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Nergård modern trawler factory

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Optimal conditions for producing high quality whitefish

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"I confirm that this paper up to the standards for the course LOK-2106"

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Abstract

This thesis will explore published scientific articles relating to the research parameters and from three leading institutes for research in Food and Biotech, emphasising optimal quality handling of fishery products; MATÍS from Iceland, NOFIMA and SINTEF from Norway. The idea is to analyse the needs for a trawler factory capable of processing 150 tons of whitefish, live weight, in 24 hours with minimal crew and produce premium quality products. This study will focus on researches that have been done in the past, in Iceland, Norway and EU, concentrating on the following subjects: ideal temperature for white fish (cod in particular), handling of the product during processing, bleeding and washing of the raw material and different freezing methods. The thesis will also take a look at the additional cost of building a high quality production factory compared to the industry standard factory trawler.

Keywords: Temperature, handling, bleeding/washing, freezing, trawler, fish.

Úrdráttur

Þessi lokaritgerð mun skoða ritrýnd vísindaleg gögn sem varða rannsóknina, þar á meðal frá þremur leiðandi stofnunum í rannsóknum á sviði matvæla og líftækni, með áherslur á hámörkun gæða með meðhöndlun á afla, MATÍS frá Íslandi, NOFIMA og SINTEF frá Noregi. Hugmyndin er að greina þarfir vinnslu um borð í togara sem hefur afkastagetu uppá 150 tonn af óslægðum hvítfiski á sólarhring, með lágmarks áhöfn og hámarks gæði á afurðum. Finna rannsóknir sem gerðar hafa verið, bæði á Íslandi, Noregi og í Evrópu, um eftirfarandi viðfangsefni: kjör hitastig fyrir hvítfisk(þorsk sérstaklega), meðferð á vöru í vinnslu, blæðingu og hreinsun á hráefni, mismunandi aðferðir við frystingu. Einnig verður skoðað kostnað við hátækni vinnsuludekk með áherslur á gæði og meðhöndlun á afla, miðað við hefðbundið vinnsludekk í togara.

Lykilorð: Hitastig, meðferð, blæðing/þvottur, frysting, togari, fiskur.

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A helpful reminder: Henry Ford.

“*Of course, it is not the employer who pays wages. He only handles the money. It is the product that pays wages and it is the management that arranges the production so that the product may pay the wages*”

-Henry Ford

Abbreviations

ATP	Adenosine triphosphate is a nucleoside triphosphate used in cells, it transport chemical energy within them and is the main source for most cellular functions (Hattula, 1997).
Chilled tank	A tank that has the purpose of cooling down the product to a temperature approaching that of melting ice.
(EFSA)	European Food Safety Authority
H/G	When a fish is gutted it is opened/cut from the anus up towards the head, then removing the guts and the head.
HACCP	Hazard analysis and critical control points, a system that identifies, evaluates and controls hazards that are significant for food safety.
Line-caught fish	Fish caught by the method of setting a line out into the sea is considered to be top quality because of survivability of fish when it reaches the boat/ship and the minimum strain that the fish has experienced.
Post Rigor	A stage after death, muscles begin to soften and the fish becomes limp again.
Pre Rigor	A stage prior to death.
Rigor Mortis	A stage of death, caused by chemical changes in the muscles after death, causing the fish to stiffen.
Raw materials	Fresh and frozen fish, or their parts that may be utilized to produce fish products intended for human consumption.
Shelf-life	The period during which the product maintains its microbiological and chemical safety and sensory qualities at a specific storage temperature.

Trawl	The net that is used for trawling is called a trawl.
Trawling	A fishing method, to fish or catch with a large net (trawl) dragged along the sea bottom.
Vision grader	A machine developed by OptimarStette that grades/sorts out fish after species (cod, saithe, and haddock) and measures the length of the fish.
(WHO)	World Health onganixation

Table of contents

Table of Figures

1 Introduction

The new ship that Nergård are considering building is a revolution on its own. The main concept is to catch the fish, attach a pump to a cod-end (similar procedure as pelagic trawlers do with their catch), pump it on-board into tanks and keep the fish alive for 6-8 hours. According to the study by Olsen S. T. (2013) there are indications on that the cod has recovered from the stress of being caught 6 hours earlier, thus the cod can be processed to maximize the quality of the fish.

In theory, the factory trawler will be capable of processing 150 tons of whitefish (live weight) in 24 hours with a minimal crew and produce premium quality products. Through the whole design of the ship and processing facilities, everything is aimed to maximize the quality of the fish, with the final goal being to maximize the value of each kilogram that is caught.

This thesis will explore published scientific articles from researchers and three main governmentally owned institutes for research in Food and Biotech, with emphasis on optimal quality handling of fishery products: MATÍS from Iceland: NOFIMA and SINTEF from Norway. The idea is to analyse the needs for a modern factory trawler. Gather and find researches that have been done in the past, both in Iceland, Norway and EU about the following parameters: ideal temperature for white fish (cod in particular), handling of the product during the processing, bleeding and washing of the raw material, different freezing methods. The thesis will also discuss the additional cost of building a high quality production factory compared to the industry standard factory trawler.

Thesis question

What are the design parameters for optimal quality for whitefish in a modern factory trawler?

2 Background

This thesis will review what past studies and key personnel for the research institutes say about ideal parameters for the following factors: handling, temperature, bleeding methods, time needed for bleed-out and freezing.

Handling

Presented here is a standard procedure of a fishing trawler, producing frozen ground fish products, cod in particular. It starts with the trawler going out to sea and finding suitable fishing grounds, casting/shooting the trawl net (fishing gear) to the bottom of the sea, dragging it along the seabed (trawling) from 20 minutes to 8 hours. The trawl net is pulled on-board the ship (usually a steep ramp aft of the ship), the cod-end emptied into the bunker (the cod-end is at the end of the trawl net and is provided with a release so the crew can empty the contents of the net into the bunker).

Prior to being taken aboard the fish have been battling against the trawl net, up the ramp and into the bunker. According to Poli (2005) and Misimi E. (2008) stress can have an effect on the quality of the fish. In a study by Poli (2005) they observed that when a fish is stressed - it strives for oxygen and when it is not getting oxygen the muscles tend to lower the pH levels in the body and the fish starts to produce lactic acid, resulting in a hastened onset of Rigor mortis. As Huss (1995) indicated an early onset of Rigor Mortis could cause gaping of the flesh. In a study by Digre H. E.-J. (2011), she indicated that the drainage of blood from a stressed cod was worse than unstressed cod.

When the fish are transported from the bunker into the factory and on the way through the processing line, they can be subjected to poor handling along the processing line. In a study by Digre H. H. (2010) there are indications that rough handling of the fish in a trawl can cause bruising of the flesh.

Temperature

As Huss (1995) pointed out, the temperature of the fish has an effect on the onset of Rigor mortis When the temperature is high, the flesh of the fish tends to lose its firmness and thus there will possibly be an increased gaping in the flesh. It has also been observed by Olafsdottir (2006) that a temperature controlled environment for the product reduces the growth of bacteria and can prolong the shelf-life of the product.

Bleeding

Botta (1986) demonstrated in his research that the bleeding of the fish is an important factor for improving the colour of the flesh. Studies by Botta (1986) and Olsen S. J. (2014) implied that the most important factor is to process the fish as soon as possible at the bleeding stage. Olsen S. J. (2014) indicated in his study that bleeding and exsanguination should take place within 30 minutes after the catch has been hauled on board. In a study by Karlsdottir (2014) bleeding the fish in a continuous renewal of fresh (for *Pollachius virens*), chilled seawater (for *Gadus morhua*) resulted in a better quality of the fish.

Freezing

According to Arason (1999), rapid and steady freezing of product is important. Rapid freezing is important to prevent water from exiting the cells and damaging proteins and muscle tissue during freezing.

Added value

With controlled quality fisheries, there are indications of a higher value of fish products (Gudmundsson (2006); Margeirsson S.H. (2010); Margeirsson S.J, (2007)). Research by Sogn-Grundvåg G. E. (2014) suggested that with a higher quality of fish, a higher profit can be obtained for the fish buyers.

2.1 Credentials

The author has been involved in the fishery industry since moving to Grímsey, a small island north of Iceland on the arctic circle where he started working in a salt fish factory at the age of 12. At age 15, he started work on trawlers and has been working as an able seaman on and off since.

Previous jobs:

Ships

1996 – 2015	Able seaman - Too many vessels to name, ranging from a small hand-line boat up to 105-meter Pelagic trawler, 7800 gross tons and everything between.

Deutsche Fischfang Union GmbH (*one of the largest fishing companies in Germany*)

2010 – 2015	Quality and production manager for the fishing fleet of DFFU– developed the position

Samherji hf – (*one of the largest fishing companies in Iceland*)

2012 – 2015	Quality and production manager for the fishing fleet DFFU

Ice Fresh Seafood - (*one of the largest fish product sales companies in Iceland*)

2013 – 2015	Quality manager for the sales group Ice Fresh Seafood – developed the position

Here are a few joint projects during the past years, individually developed and jointly with others:

2010 – 2015	Quality and production manager for the fishing fleet of DFFU – developed the position
2013 – 2015	Quality manager for the sales group Ice Fresh Seafood – developed the position
Joint Developed	Quality system for the ground fishing fleet in Iceland/Europe for Samherji and DFFU, cod, saithe, haddock and Greenland halibut. Developed with sales representatives and department of ship operatorsions.
Joint Developed	Quality system for the pelagic fleet in Iceland for Samherji, herring, capelin, mackerel. Developed with sales representatives and department of ship operatorsions.
Joint Developed	Improving numerous factories and workflow with captains, foremen and department of ship operatorsions.

2.2 General information relating to flow in the factory

In every food production facility, it is important and legally necessary to implement a flowchart for the factory. In a standard H/G (headed and gutted) frozen production unit the following steps are defined.

H/G frozen product- description of the process of production

1. Fishing.
2. Empty the net. Having put the trawl on the deck, remove the fish from the net into the bunker.
3. Raw material: The bunkers are to be partially filled with seawater before putting the fish in them.
4. Transport to the factory by conveyors. Fish are moved from the bunker to the factory deck.
5. Manual sorting. Employees sort the fish according to species. Damaged fish are put aside as waste. Fish moved to the gutting line.
6. Fish are headed and gutted, either with collarbone or without, and bled. Fish go to bleeding bin no. 1.
7. Transport by conveyor. An automatic transporter moves the fish to the automatic grader. Sorting machine transfers the fish to the bleeding bin no. 2.
8. Transport. An automatic transporter conveys the fish to the vertical freezers.
9. Fish are manually placed in (packing) the vertical freezers. Freezing of the product in the vertical freezers. The product must reach at least -18°C at the core of the block (22 kg – 45 kg fish blocks).
10. Manually unloading the freezer, before the next portion of fish is loaded.
11. Packaging (Norwegian paper bag). Block is sealed in a Norwegian paper bag and marked with a label (vessel, product, date of catch, etc.).
12. Transport to cargo hold. The final product is arranged in the cargo hold. Stored in the cargo hold, (storage temperature between -18°C to -25°C).
13. Unloading. Manually unload the final product, arranging blocks on pallets, according to size and species of fish in cargo hold/storage and using cranes.

    Below in figure 1 a standard flowchart is presented.

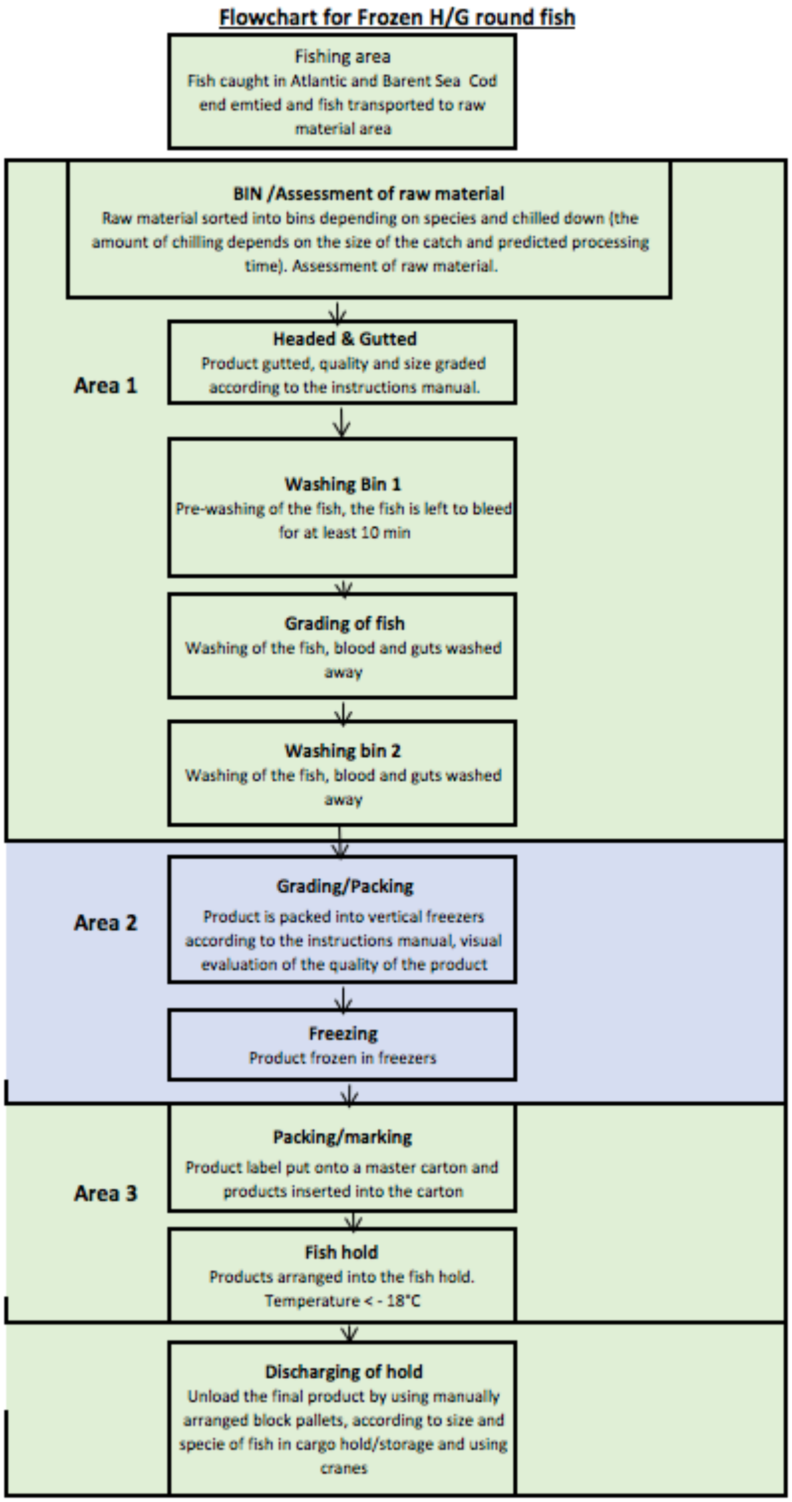

Figure 1 - Demonstration of a standard flow chart for H/G frozen products

3 State of the art

In this chapter we will review scientific research on handling, temperature, bleeding/washing, freezing and added value of quality.

3.1 A review of scientific research

Handling

Handling of the fish has been shown to be of great importance and relevant to improved quality of fishery products (Botta (1986); Digre H. H. (2010); Digre H. E.-J. (2011); Margeirsson S.J. (2007); Olsen S.J. (2014)). The hazards, both chemical and biological, the conditions, structure and flow through a factory deck required to obtain approval for food production, are established from governmental agencies and laws based on the concept of hazard analysis and critical control points or HACCP. HACCP is based on European food safety law with the common code of practice by the Food and Agriculture Organization of the United Nations (FAO) and World Health Organization (WHO) (Secretariat of the Codex Alimentarius Commission (2011); REGULATION (EC) No 852/2004 (2004); REGULATION (EC) No 853/2004 (2004)).

According to Huss (1995) rigor mortis is a recognizable sign of death, defined in three stages, pre-rigor, rigor mortis and post-rigor. In the stage of pre-rigor the fish is alive and on its way to death. Huss (1995) described the stages of rigor mortis, the muscles of the fish as relaxed and having an elastic texture for the first hours, after that the muscles will contract and stiffen. When the fish is in its peak of rigor mortis, it is totally stiff and inflexible; this process can take about a day. After the rigor mortis stage is over, the fish enters its last stage of rigor mortis or post-rigor stage. In the post-rigor stage, the muscles relax again and the fish becomes limp. However, fish has lost the elasticity it had in the pre-rigor stage. According to Huss (1995) and Poli (2005) many factors affect the onset of rigor mortis, such as temperature, handling and the physical condition of the fish. The onset of rigor mortis can differ between species, as was pointed out in a study by Erikson (2011). His results implied that the Atlantic salmon (*Salmo salar*) went through the rigor mortis stage faster than cod (*Gadus morhua*) and suggested that the cod (*Gadus morhua*) could be a sedative species.

According to Poli (2005) and Misimi E. (2008) stress can affect the quality of the fish. It was observed in a study by Poli (2005), that when the fish suffers from stress conditions, it reacts in such a way that it uses up the energy of the muscles (ATP), lowers the pH level in muscles, produces more lactic acid and speeds up the onset of rigor mortis. Research by Misimi E. (2008) concluded that unstressed cod fillets had more width than fillets from a stressed cod in post-rigor mortis. Early onset of rigor mortis could cause gaping in the flesh (Huss, 1995). Research by Digre H. E.-J., 2011 (2011) indicated that the drainage of the blood from stressed cod (*Gadus morhua*) was worse than from an unstressed cod (*Gadus morhua*).

Temperature

According to Olafsdottir (2006) her study concluded that controlling and keeping the right temperature is an important factor in preserving the quality of the fish, since a high product temperature can influence the growth of bacteria. As reported by Lauzon (2010) and Olafsdottir (2006), their studies indicated that a lower the temperature, prolonged the shelf-life of fresh fish. Temperature is one of the key factors in the onset of rigor mortis (Huss, 1995). By cooling down the fish to around 0°C, you can delay the onset of rigor mortis and thus the subtractions of the muscles will be less powerful and extreme than when the fish goes through rigor mortis at higher temperatures, resulting in gaping in the flesh (Huss, 1995).

Bleeding/washing

Bleeding and the method of bleeding is a vital factor in exsanguination of the muscles (Botta (1986); Karl (2007); Roth (2009)). Karlsdottir (2014) researched the effect of different bleeding methods on quality and storage life of cod and saithe products and their main results indicated that cooling and washing the cod (*Gadus morhua*) in slurry ice, resulted in a considerable difference in the end quality of the product. Their results of their study also suggested that saithe (*Pollachius virens*) showed the opposite reaction to chilled seawater compared to cod (*Gadus morhua*), as saithe (*Pollachius virens*) showed better end quality in standard seawater. If myoglobin and haemoglobin proteins remain in the white muscle tissue, the effect of an improper exsanguination of the muscles can cause early rancidity of the product and shorten shelf-life.

There are debates as to the best methods of cutting or bleeding fish. The main three methods are a gill cut[1], cutting of the throat[2] or cutting the throat and gutting in a one-step procedure, where you are cutting the throat without touching the backbone and then directly gutting the fish. This is the most common practice is fresh fish fisheries (Botta, 1986).

The most important aspect of the procedure of bleeding, was noted in the following studies by (Botta (1986); Karl (2007); Olsen S.J. (2014)). They all indicated that the time-factor was more important than the method itself.

In a study by Olsen S.J. (2014), it was discovered that the fish needed to start bleeding within 30 minutes after the fish arrived on the factory deck to produce the best exsanguination of the blood from the muscles. Another study by Roth (2009) observed that the washing of the fish for a minimum of 12 minutes in a constant supply of clean seawater streaming into a washing bin, could result in improving the exsanguination of the blood from the muscles.

Freezing

According to Arason (1999), a rapid and steady freezing process of product is important. The reason for a rapid process is to prevent the water from exiting the cells and damaging proteins and muscle tissue during freezing. Another reason is to contain the bacterial growth and reduce the effectiveness of enzymes that result in deteriorating quality of products as enzymes can break down the proteins within the fish and can have an effect on texture (Arason, 1999).

The report "Code of practice and fishery products", identifying the hazards in the processing line by using the HACCP (Hazard analysis and critical control points) system REGULATION (EC) No 852/2004 (2004), clearly states that the minimum requirement is to reach the temperature of -18°C and the process should be as quick as possible. If the process is slow the temperature of the product will rise and can thus reduce shelf-life because of micro-organisms and undesirable chemical reactions (Secretariat of the Codex Alimentarius Commission, 2011).

[1] Where a knife is cutting into the gill and piercing the artery (known as a two step procedure)
[2] Cutting of the throat down to the backbone (also known as a two step procedure),

Added value

Studies conducted by Gudmundsson (2006), Margeirsson S. H. (2010) and Margeirsson S. J. (2007) concluded that by monitoring the quality of fisheries with regard to fishing grounds, time of year and thus the changing conditions of the fish through the year, there are indications of higher value for the fisheries. In his study, Margeirsson S. J. (2007), examined the influencing factors on yield, gaping, bruising and nematodes in cod, concluding that the most important factors were the fishing grounds, age of raw material and time of catch. He followed up on his previous study with Margeirsson S. H. (2010), where he indicated that extensive data collecting from fisheries, in combination with integrated fisheries and processing, could result in added value for the fisheries.

Sogn-Grundvåg G. L. (2013) examined the value of line-caught fish; he showed that line-caught fish for sale in the supermarkets in the United Kingdom received a higher premium compared to fish caught with other fishing gear, 18% higher for line-caught cod(*Gadus morhua)* and 10% for haddock (*Melanogrammus aeglefinus*). A study carried out by Sogn-Grundvåg G. E. (2014), where they interviewed parties involved in the fishing industry (coastal fishing fleet and fish buyers), as well as collecting price data, showed that higher quality fishery products can give a higher yield and higher profitability for the fish buyers.

3.2 Design concept for Nergård Trawler

In the modern world there is a need for constant improvement or adaptation to stay ahead in the market (Boundless, 2016). The core objective of the project is to be able to produce trawled ground fish (especially cod) at the quality level of line-caught fisheries. The main reason for wanting to be able to produce line-caught quality fish is that there are indications of a market willing to pay a higher premium for the product (Sogn-Grundvåg G. L., 2013).

Therefore, all the design of this new concept ship has been focused on maintaining the caught fish in similar or better conditions, compared line-caught fisheries, as regards handling and bleeding. The concept starts by catching the fish in a trawl with modified fishing gear so the crew is able to pump the fish alive on board, as demonstrated in studies by Leif Akse (2011) and Olsen S. T. (2013), instead of taking it up the ramp, causing possible stress through poor handling of the fish that could result in bruises of the flesh and reduced quality (Digre H. H., 2010). After the fish have been pumped on board into the specially designed bunker aft in the ship, the dead fish are removed from the bunker first and taken straight into bleeding, then into a washing/chilling tank. The concept is that after the dead fish have been processed, the remaining live fish of the haul are pumped out via seawater to minimize stress due to handling (Digre H. E.-J., 2011). Studies have shown that the fish remaining alive can range from 97.6% Digre H. H. (2010) to 73.2% Olsen S. T. (2013) of the catch.

The concept of the factory is to grade the whole fish by a vision grading system from OptimarStette, where the grader determines both species and length of fish (at a development stage). After the grading, the fish are delivered into live-storage tanks (10 tanks $4m^3$ and 10 tanks $5m^3$, about 1,600 kg/2,200 kg capacity for live fish). The tanks are modified, focusing on oxidizing the seawater and maximizing the square meters of each tank instead of the conventional cubic meters; thus the tanks are designed with low height and more square footage (Olsen S. T., 2013). The reason for this design of the tanks is that while the fish are recovering from the strains of being caught into a trawl from the depth of the sea, they tend to sink to the bottom as the swimming bladder can be punctured and the fish buoyancy thus disturbed (Humborstad, 2013). According to Olsen S. T. (2013) it takes the fish at least 6 hours to recover and also to redistribute the blood out of the white muscles and gain whiter coloration.

The concept is that after at least 6 hours of recovery time for the live fish in the oxidized tank, the operator on the factory deck selects the size of fish and species he is going to process. The selected fish tank is opened and the fish transported via conveyor to a machine that stuns the fish (by giving an electric pulse to the body) so they will be immobilized, as described in a study by (EFSA, 2009). From the stunning machine the fish enter a robotic bleeding machine, which cuts into the gill, causing the fish to start bleeding (at a developing stage). It is important to bleed the fish as soon as possible since this gives the fillets a whiter coloration, as reported by Botta (1986) and Olsen S. J. (2014). Indications of economic benefits have been observed in the following studies (Margeirsson S. J., 2007; Margeirsson S. H., 2010).

After the fish have been gill cut and started the bleeding, the concept is to transport them to the chilled rotary bleeding tanks, where they are bled in chilled seawater under powerful circulation. The concept of the design of the tank is to emphasize cooling down the product, bleeding it in continuously flowing clean seawater as shown in a study by (Lauzon, 2010). The concept behind a rotary tank is to utilize the “first-in first-out” method and time control the process. After the fish have been chilled and bled, they are transported to the heading/gutting machines where a crewman manually inserts the fish into the machines. The fish are either headed and gutted in a (Baader 444) machine or just headed in a (big cod Baader IS-033) machine. After the heading and gutting, the fish go through a washing bin, onto a conveyor where the crew can inspect for any faults in the gutting/heading process and remove any remains of intestines.

The fish then get graded again into batches where the packers pack the H/G fish into trays. Automatic loading and discharging of the horizontal plate-freezers is provided by technology from OptimarSette. When the product has reached the optimal freezing point the concept is that it proceeds into an automatic packing line, where it is packed into Norwegian paper bags, labelled, palletized, registered and stacked into the cargo hold.

In this new concept, the goal is to have a protein plant to convert the intestines, fish heads, trimmings and any non-commercial by-products into fish meal and fish oil. Please see Annex IV for a detailed description.

By utilizing the technology available for processing factories, a possible solution from Marel, such as The Marel Innova Software and the Marel equipment (scales, graders), can be used to the company's advantage. Research by Margeirsson S. H. (2010) showed that, by means of integrated data collecting, fisheries could give a higher yield and possibly added value. Please see Annex III for detailed description.

4 Materials and Methods

Method

The methodology of this study was to analyse through the individual experience of interviewers and researches what has been done with regard to the four main topics that can affect the quality of raw material in a fishery production factory, namely, temperature, handling, bleeding/washing and freezing. This methodology is based on Grounded Theory, a qualitative research technique originally developed by Barney Glaser and Anselm Strauss (Glaser, 1967). It is a characteristic of this methodology that the researcher is open minded, flexible and not afraid of using his or her own experience in the research. The core concept of the theory is openness in analysis of data and findings produced by the data; thus not embarking on the research with a predetermined theory in mind (Strauss, 1998).

Material

The data collected for this thesis is mainly derived from the database for scientific researches *Web of Science* (http://ipscience.thomsonreuters.com), trawling through cited researches and articles, as for example the homepages of *MATIS*(http://www.matis.is/midlun/utgefid-efni), *NOFIMA*(http://nofima.no/publikasjoner), *SINTEF*(http://www.sintef.no) and *Google Scholar*(https://scholar.google.no), which were used to search for cited publications. A direct questionnaire was sent out to key personnel in the field of processing in research departments for whitefish in NOFIMA, SINTEF and MATIS (ANNEX I), and their answers are presented in chapter 5 of this thesis.

All participants were informed about the purpose of the research by e-mail sent out to them along with the questionnaire. The questions in the questionnaire are open ended questions and their design derives from the researchers own professional work experience in the industry, in analysing the critical points in factory trawlers. (ANNEX I)

5 Results - Focus points of production

In this chapter we are going to combine research done in the past and answers from key personnel of the research institutes concerned.

5.1 Handling

Poor handling can affect the quality of a product as shown in a study by (Poli, 2005). According to Huss (1995) and Poli (2005), handling is one of the causes of early onset of rigor mortis, thus possibly increasing the gaping of the flesh. Improved handling can result in a higher value of the product as Sogn-Grundvåg G. L. (2013) showed in their research where line-caught fish received a higher premium, compared to fish caught with other fishing gear.

What does the research say about the effect of handling during processing?

Handling of the fish has been shown to be of great importance and relevant to improved quality of fishery products (Digre H. E.-J., 2011; Margeirsson S. J., 2007; Olsen S. J., 2014; Özyurt, 2007). Studies by Digre H. H. (2010), Huss (1995) and Poli (2005) have observed that the flesh or muscles of the fish suffer when abused by stress conditions, reacting in the way that fish spend their muscle energies (ATP), lowering the pH level in muscles and producing more lactic acid. According to research by Poli (2005) and Misimi (2008) stress can have an effect on the quality of the fish. As reported by Margeirsson S. J. (2007) poor handling could possibly affect the yield of the fish; this is also in line with a study by (Sogn-Grundvåg G. E., 2014).

What do experts from research departments say?

- In the opinion of key personnel member A, the falling of an IQF-frozen product breaks the glazing and for fresh fish any fall will produce more bruising and gaping of the flesh. Critical points to look for are where any fall is particularly undesirable and the development of the process should be such a way that the raw material is treated gently. He based his opinion on own studies and others, none specified.

- In the opinion of key personnel member B, while the fish is still alive, a fall may cause bruising and flesh damage. Critical points to look for are how to prevent falls and avoid the risk of squeezing of the fish. He based his opinion on own studies, none specified.

- In the opinion of key personnel member C, it could be a challenge to answer the questions regarding handling. Critical points to look for are blood spots and quality; he referred to studies, basing his opinion on specified literature: See below and Annex II for detailed references:

  (Digre, H., Jes Hansen, U. & Erikson, U. 2010.),(Esaiassen, M., Nilsen, H., Joensen, S., Skjerdal, T., Carlehøg, M., Eilertsen, G., Gundersen, B. & Elvevoll, E. 2004.)
  (Margeirsson, S., Nielsen, A. A., Jonsson, G. R. & Arason, S. 2006.)
  (Olsen, S.H., Tobiassen, T., Akse L., Evensen, T.H., & Midling, K.Ø. 2013.)
  (Olsen, S.H., Joensen, S., Tobiassen, T., Heia, K., Akse, L., & Nilsen, H. 2014.)
  (Özyurt, G., Özogul, Y., Özyurt, C. E., Polat, A., Özogul, F., Gökbulut, C., Ersoy, B. &Küley, E.),(Rotabakk, T.B., Skipnes, D., Akse, L. & Birkeland, S. 2011.)
  (Valdimarsson, G., Matthiasson, A., & Stefansson, G. 1984.)

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5.2 Temperature

Controlling and keeping the right temperature is a vital to the quality of the fish and delaying the onset of rigor mortis (Huss, 1995).

What does the research say about the effect of temperature during processing?

Research by Lauzon (2010) and Olafsdottir (2006) has indicated that controlling and keeping the right temperature is important for the quality of the fish and prolonged shelf-life, as temperature is one of the factors in the onset of the rigor mortis stage (Huss, 1995). By cooling down the fish to around 0°C, you can delay the onset of the rigor mortis stage and thus the contractions of the muscles will be less powerful and extreme, whereas high temperatures tend to have the opposite effect (Lauzon, 2010). A study by Olafsdottir (2006), indicated that by lowering the temperature of the fish, bacterial growth was also reduced and shelf-life prolonged.

What do experts from the research departments say?

- In the opinion key personnel member A, the temperature for frozen fish is -25°C for cod products and fresh storage should be 0°C to -0,5°. Critical points to look for were keeping the temperature stable with little temperature fluctuation. He based his opinion on own studies and those of others, none specified.

- In the opinion of key personnel member B, the temperature for fresh fish ranges from 0°C to -1°C. His opinion was that the natural bacterial flora is adapted to cold seawater and therefore chilling the product would prolong shelf-life. Critical points to look for were cleanliness, hygiene and a cold processing chain. He based his opinion on own studies and those of others, none specified.

- In the opinion of key personnel member C, the temperature for processing should be slightly sub-zero, or ranging from 0°C to -1°C. His opinion was that in this way you could gain better yield and cleaner cuts. Critical points to look for were to start chilling immediately and that precise temperature control is essential to avoid unwanted freezing of the product, as ice fractions versus temperature gradient, is steep in relevant sub-zero region. He based his opinion on a study from *Skaginn Processing line and related publications*, one other specified. Please see Annex II for detailed references: (Digre, H., Erikson, U., Aursand, I.G., Gallart-Jornet, L., Misimi, E. 2011.)

5.3 Bleeding/washing

Bleeding and the method of bleeding is an important factor in exsanguination from the muscles (Botta, 1986; Karl, 2007; Roth, 2009).

What does the research say about bleeding techniques and their effect on bleed out?

Studies by Botta (1986), Karl (2007) and Roth (2009), have shown that bleeding and the method of bleeding is a vital factor in exsanguination from the muscles of the fish. If myoglobin and haemoglobin proteins stay in the white muscle tissue and are improperly exsanguinated out of muscles, this can cause early rancidity of the product and shorten shelf-life (Karlsdottir, 2014). In the opinion of Olsen S. J. (2014), where he wrote; incorrect bleeding methods are among major causes in downgrading the quality of fish, due to discoloration of the fillets. There are divided opinions as to the best methods of cutting or bleeding fish. The newest study by Digre H. E.-J. (2011) indicated that a gill cut showed the best results in exsanguination of cod (*Gadus morhua*). As stated by these studies: Botta (1986), Karl (2007) and Olsen S.J. (2014), the most influential factor was time. According to Olsen S. J. (2014) conducting the bleeding process within 30 minutes after the catch has been hauled on board, showed the best results in exsanguination from the muscles. It was observed in a study by Roth (2009), that washing the fish for a minimum of 12 minutes in a constant running flow of clean seawater resulted in improved quality. As reported by Lauzon (2010), the chilling of seawater could increase shelf-life.

What do the experts from the research departments say?

- In the opinion of key personnel member A, bleeding should be carried out with controlled temperature and high water exchange. Bleeding time could vary from 5-15 minutes depending on which species, the movement in the bin, water exchange and other factors. Bleeding should be done immediately after catching. Critical points to look for were making sure that bleeding took place in a short time from catching and it was also important to maintain rapid and high water flow. His opinion was that most studies are done in close cooperation with industry; equipment is rather irrelevant compared to method regarding the quality of the product, no particular study specified.

- In the opinion of key personnel member B, bleeding should be carried out by cutting the throat, inserting the fish into cold running water and letting it bleed-out for at least 30 minutes. He considered it best to gut and cleanse the intestines as soon as possible, due to that residual of blood and intestinal will contribute to higher microbial growth. Critical points to look for were the overloading the slaughter due to excessive catches, which would result in fish dying before bleeding and that the end result would be poor bleeding. He based his opinion on own studies and others, none specified.

- In the opinion of key personnel member C, the ultimate goal for bleeding would be to catch the fish alive and keep them alive to facilitate efficient bleeding for the whole catch. He referred to studies (Kelly, 1969; Huss and Asenjo, 1976; Valdimarsson et al., 1984; Botta et al., 1986; Olsen et al., 2014) which showed that immediate bleeding of the catch after capture would improve bleed-out and minimize discoloration of fillets. Critical points to look for were that the effect of capture was not fully understood and making sure not to have any delays after capture before bleeding. He based his opinion on a number of publications, his own and those of others. See below and Annex II for detailed references:
  (Botta, J. R., Squires, B. E. & Johnson, J. 1986.) ,(Huss, H. H. & Asenjo, I. 1976.),
  (Kelly, T. R. 1969.)
  ,(Digre H, Erikson U, Misimi E, Standal IB, Gallart-Jornet L, Riebroy S, Rustad T. 2011.)

5.4 Freezing

It is important to introduce freezing soon after the fish have been processed. Also a rapid freezing time and stable freezing conditions (Huss, (1995); Secretariat of the Codex Alimentarius Commission (2011); REGULATION (EC) No 853/2004 (2004)).

Method, what does the research say about the different ways of freezing? – Ammoniac vs. CO_2

Unfortunately, the research did not find a proper study on the matter. There were many studies on Ammoniac versus CO_2, but they all shared the particular feature that the research was conducted on commercial refrigerators. The research aimed for should focus on industrial usage and food processing.

The key factor in freezing, was to have a rapid freezing time according to Secretariat of the Codex Alimentarius Commission (2011) and freeze below -18°C at minimum (REGULATION (EC) No 853/2004 (2004)). Creating stable conditions for the process of freezing is essential and storing the end product at a minimum of -18°C with minimal fluctuation of the temperature (Huss, 1995) (Secretariat of the Codex Alimentarius Commission, 2011). According to Arason (1999) rapid and steady freezing prevents the water from exiting the cells and damaging proteins and muscles, controls bacterial growth and reduces the effect of enzymes.

What do the experts from the research departments say?

- In the opinion of key personnel member A, most ships in the past have been using ammoniac or Freon as their refrigerant; CO_2 has recently entered the industry. CO_2 has many advantages, but needs further development to adapt to the fishing vessel environment; it could be a future element, however. Critical points to look for were that the freezing equipment should be capable of rapidly freezing the product down to storage temperature. The temperature of the storage room should be stable and preferably kept at -25°C. Also, to classify the products immediately in storage on board, shipping them directly in refrigerated containers or cold stores at -25°C. He based his opinion on own studies and those of others, none specified.

- In the opinion of key personnel member B, CO_2 freezes fish faster and contributes to less cell damage. Due to poor defrosting methods of the fish, the above opinion is irrelevant as the difference between ammonia and CO_2 systems may be gone.
  Points to look for are, in the opinion of key personnel member B, that freezing of fish will always be tied to health, safety, environment and running cost benefit for the company. A driving force for implementing CO_2 systems on board ships will have to come from the market, where there is demand for quick frozen products and consequently willingness to pay a higher premium for them.
  He based his opinion on own studies and those of others, none specified.

- In the opinion of key personnel member C, the freezing rate, method of freezing and the effect that it has on quality, seem to be less critical than assumed before. It is nevertheless a good principle to adopt rapid freezing. Points to look for are, in the opinion of key personnel member C, that if energy consumption is taken into account, the difference between methods can be is significant. He did not refer to any studies.

6 Discussion

In this chapter we will go over the findings of this research on the topics of: handling, temperature, bleeding, freezing and discuss added value and cost increased quality.

6.1 Discussion on handling

The state of the art for handling, as expressed by Digre H. H. (2010), Digre H. E.-J. (2011) and Olsen S. J. (2014) indicated that gentle handling improves the quality of the fishery products. It was observed in studies by Digre H. H. (2010), Huss (1995) and Poli (2005) that poor handling could result in lower pH levels, creating lactic acid in the body. According to Huss (1995) poor handling could quicken the onset of the rigor mortis stage, resulting in more gaping. Research by Digre H. E.-J. (2011) showed worse exsanguination as a result of poor handling.

All the key personnel agree that falling can degrade the quality of the product and prevention of any unnecessary falls should be avoided. The process should be designed in such a way as to render the handling as gentle as possible. Their opinion reflects conclusions of past research (Digre H. H., 2010; Digre H. E.-J., 2011; Olsen S. J., 2014; Özyurt, 2007).

To draw a conclusion on the above findings, I suggest, with regard to this topic, that transportation through the factory deck and handling of the product can affect the coloration of the flesh, thus causing a drop in yield and possibly value. Therefore, the design of the factory and transportation system should have as gentle as possible effect on the fish, minimizing any unnecessary handling and roughness.

6.2 Discussion on temperature

Research by Lauzon (2010) indicated that lowering fish temperature could result in prolonging the shelf-life of fresh fish. This is also in accordance with research by Olafsdottir (2006) who suggested that by lowering the temperature a reduction in bacterial growth could be achieved.

All the key personnel agree that a high temperature can degrade the quality of the product and confirm the importance of maintaining a stable and cool environment throughout the processing area, or around 0°C to -1°C in a fresh state, and in frozen storage stage -25°C. Previous research on the matter supports this opinion (Huss, 1995; Lauzon, 2010; Olafsdottir, 2006).

To draw a conclusion on the above findings, I suggest that the bleed-out tanks need to be supplied with constant running of clean cold seawater and a temperature close to environment of the species that is being caught. As this a concept of a factory trawler in the North Atlantic Ocean, the temperature should be around the sub-zero.

6.3 Discussion on bleeding and washing

According to studies by Botta (1986), Digre H. E.-J. (2011), Karl (2007) and Roth (2009), bleeding method can significantly impact quality. In a study by Karlsdottir (2014) there are indications that bleeding fish in ice slurry could result in a better end-quality product. This, however, cannot be generalized with regard to all fish species. As reported by Olafsdottir (2006) there is a possibility of hindering bacterial growth in cod with lowered temperatures (*Gadus morhua*) during washing in bleed-out. Research by Roth (2009) states that a constant supply of clean seawater for 12 minutes during the washing of the fish could result in better exsanguination.

As stated by studies from Botta (1986), Karl (2007) and Olsen S. J. (2014), the most influential factor was time. Olsen S. J. (2014) has suggested that bleeding the fish 30 minutes after it arrives on the factory deck, could result in better exsanguination. The newest study by Digre H. E.-J. (2011) indicated that a gill cut showed the best results in the exsanguination of cod (*Gadus morhua*).

All the key personnel agree that the main factor of bleeding is to start the process as soon as possible after catch. This is supported by other research (Botta, 1986; Karl, 2007; Olsen S. J., 2014). The time for bleed-out differed to some extent, from 5 minutes to 30 minutes in the opinion of the key personnel, depending on conditions.

To draw a conclusion on the above findings, I suggest for this concept that the method of bleeding for an H/G frozen product should be a two-step method, cutting into the gill first and heading and gutting the fish later. The bleed-out should be minimum of 12 minutes and preferably over 15 minutes with cold high water exchange, controlled timing and seawater temperature, with two sets of tanks, one after bleeding and one after heading/gutting of the fish.

6.4 Discussion on Freezing

According to Arason (1999), a rapid and steady freezing process showed improved texture and quality.

Only one key personnel member mentioned the specific temperature of freezer storage and is there is a slight difference between the minimum required by the law: -18°C REGULATION (EC) No 853/2004 (2004) and the key persons' opinion: -25°C. The report by Arason (1999) states that the legal requirement in Iceland to store frozen products is -24°C.

The key personnel agreed that rapid freezing was an important factor and previous research on this matter supports their opinion (Arason (1999); Secretariat of the Codex Alimentarius Commission (2011); REGULATION (EC) No 853/2004 (2004)).

I was unable to find any proper research on Ammoniac versus CO_2 systems for industrial usage for fishing vessels or food production factories. To draw a conclusion on the above findings, I suggest for this concept that the freezing process should be rapid and stable. The storage of frozen fishery products should be kept between -24°C and -28°C, as fluctuation above -18°C (which is the minimum) can lead to a downgrading of the product.

6.5 Added value and cost increased quality

The importance of sustained premium quality has been researched both in Norway and Iceland in cooperation with the industry (Margeirsson S. H., 2010; Margeirsson S. J., 2007; Sogn-Grundvåg G. E., 2014). It was observed in studies by Gudmundsson (2006) and Margeirsson S. H. (2010) that time of year, fishing grounds and condition of the fish could affect yield.

That being said, the cost of setting up a modern high quality factory trawler will certainly be greater than that of building a conventional vessel, due to the extra cost of specialized fishing gear, pumping system, live tanks, extra engineering cost, protein plant, stunning machine, robotic bleeding machine, automation in freezers and controlled bleed-out tanks for the parameters of time and temperature.

The potential benefits are indicated in a study by Sogn-Grundvåg G. L. (2013) where he observed that line-caught fish are getting a higher premium than fish caught with other gear, possibly because of gentle handling, good quality fish or better effect on the environment. Therefore, the design concept of this Nergård modern factory trawler could possibly give some return on the original investment of extra equipment (Sogn-Grundvåg G. L., 2013). The moral benefits are also part of the equation. Is the company utilizing its limited natural resources and practising responsible fisheries as best as they can? A precise price tag on responsible fisheries is hard to determine; research by Sogn-Grundvåg G. L. (2013) noted that eco-labelling the haddock(*Melanogrammus aeglefinus*) with MSC(Marine Stewardship Council) gave a 10% higher premium. The trend, in my opinion, is a growing importance of eco-labelling. This, combined with the awareness of the people buying the end product, traceability and pressure from green parties in the EU on governmental officials to utilize and conduct responsible fisheries is bound to have a profound effect. Thus, the question is not whether demand for this kind of processing vessel is in the cards, but rather, how soon it will come.

7 Conclusion

In this chapter we will draw a conclusion on this concept of a factory trawler that Nergård are considering building, based on the parameters for handling, temperature, bleeding/washing of the product and freezing.

7.1 Optimal modern factory trawler conditions

Thesis question. *“What are the design parameters for optimal quality for whitefish in a modern factory trawler?”*

To draw a conclusion on this concept of a factory trawler that Nergård are considering building, I suggest that the development of the factory and transportation system should have the gentlest possible effect on the fish, minimizing any unnecessary handling and roughness with regard to the product. The bleed-out tank needs to be time controlled, supplied with constant running of clean cold seawater, at a temperature close to the environment of the species being caught; this temperature should be around sub-zero. The bleed-out should be a minimum of 12 minutes and preferably over 15 minutes, with two sets of bins, one after bleeding and one after the heading/gutting of the fish. The method of bleeding for H/G frozen product should be swift and a two-step method; first, cutting into the gill, then heading and gutting the fish later. The freezing process should be rapid and stable. The storage of the frozen fishery product is kept between
-24°C and -28°C.

Any trimmings, intestines, fish heads, and any non-commercial by-products are to be transported to the protein plant and processed there for fishmeal and fish oil (Hedinn, 2016).

During the above process, a software program would register the temperature, fishing grounds, processing through-put, labels, grading, inspections and weight of blocks. It is vital that the whole process is done thoroughly and GMP/HACCP practices should be adopted by all the crew. All the phases in this process must have an even and steady flow to maximize the capacity of the factory.

In chapter 7.2 there is a flow description and a flowchart.

7.2 Optimal modern factory trawler – flow and flowchart

In an optimal parameter H/G (headed and gutted) frozen production the following steps are defined:

H/G frozen production - description of the process of production

1. Fishing.
2. Pumping the fish alive on board and into the bunker and keeping the fish alive.
3. Raw material area: The tanks are filled with seawater before putting the fish in them.
4. Fish are moved from the raw material area to the factory deck. Gentle transportation arranged through slides with a seawater stream to create the movement for the transportation of the fish, with minimal handling.
5. Manual sorting of dead or damaged fish, damaged fish and non-commercial fish are transported to the protein plant.
6. Automatic graded/sorting of the fish according to their species and length. Fish moved into the live tanks were they will recuperate for at least 6 hours.
7. Fish transported to the stunning machine and into the robotic bleeding machine.
8. Fish go to a timed-temperature controlled washing rotary–tank for a minimum of 15 minutes.
9. Fish are headed and gutted, either with collarbone or without.
10. Fish are transported by conveyor to temperature controlled washing tank no. 2.
11. Fish transport by conveyor to a table where fish are inspected for any residue of intestines and then fed to the grader for packing.
12. Manual packaging of the product into trays, (size, species).
13. Automatic transporter moves the trays with product to the horizontal freezers.
14. Automatic freezing of the product in the horizontal freezers. Automatic monitoring of the product to determine when it reaches -22°C at the core of the block (22 kg – 45 kg fish blocks).
15. Automatic unloading of the freezer.

16. Automatic packaging (Norwegian paper bag). The block is sealed in a Norwegian paper bag and automatically marked with a label (vessel, product, date of catch etc.).
17. Manually arranging the frozen, packed and labelled blocks on a pallet.
18. Pallet wrapped in plastic and labelled accordingly to species, size, vessel etc.
19. Transport of pallet to cargo hold/storage. Pallets are safely arranged in the cargo hold/storage via forklift. Stored in the final product hold, (storage temperature between -20°C and -28°C).
20. Unloading. Unload the final product by forklifts and cranes.

Below, in figure 2, a standard flowchart is presented.

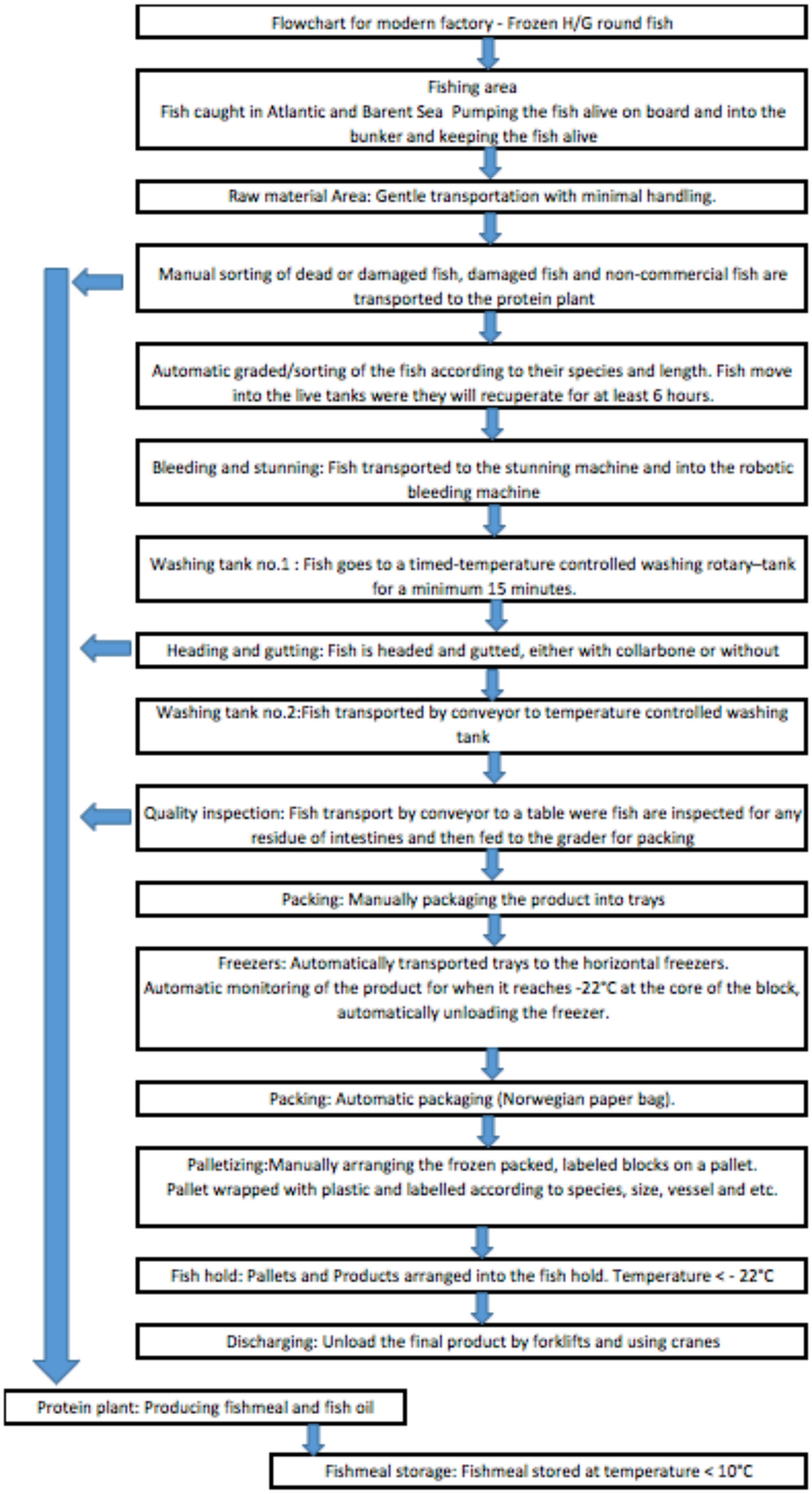

Figure 2 - Demonstration of an optimal modern factory trawler for H/G frozen fish products

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Figures

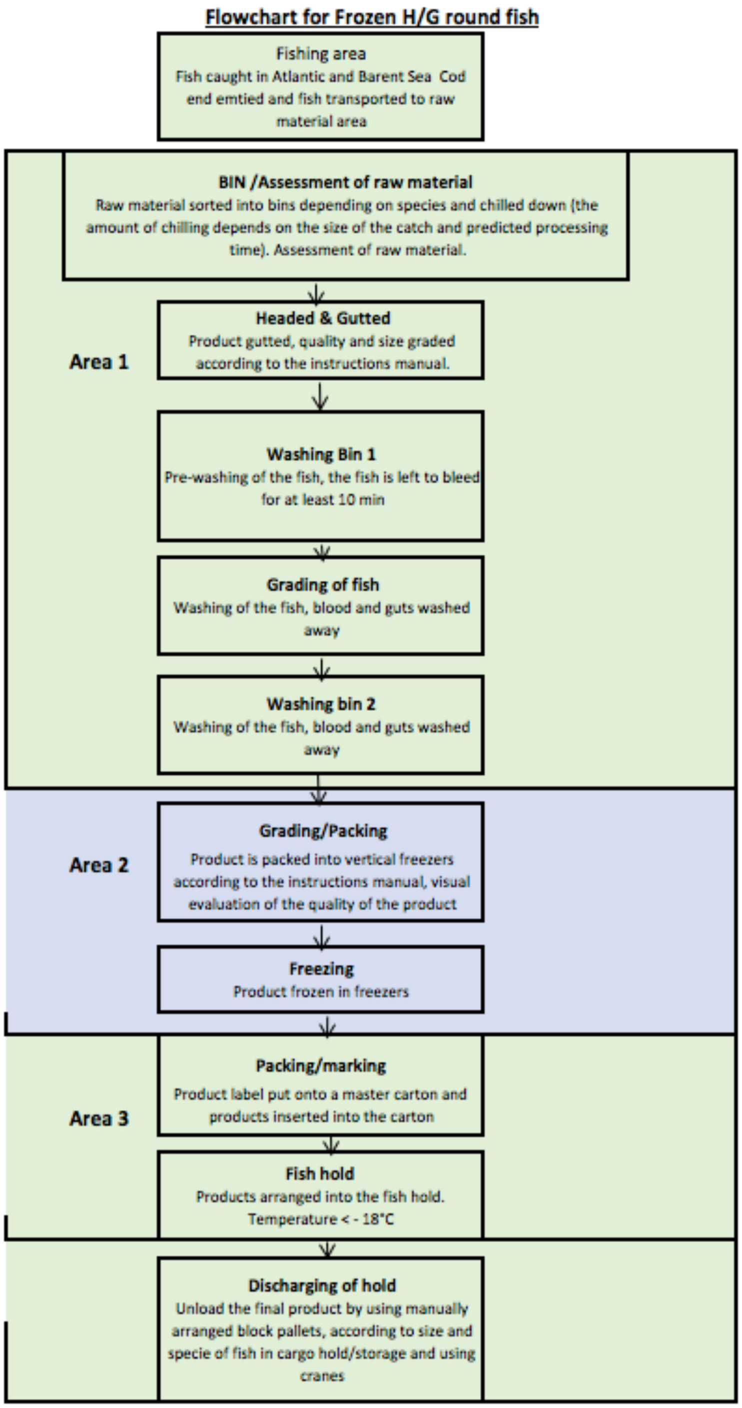

Figure 1. Demonstration of standard flowchart for H/G frozen fish products. Made by Pétur Jakob Pétursson. 2016.

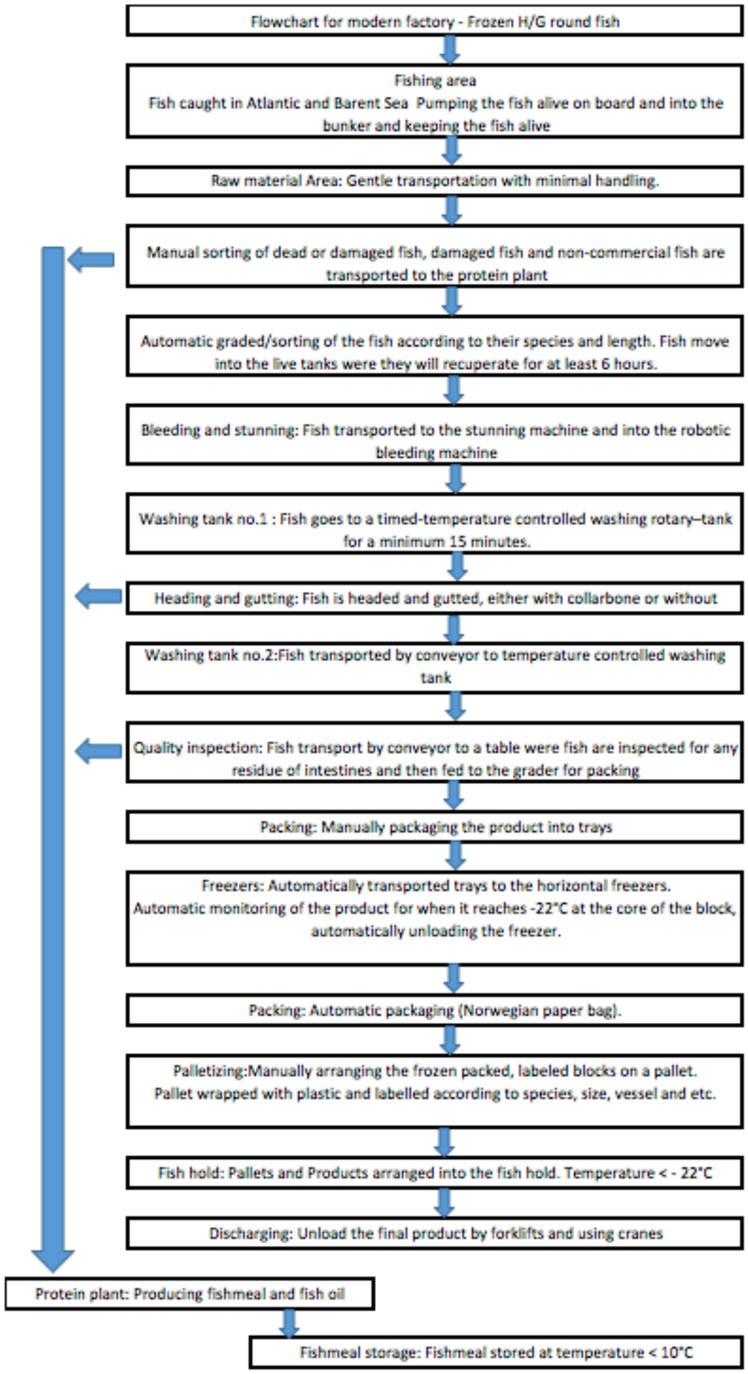

Figure 2. Demonstration on optimal modern trawler factory for H/G frozen fish products. Made by Pétur Jakob Pétursson. 2016.

ANNEX I

According to your opinion:

Topic one - What is the Ideal temperature for white fish (Cod in particular)

Answer:

Topic one - Which studies support the above opinion? (own institutes studies/other)

Answer:

Topic one - Which are the critical points to look for? – Possible opportunities?

Answer:

Topic two - how does drop/fall affect the product during processing?

Answer:

Topic two - Which studies support the above opinion? (own institutes studies/other)

Answer:

Topic two - Which are the critical points to look for? – Possible opportunities?

Answer:

Topic tree - What is the ideal bleeding and washing for whitefish? - time & method?

Answer:

Topic three - Which studies support the above opinion? (own institutes studies/other)

Answer:

Topic three - Which are the critical points to look for? – Possible opportunities?

Answer:

Topic four - What is the difference between Ammoniac and CO^2 freezing methods on ground fish?

Answer:

Topic four - Which studies support the above opinion? (own institutes studies/other)

Answer:

Topic four - Any other form of freezing methods? Possible opportunities?

Answer:

ANNEX II

References made by key personal C regarding Handling:

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ANNEX III

Discussion on usage of modern software technology

By utilizing available technology; that is, the monitoring in "real-time" of the production and traceability brings the factory up to new standards. Research by Margeirsson S. H. (2010) showed that with integrated data collecting fisheries could give a higher yield and possibly added value. The solution from Marel, such as The Marel Innova Software and the Marel equipment (scales, graders) can be used to the company's advantage when processing any kind of fish, such as whole round fish, fresh gutted fish, frozen gutted fish, heads, waste (fishmeal, fish oil). The possibility of monitoring yield, facilitates the distribution of the fish in each product code margin and the quality assessment of the product. The monitoring of the process could result in added value. People on-board can adjust their production in "real-time" and the people on-shore can also follow up on the production via an internet connection to the vessel. With the Marel Innova Software, there is a possibility of connecting the machines on the factory deck and obtaining overall results on the cargo that is brought to shore and ready for sales. The benefits of a Marel Innova system are:

- Instant Quality reports
- Better overview of the fishing in one place, haul sizes, time towing and position
- Label system that can easily be accessed for modification or to get digital copies of current and past labels
- Better tally of the cargo than "human counting" of the cargo
- If there is a scale that weighs the boxes/blocks with your product you can see accurately how many kilograms have been fished in one fishing zone, as an example (legal reasons, quota)
- Registration of temperature in the product is done digitally and linked to the production (better traceability)
- Much better overview for people in the onshore office of current production
- Better control of the processing in "real time"
- Comprehensive database that can collect data for years about fishing, production and fishing grounds
- Above data linked to a database on shore that connects to a stock software system and can be used in a one-page overview sales report, this can help the sales representatives to gain fast access to the goods they have to offer the clients, both quality and quantity
- Better traceability, down to a box/pallet

- To have all the above information in one place with easy access to get full overview of production, product and fishing

ANNEX IV

By-products

In this new concept, the goal is to have a protein plant to convert the intestines, fish heads, trimmings and any non-commercial by-products into fish meal and fish oil. By operating the protein plant you are utilizing your quota with better efficiency and showing more environmentally responsible behaviour by fully utilizing each kilogram that you are catching, instead of discarding the waste. The protein plant can produce valuable fishmeal and fish oil of the greatest freshness (Hedinn, 2016).