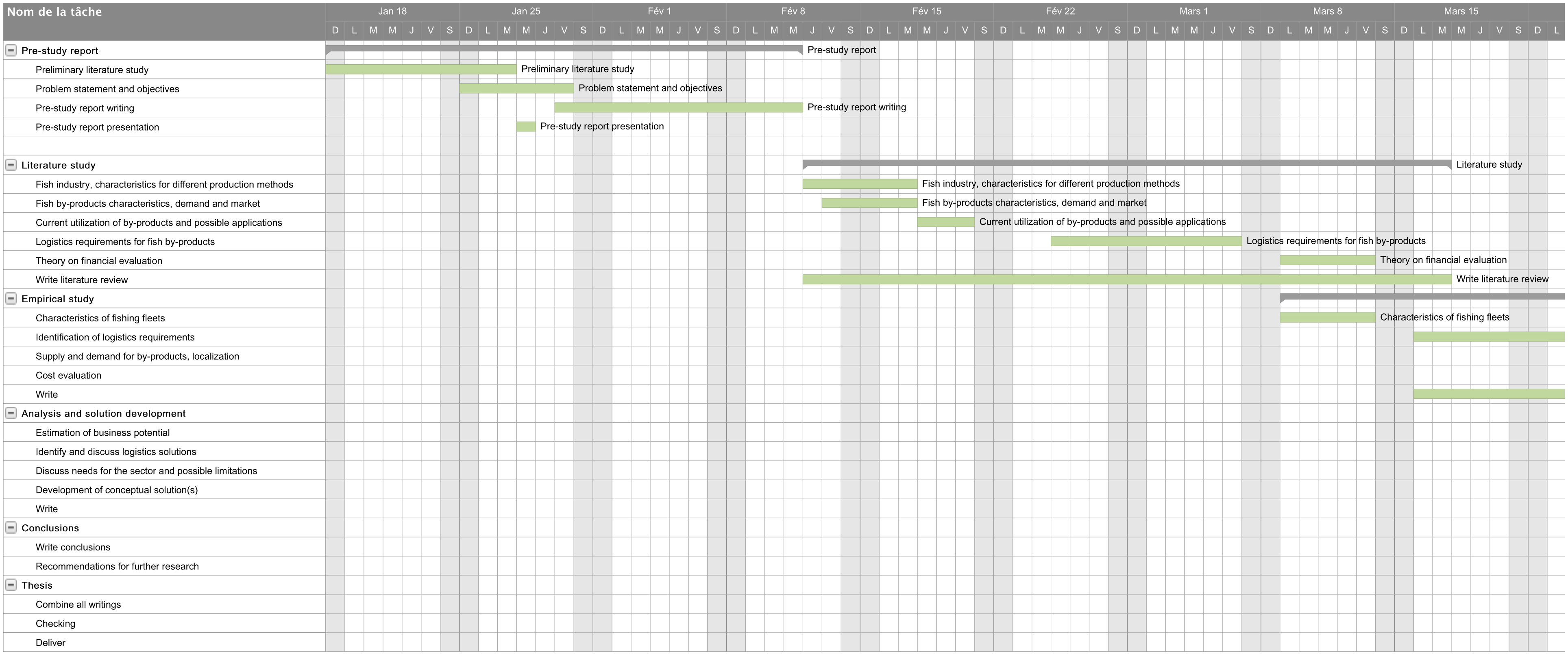
Table 1 - Milestones

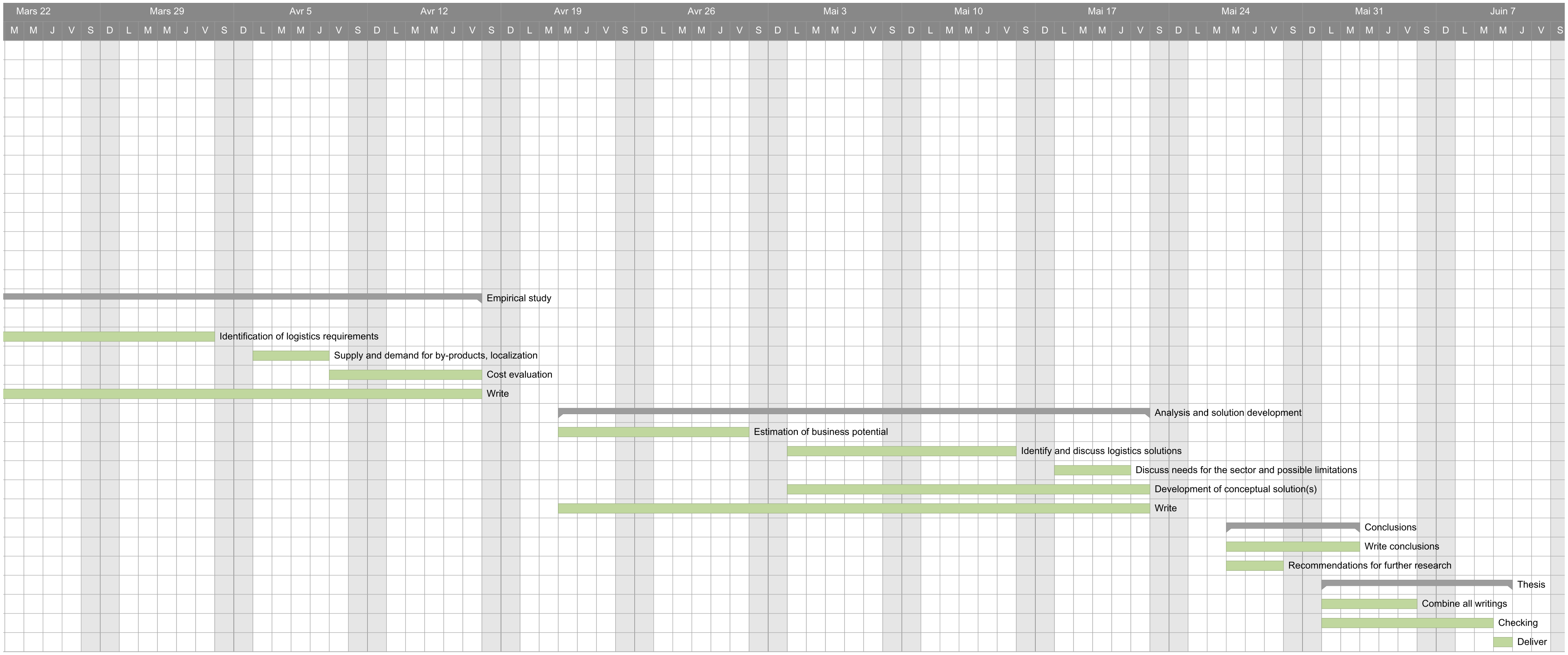
Activity	Date
Thesis starts	January 14th
Presentation of pre-study report	January 28th
Pre-study report submission	February 6th
Progress report submission	April 10th
Final thesis submission	June 10th

The progress of the thesis is documented in the Gantt chart and Work Breakdown Structure (WBS), which can be found in Appendix 1 and 2 correspondingly.

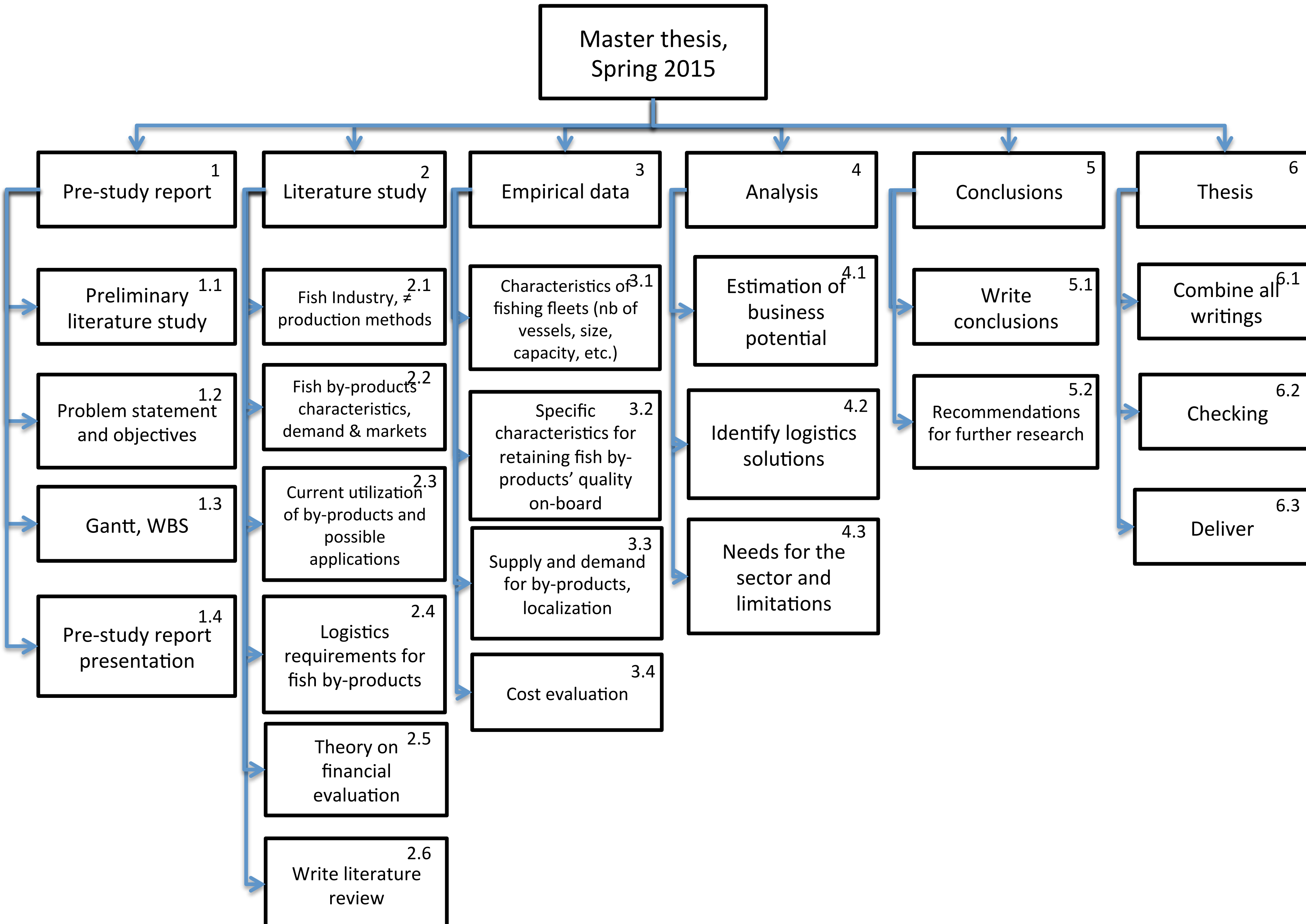
APPENDIX

APPENDIX 1 - Gantt diagram


Nom de la tâche
Jan 18
Jan 25
Fév 1
Fév 8
Fév 15
Fév 22
Mars 1
Mars 8
Mars 15
D L M M J V S
Pre-study report
Preliminary literature study
Problem statement and objectives
Pre-study report writing
Pre-study report presentation
Literature study
Fish industry, characteristics for different production methods
Fish by-products characteristics, demand and market
Current utilization of by-products and possible applications
Logistics requirements for fish by-products
Theory on financial evaluation
Write literature review
Empirical study
Characteristics of fishing fleets
Identification of logistics requirements
Supply and demand for by-products, localization
Cost evaluation
Write
Analysis and solution development
Estimation of business potential
Identify and discuss logistics solutions
Discuss needs for the sector and possible limitations
Development of conceptual solution(s)
Write
Conclusions
Write conclusions
Recommendations for further research
Thesis
Combine all writings
Checking
Deliver


Mars 22
Mars 29
Avr 5
Avr 12
Avr 19
Avr 26
Mai 3
Mai 10
Mai 17
Mai 24
Mai 31
Juin 7
Empirical study
Identification of logistics requirements
Supply and demand for by-products, localization
Cost evaluation
Write
Analysis and solution development
Estimation of business potential
Identify and discuss logistics solutions
Discuss needs for the sector and possible limitations
Development of conceptual solution(s)
Write
Conclusions
Write conclusions
Recommendations for further research
Thesis
Combine all writings
Checking
Deliver

APPENDIX 2 – Work Breakdown Structure


Master thesis, Spring 2015
1
Pre-study report
1.1
Preliminary literature study
1.2
Problem statement and objectives
1.3
Gantt, WBS
1.4
Pre-study report presentation
2
Literature study
2.1
Fish Industry, ≠ production methods
2.2
Fish by-products characteristics, demand & markets
2.3
Current utilization of by-products and possible applications
2.4
Logistics requirements for fish by-products
2.5
Theory on financial evaluation
2.6
Write literature review
3
Empirical data
3.1
Characteristics of fishing fleets (nb of vessels, size, capacity, etc.)
3.2
Specific characteristics for retaining fish by-products' quality on-board
3.3
Supply and demand for by-products, localization
3.4
Cost evaluation
4
Analysis
4.1
Estimation of business potential
4.2
Identify logistics solutions
4.3
Needs for the sector and limitations
5
Conclusions
5.1
Write conclusions
5.2
Recommendations for further research
6
Thesis
6.1
Combine all writings
6.2
Checking
6.3
Deliver

Appendix 5: Progress report

Faculty of Engineering Science and Technology
Department of Production and Quality Engineering

Progress report 10.04.2015

Utilisation of rest raw materials from the fish industry: business opportunities and logistics requirements

Laura Jouvenot

Supervisor: Anita Romsdal

Spring 2015
Master thesis

NTNU
Norwegian University of Science and Technology

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Work description

So far, the work has been focused on establishing the theoretical and empirical backgrounds.

The theoretical background has revealed to be quite challenging to write, as the objectives of the thesis are quite practical and all background information regarding the fish industry is empirical background. The main theoretical issues behind the thesis are sustainability and reverse logistics, with the growing idea that the flow 'backwards' the supply chain is also important, supply chain collaboration.

As for the empirical background, a lot of different aspects can be approached and referred to, while certain information is difficult to access. A general overview of the fishing industry has been done, including fishing vessels types, fish species in focus, description of the fish processing steps, an introduction to the regulations ruling the industry. Then, the composition of the rest raw materials generated by processing was investigated, as well as the outcomes that further processing of those parts can reach.

As for obtaining more information regarding the practical data I would need to improve the precision degree of the research and solution, I sent email to several onshore companies that have developed a business out of the utilization of rest raw materials generated from onshore processing, but they are for now without response. Through the project manager of the EU BE-FAIR project conducted between 2005 and 2008, I managed to obtain some documentation written during their research.

Challenges and difficulties

From the literature study, it appears that most of the raw materials generated during onshore processing are actually utilized and processed into value-added products. The potential in utilizing more rest raw materials lies in the ones generated during onboard processing, as they are almost always thrown back at sea. However, it could be interesting to analyse if the rest raw materials generated onshore are used for "low value" products such as fishmeal or silage, or for higher value products such as gelatine.

Developing a solution to collect and utilize the raw materials generated by onboard processing appears to be rather challenging, due especially to the lack of information on a few key parameters. One of the difficulties is for example to clearly find out how the rest raw materials should be stored and preserved to retain the highest quality, so that they could be transported onshore and further processed there. Another example of information is boat's route and the number of days it stays at sea, its storage capacity and processing rate are parameters I have trouble to find. Also, it is difficult to make a link between the types of boats described in the literature and the ones that are present in the Norwegian fishing fleet. Finally, the fact that the vessels company websites are mostly in Norwegian doesn't help.

The research on utilising the rest raw materials has been on-going for more than a decade and has seen several EU projects focusing on the subject, but still the problem remains. At this point of the research, it seems that the reason could be due to the fishing vessels, which do not have enough incentives to allocate space onboard to "lower-value" products compared to the main products.

However, as the EU legislation is already forbidding discards of by-catch (unintentional capture of non-target species), there is a possibility that in the years to come, rejection of processing waste like heads, guts, and skeletons will also be forbidden. Then, as fishermen will be forced to allocate some of their space to store these parts, a logistic solution in order to minimize this allocated space could be of great value for them.

The main challenge of the study is also that it seems impossible to define a solution that is applicable is all cases, considering the enormous range of fishing boats, fishing nets, methods of processing onboard (from just gutting to the complete filleting factory). I might have to take an example of one type of boat.

Research questions and scope

The study will firstly identify the different types of rest raw materials that arise in the different stages of the fish supply chain, and secondly outline some potential applications for the co-streams. Based on the findings from stage 1 and 2, the study will identify business opportunities associated with creating value from what is currently considered as waste, and discuss the logistics requirements related to the supply chains that are created.

The research questions that were defined at the beginning of the study were:

RQ1: What types of rest raw materials are generated in the fish supply chain?

RQ2: What are the potential uses for the rest raw materials?

RQ3: What would be the logistics requirements to the new supply chains?

Considering the scope, I would like to modify RQ1 to:

RQ1: *What types of rest raw materials are generated in the fish processing industry?*

Indeed, in this thesis I am not looking at the whole fish supply chain, and different types of 'waste' are created along the supply chain, especially at the retail and consumer stage as seen in the project thesis last semester, and I will not look at those types in this research.

I would also like to modify RQ3 into a more precise question regarding the scope I am focusing on:

RQ3: *What would be the logistics requirements for collecting and bring onshore the rest raw materials generated by onboard processing so that they can be further processed into value-added products instead of being thrown back at sea?*

Remaining work

The tasks defined in the beginning of the research were:

- General description of the fish industry, product characteristics for different species and different production methods (aquaculture, small and large fishing vessels, with focus on large trawlers)
- Fish rest raw materials: characteristics, market demand, equipment needed for processing
- Current utilization of by-products for the different production methods and opportunities
- Logistics, treatment, process, transportation: identify the requirements needed to retain quality of fish by-products
- Investigation of the financial potential

The first 3 tasks have been conducted, although the final written version is not finished. Now, the logistic solution should be thought of. It will still imply literature research on different subjects, for example on fishing vessels design and collector boat design, in order to determine if it is feasible to establish a transfer of boxes of containers while still at sea, or if it should go through "stable" stations.

The structure of the solution development part is still quite "undefined", it should be done soon in order to clarify the development of the solution and further work.

Project plan

Tasks

The remaining tasks are:

- Discuss the requirements for the physical logistics solutions
- Develop and discuss a business concept for utilisation of rest raw materials

- Discuss the needs for the sector in order to put the business in motion

Regarding the timetable, the analysis and solution development was supposed to start Week 17. However, the time line was not as lean as described in the first Gantt chart. Theoretical and empirical backgrounds research was more intertwined, and some parts remain to be written.

The first Gantt chart is thus still valid, except that in the time allocated to writing “conclusions”, I would like to add that I should also use it to write the introduction, methodology and summary of the thesis.