

QUALITY CHANGES OF FISH FROM CATCH TO PROCESSING AND DURING STORAGE WITH FOCUS ON COOLING PRACTICES AND PRACTICAL APPLICATION OF SIERRA LEONE.

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ABSTRACT

Sierra Leone has rich resources of fish, shrimp, lobsters and other cephalopods. However, these cannot be exported to EU Markets because of the lack of quality infrastructure and control in Sierra Leone. The purpose of this project was to assess the quality changes in fish from catch to processing and compare the effects of different cooling methods; super chilling (SC) and conventionally chilled with ice (NC). The fish quality was evaluated with sensory evaluation, including Quality Index Method (QIM), Quantitative Descriptive Analysis (QDA), Torry Freshness Score Sheet and chemical and microbial analysis after 1, 4, 6, 11, 14 and 18 days after catch. The mean ambient temperature was -1.3°C for the SC and -1.4°C for the NC group. The product temperature for the NC group ranged from -1°C to -0.5°C and from -1°C to -0.9°C for the SC. Sensory evaluation with QIM showed that the scores for all the quality attributes increased with storage time with some differences in a few quality parameters between the SC and NC groups. The sum of scores, the Quality Index (QI) increased linearly with storage time and was similar for SC and NC during the storage time. The QDA results show minor differences between the groups until day 18, when scores for spoilage related to odour and flavour attributes became more evident for the NC group. The Torry Scores were in line with the QDA results, after 18 days the NC was past shelf life and the SC at the end of shelf life. Microbial results showed that the total viable counts (TVC) were similar for the two groups on storage day 18, though slightly higher for NC and the number of H₂S producing bacteria was higher for NC. The TVB-N values for NC were higher on storage day 18 compared to SC. Thus, the above results show that the SC cooling having longer shelf life extension than the NC group.

Keywords: Quality, Cooling techniques, Super-Chilled and Non-Super chilled, ambient and product temperature, whole cod and fillets, freshness, and shelf life.

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1 INTRODUCTION

1.1 Background History

Sierra Leone lies between Latitudes 7° N and 10° N, and between Longitudes 10°30'W and 13° W on the coast of West Africa. It is bordered on West, North and Northeast by the Republic of Guinea and to the Southeast by Liberia (Figure 1). Sierra Leone covers a total area of about 71,740 km² with a coastline of about 560 km. The Continental shelf of the coast of Sierra Leone is about 140 km wide in the north and tapers to about 32 km in the south towards Liberia. The total continental shelf area covers about 30,000 km². The coastline is characterized by extensive flora of mangrove plants, mainly the *Rhizophora spp.*, together with a number of estuaries and rivers that are navigable for short distances. The area of the 200-mile Exclusive Economic Zone (EEZ) is about 157,000km² (Sheriff *et.al.* 2009).



Figure 1: The Map of Sierra Leone.

The fisheries sector of Sierra Leone has great potential to make significant contributions to food security and the national economy.

From a nutritional point of view, fish is a major source of animal protein for Sierra Leoneans. The fisheries sector contributes 8% of Sierra Leone's GDP, and fish is the largest single source of animal protein for the majority of Sierra Leoneans, supplying about 80% of the total animal protein for consumption. Small-scale artisanal fishery is a significant source of employment. The industrial fishery sub-sector is highly capital intensive, it is estimated that it currently employs about 1000 people and contributes between 15-20% of total fish production in the country. Total estimated fish production is about 20,000 million tons and this comprises shrimps, other shellfish and demersal fish. The sector has a potential to contribute significantly to economic growth and development through major investment and an effective fisheries surveillance system (EU Delegation 2009).

Sierra Leonean waters are generally believed to have rich fishing grounds for a wide variety of fish, including the high value species such as shrimp, lobsters, cuttlefish, breams and snappers. The rivers, estuaries and tributaries with their extensive mangrove vegetation provide favourable conditions of shelter and nursery of peneiad shrimp and fish such as Bonga (*Ethmalosa fimbriata*) and Croakers (*Pseudotolithus species*) (Sheriff *et.al.* 2009).

Presently, Sierra Leone is not exporting fish and fisheries products to the European Union (EU) due to EU Regulations relating to hygiene of food and feed [EU Regulation No. 852/2004; 853/2004; 183/2005] and official controls [EU Regulation No. 882/2004; 854/2004]. In Sierra Leone, the on-going official controls for fish products intended for the EU market includes organoleptic checks, microbiological tests and chemical tests for histamine, contaminants including heavy metals and dioxins. Only one company fulfils the requirements for official controls of ice and water in line with relevant EU community requirement, which is the Sierra Leone Fishing Company. The industry has no fish-processing establishment for adding value. The fish and shellfish products are blast frozen on board the fishing vessels and packaged normally in 20kg cartons for overseas destinations (in mother ships with freezing facilities). Five fishing companies have onshore cold-room facilities for preserving fish intended for sale in the marketplace (FVO Reports 2009).

The Food and Veterinary Office (FVO) had a mission to Sierra Leone in October 2009 and they identified some lapses in the fish production chain that needed correction. The regulations were clearly documented in the FVO report on fishery sector and export of fish and fisheries products from Sierra Leone. The Ministry of Fisheries and Marine Resources, the competent authority, and the Standards Bureau are all working together to meet the requirements for export to the EU. The Sierra Leone Standards Bureau (SLSB) has adopted the CODEX Standards that regulate the production of food and Codes of Hygiene and Sanitary practices of fish, as the National Standards for the fish products, to meet the EU requirements. In Freetown, Sierra Leone has signed an agreement with Dutch firm Precon to facilitate access to EU markets for its fish and fisheries products. The Dutch firm specialises in hygiene, food safety and consumer health protection (MFMR 2011).

Presently, there is still a problem of cooling facilities from catch to processing and consumers in the Fisheries Industries of Sierra Leone, and this has been clearly explained in the FVO Report, 2009. This report explains why exporters in these industries cannot meet EU requirement on export. In this report, it was stated that the EU mission team noted there were no automatic temperature recording devices in the cold stores and that unwrapped fish were stored together with fish in cartons on pallets. Freshness indicators (*i.e.* total volatile basic nitrogen (TVB-N) and trimethylamine nitrogen (TMA-N)), when the organoleptic examination reveals any doubt as to the freshness of the fish product (FP), are not analysed at present. The system of official controls has deficiencies in implementation and no monitoring plans for tests of FP and water/ice. Vessels, cold stores, ice factories and processing establishments visited during the mission did not meet all required community standards. The findings from EU are correct, and that is why this project is focusing on the quality changes in fish from catch to processing and during storage with focus on cooling practices and practical application for Sierra Leone. It is important to note that the quality of the fish largely depends on the type of cooling system or storage in terms of freshness indicators, product safety, and shelf-life determination of the fish for export.

Thus, this project at the United Nations University Fisheries Training Programme (UNU-FTP) in Iceland will prepare my work as a Project Manager at Sierra Leone Standards Bureau, and ensure cooperation with the Ministry of Fisheries and Marine Resources in monitoring of fish standards on fish quality and cooling facilities from catch to consumer, and updating export requirements of fish from Sierra Leone to the EU and other International markets. Also, the Project Manager will organise training workshops and seminars on quality management in fish processing and handling techniques with reference to the non-chilled and super chilled cooling systems. Hence, this project will serve as a guide for training programmes on quality control and the importance of cooling in the fisheries industries in Sierra Leone and at international level.

1.2 Gender issues in the fisheries sector in Sierra Leone.

Sierra Leone is among the few countries in the world with a special Fisheries Division established under the Ministry of Trade and Industry and comprehensive legislation on fisheries. The focus of the legislation and the government agency is on the improvement and development of artisanal fisheries. The war in Sierra Leone seriously affected artisanal fishing activities when many fishermen were killed, maimed, or driven away from their communities and women were forced to seek refuge in safer places.

In Sierra Leone, every fishing community has men, women, and children with clearly defined activities to perform on a daily basis. Traditionally, men do the fishing while women play a supporting role. Men perform the actual fishing operation. They go out in their canoes with their various types of fishing gear. Other activities performed by men in their various fishing communities are boat building/repairs, and net (fishing gear) mending.

Normally, in the traditional and artisanal sectors, children (boys and girls) accompany adult fishing crew and do jobs like removing of the fish fins and enterons in some species, fetch firewood and help in the drying of the fish through the Local Banda (i.e. pit of stones and sticks with 3 to 3.5ft high for the fish). The children and women do the selling of the fresh catch or processed fish.

Also, women fish in rivers, streams, creeks and small water bodies using 'Beimbe', the local scooping nets. This type of fishing normally takes place in the dry season between September and March. Ninety-nine per cent of fish caught by this method are for domestic consumption. Usually, this type of fishing comprises 3 to 5 women in a fishing group with different tasks to perform. The first step occurs when one or two women can determine and show the rest of the group where along the river, creek, or stream the highest population of fish is located. Then they start disturbing the water to locate the hiding places of the fish and one or two women holding the scoop net will then come closer to the first batch of women in readiness to receive the escaping fish.

However, very few women have the opportunity to upgrade their activities through training and improved technology, which forms one of the important roles of women in the fish processing industry. Also, in the artisanal sector, most women are still using rudimentary and fuel-inefficient technology in spite of the development of fuel-efficient smoking ovens.

Women can influence business decisions since they run and manage the affairs of the family at home. But, women have always expressed major concerns about the quest for better markets for their products and the lack of credit facilities to improve their activities. Children are not always directly involved in fishing activities within their communities because their parents care for them. Also, for those children who cannot afford to go to school or study beyond primary education, the parents engage them in fishing activities. The male child is usually taught net mending and repair skills, and is expected to help fetch fuel wood for fish processing and so on. The female child is always with her mother helping out with purchasing, processing and marketing of fish, and other household functions such as cooking (Browne 2001).

However, it is worthy to note that in a 'male –dominated' industry, some women have taken the lead by becoming wealthy and owning trawlers or motorized boats for fishing. The industrial fishing has created employment, foreign exchange, increased household income, and high nutritional level for women in Sierra Leone. Hence, it is important for women to play a role in the family, socio-cultural and economic development of a country, irrespective of ethnic or socio-economic factors, with a separate budget in the Ministry of Gender, Children and Social Affairs, which will help in reduction of poverty and plights of women in Sierra Leone.

1.3 Project Goal

The overall goal of this project is to provide a basis in understanding the quality and safety of fish through processing, handling and storage, in connection to export requirements.

1.4 Project Objectives.

The objectives were:

- To study different methods of fish handling techniques from the fishing vessel or catch to the producers and consumers, by comparing and evaluating the traditional icing and super-chilling of whole fish soon after catch and thereafter while kept in ice.
- To study methods to evaluate fish quality.
- To study the quality changes during shelf life from raw material to final product:
 - o Study the sensory, microbial and chemical changes.
 - o Compare the results of sensory, chemical and microbial measurements.
- To identify the various techniques or types of fish storage (temperature, different methods of cooling) and regulations relating to fish quality.
- Provide the basis for guidelines, for export of fish and fishery products, for the fishing industry in Sierra Leone with regard to quality management on handling, processing and storage.

The key questions in the project were:

- What are the effects of super chilling on the whole fish regarding quality and shelf life as compared to traditional icing?
- How do the quality methods reflect the cooling systems, quality and shelf life of the fish?
- Are these cooling and quality methods important for the fisheries sector in the country?

1.5 Project Justification

Fish is the largest single source of animal protein for the majority of Sierra Leoneans, which account for about 80% of the total animal protein consumption (EU Delegation 2009). Immediately after catching, fish spoilage starts. However, the rate of spoilage is different depending on the cooling system, ambient conditions, fishing technology, fishing equipment, species of fish, catching season, handling and preservation methods. Commonly the spoilage due to autolysis occurs first and is followed by spoilage due to bacteria and rancidity.

Maintaining good quality of fish raw material for processing and the type of cooling system is very important. Both the Ministry of Fisheries and the Competent Authority supervise the compliance of fishing vessels and establishments involved in the EU fish production chain. Key issues to be addressed in the effort to meet EU requirements for fish export from Sierra Leone to the EU are:

- Standards for handling fish and fisheries products from the fishing vessel to the consumers (fish receiving centers at the landing sites, water quality and ice availability and quality)
- Fish processing (modification of existing smoking techniques, improvement of drying techniques, and fresh fish processing materials and equipment)
- Fish storage (provision of cold rooms, use of ice)
- Appropriate Food Safety and Quality Control measures

Thus, the rapid development of globalization in the International food trade and in fish and fishery products has shown a parallel increase in the emphasis on quality and safety of food entering the National and International market. Hence, exporters of fish and fishery products from developing countries must meet certain 'quality requirement in getting access to markets in industrialized countries, which has increasing demand and rigorous regulations on health standards and trade. The presence of fish and fishery products on the export markets depend on:

- The ability to meet the standards and guidelines of the Codex Alimentarius included in the national legislation of the country.
- The gradual adaption/adoption of the regulatory framework governing international trade in fish and fishery products is contained in the Agreement of the World Trade Organization (WTO) and the Agreement on Sanitary and Phytosanitary (SPS) measures.

Hence, a guide is needed for the fishing industries in Sierra Leone on quality changes of fish from catch to processing and during storage with focus on the different cooling practices. This will help in facilitating export requirements on fish and fishery products from Sierra Leone to the EU market and the world at large.

2 LITERATURE REVIEW

2.1 Quality Assurance of Fisheries Industries at International Levels

Generally, quality is the key to successful market access, which creates increase in revenue collection for producers/exporters and country as a whole. Quality is based on consumer satisfaction, and in delivering safe, legal and consistent products. Thus, quality assurance creates a system that has the different requirements of different markets based on the expectations of the consumers (Huss *et. al.* 1992).

In the international marketplace, there are stringent laws that exporters must meet in terms of technical specifications and requirements. In installing or establishing a quality assurance system in the fisheries industry of a country, efficiency and effectiveness must be ensured in improving the competitiveness of enterprising in the developing and transitional countries by enhancing their capacity to meet technical requirements in export markets and overcome technical barriers to trade.

Global trade and marketing of goods and services is the framework of the trade rule established by WTO. Developed countries use Sanitary and Phytosanitary (SPS) and Technical barriers to Trade (TBT) in regulating their market, facilitating trade, protecting the

consumers and the environment especially in the fisheries industries. Less developed countries find it very difficult to implement the SPS and TBT agreement, but seek technical assistance for these agreements to be implemented in order to avoid the creation of unnecessary barriers to trade of fish and fisheries product (Massaquoi 2010).

More than 50% of fish and fishery products involved in international trade are from developing countries. About 80% of world fish and fishery product imports are sent to the European Community, Japan and the United States. These economies dominate the market both in terms of prices and quality requirements. Many developing countries export some fish and fishery products that provide the major source of foreign currencies and revenue collections. But, exporters of fish and fishery products in developing countries are constrained due to the different standards and regulations imposed by importing countries in the international market. The differences between the legislation, organization and function of inspection services cause obstacles for developing countries in meeting EU export requirements. Also, the different certificate requirements and language barriers of different countries create inconveniences for the exporter and government regulatory authorities (Huss *et al.* 1992).

Very recently, developing countries have started using an advanced Quality Assurance System that will ensure high quality of fish and fisheries products for consumers with financial and technical input/support in the development of a Quality Assurance System from the buying fisheries industries in developed nations.

A developed country like Iceland with a good Quality Assurance System in place in the fisheries industries, and laws and regulations that cater to the requirements of the importing countries, creates a good model for Sierra Leone to follow. Also, the Icelandic seafood market works with the regulations and requirements of European Union Directives in line with the Icelandic Standards on fish safety and quality assurance. The Icelandic Government provides financial and technical support to developing countries like Liberia, Sierra Leone, Ghana, Uganda, Mozambique, South Africa and Namibia for the development of Quality Assurance Systems in these countries through the UNU-FTP and other agencies. Thus, in Iceland, the laws control all the activities related to seafood production, handling, processing and export and the regulations covering the hygienic operating requirement from importing countries create a working system the developing countries can learn from.

The Sanitary and SPS under the WTO is expected to continue between various national standards and inspection bodies with the aim to create non-tariff trade barriers. Meeting the harmonization of food safety objectives on hazard analytical critical control point (HACCP) principle by the Codex Alimentarius Commission is important in the channel of seafood trade at the international level (FAO 2001).

Thus, the enforcement of the laws and regulations on food safety and quality by a national authority and implementation of the HACCP principle in quality assurance by producers the fish industry will solve the problems of export requirements to the EU and other International markets on fish and fisheries products of developing countries like Sierra Leone.

2.2 Quality Assurance of Fisheries Industries in Sierra Leone

The Ministry of Fisheries and Marine Resources is currently facing challenges on access of fish and fisheries products to the EU markets. Thus, the Ministry facilitated a visit of the EU Inspection team in October 2009 in accessing the capacity of Sierra Leone to comply with the EU export requirements of fish and fisheries products to the EU market (FVO Reports 2009).

The report concludes that, in general, the system of public health controls in Sierra Leone cannot offer guarantees equivalent to those foreseen in the EU for the production of fishery products. The national standards analysed during the mission were generally in line with community requirements. Only one company fulfils the requirements for official controls for water and ice in line with the relevant EU community requirement. Written procedures to form a quality manual for the work of the CA are currently being developed (FVO Reports 2009).

Also, the system of official controls has deficiencies in implementation and no monitoring plans for tests of FPs and water/ice. Vessels, cold stores, ice factories and processing establishments visited during the mission did not meet all required community standards. The report addresses the Competent Authority of Sierra Leone and has a number of recommendations aimed at rectifying identified shortcomings and enhancing the control system in place.

The outcome of an EU Food and Veterinary Office (FVO) mission in Sierra Leone carried out between 19 and 23 October 2009 gave the following recommendations:

- To ensure official controls for FPs intended for the EU Market through Organoleptic checks, freshness indicators, Histamine, Microbiological tests, contaminants including heavy metals, Dioxins, PCB's and Poisonous FP.
- Official controls for water and ice and the appropriate training for the water quality laboratory to be in line with the requirements (FVO Reports 2009).

Finally, support from United Nation Industrial Development Organization (UNIDO) and EU to establish accredited laboratories is still on-going to ensure that laboratories performing official analyses are assessed and that adequate Quality Controls are in place to provide for the reliability of the test results.

2.3 Fish quality

The word quality is an aesthetic concept which means the 'totality of characteristics of a recently harvested product that bear on its ability to meet stated or implied requirements. The product is characteristics of the species and may be live, whole, in fillets or in pieces' (Bremner 2002). Traditionally, fish quality is based on the degree of spoilage of the raw material or the product. The methods of quality changes in a fish are based on autolytic changes, oxidation of lipids and development of microbial growth (Huss *et.al.* 1992).

After fish are dead, their bodies can remain soft for a few hours but later become stiff. This phenomenon is called "rigor mortis." The fish stays in rigor mortis condition for a while, but then their flesh muscles become relaxed again and at that point the fish quality starts to deteriorate. The quality changes can easily be noticed and consist of changes in colour, odour, smell, taste, appearance and texture, and are therefore called sensory changes.

One of the differences between fish appearance before and after rigor mortis is that the fish muscle is more elastic before rigor mortis. The time of pre-rigor mortis and rigor mortis varies depending on the species. The rate onset and resolution of rigor mortis varies from species to species and is affected by temperature, handling, size and physical condition of the fish.

Autolysis has been known for many years to lead to one of the two types of fish spoilage, bacterial and enzymatic (autolysis). For cod and yellowtail tuna, enzymatic changes related to fish freshness preceded and were unrelated to changes in the microbiological quality. In some species like herring and squid, the enzymatic changes precede and predominate the spoilage of chilled food. Bacteria are capable of causing spoilage for two reasons. First they are psychotropic which multiply at refrigerated temperatures. Secondly, they attach various substances in the fish tissue to produce compounds that are associated with off-flavours and off-odours.

In fresh iced fish, fat oxidation usually occurs after autolysis and bacterial spoilage. The lipid concentration in fish can contribute to the spoilage process in fish. The fats in fish are mainly unsaturated fatty acids that are easily oxidized by oxygen from the atmosphere. High temperature or exposure to light can increase the oxidation rate. For fatty fish preserved in ice, spoilage due to rancidity is mainly caused by oxidation. This produces an unpleasant odour as well as a rancid taste. Fatty fish species like herring, mackerel and salmon are mostly affected by rancidity.

A quality fish is one that has been harvested without undue stress, processed and handled by good manufacturing practice, and has the characteristic shape, size, appearance, colour, odour, flavour, textural composition and other properties of the species type. Proper cooling during the whole value chain is a key factor in maintaining maximum quality as long as possible.

2.4 Cooling and its importance in the Fisheries Sector

Cooling and handling of fish affect all stages of the value chain from catch to market. The fish quality depends on the impact of fish handling, processing, storage and logistics on fish quality deterioration. Thus, care must be taken to handle fish properly at all stages during processing to ensure the highest quality and obtaining the most possible valuable products.

The condition of the raw material is vital for the quality and utilisation of the fish. Factors, which can affect the raw material quality, are fishing season, fishing area, fishing gear, nutritional status and age of raw material, rigor mortis and handling before and after processing.

The factors that are important during each step of the processing in a fisheries industry are; hygiene, relative humidity of air, temperature control, and handling. The two main tasks in cooling are the fast reduction of the product temperature down to the desired low temperature and maintenance of the temperature over a longer period. In connection to some processing operation or storage and the maintenance at a constant low temperature over a longer period during storage or transport, fast reduction of the temperature is achieved by cooling equipment. So, the aim of precooling in fisheries industries is to slow down the process of

microbial growth by lowering the temperature and it ensure the fresh fish products receive optimum handling (Valtýsdóttir *et.al.* 2010).

According to regulations of the Administration of Occupational Safety and Health in Iceland (AOSH) with regard to work in cold rooms in food processing industry, the ambient temperature should be as close to 16°C as possible on regular basis. The temperature should not drop below 10°C on regular basis implying that continuous work cannot exceed 1 hour, or maximum 2 hours per day. Because all these factors are linked to the quality of the product, the failure of one of them may result in a shorter product shelf life (Valtýsdóttir *et.al.* 2010).

The different types of cooling systems used in the fisheries industries in Iceland are liquid ice, flow-ice, flake ice, and Combined Blast and Contact (CBC) (super chilling). The CBC cooling is the most advance cooling technique for fisheries industries and it was developed by Skaginn hf. In this cooling system, heat is extracted from fillets both by conduction through a Teflon coated aluminium conveyor belt and by convection, where cold air is simultaneously blasted over the fillets. Liquid cooling is a part of the CBC cooling process. It is performed before the CBC cooling to decrease the temperature of the fillets and slightly increase their salt content. Liquid cooling of fillets can be used to lower the temperature in process prior to packaging. Microbiological quality of the cooling medium, its renewal and temperature control are necessary for success. Otherwise, high microbial load of specific spoilage organisms (SSO), mainly *Photobacterium phosphoreum*, pseudomonads and H₂S-producing bacteria, in the cooling medium will lead to contamination of the fillets and rapid growth of SSO during storage of the products, especially under temperature abuse (Valtýsdóttir *et.al.* 2010).

However, the impact of CBC cooling on the temperature maintenance of abused fillets has been found to be considerable when compared to liquid cooling only (LC) in processed or untreated fillets. Fillets treated with CBC and LC were found to have 100% and 25% extended shelf life, compared to regular fillets with a shelf life of 6 days. Processing from CBC cooling can lead to freshness and shelf life extension of cod fillet. It is therefore an advantageous method to process fillets to be shipped as fresh products because it will help in maintaining freshness and shelf life despite breakage in the cold chain. Furthermore, a bacterial growth-retarding effect of CBC processing on SSO has been observed (Magnússon *et.al.* 2009).

2.5 Sensory evaluation of a fish

Sensory evaluation is defined as the scientific discipline used to evoke measure analyses and interpret human reactions to characteristics of food perceived through the senses of sight, smell, taste, touch and hearing. Sensory evaluation is a systematic assessment of the odour, flavour, appearance and texture of food. Sensory assessment is a direct measurement that is performed in a proper way, rapid and an accurate tool, which provides unique information about food.

Sensory analysis is a daily occurrence in food companies. The tasting of fish products involves maintaining the awareness of a company or competitor products, promoting company products to potential customers, demonstrating latest products to the sales team, keeping the project team or management up to date on product development progress or production issues, seeking customers' approval, and deciding on changes to products and

checking that product quality matches a target or meets a specification. Using sensory analysis portrays professionalism, which benefits the company in its dealings with the customers. Sensory analysis tackles the issues raised in product assessment minefield, based on scientific approaches to obtain complete and appropriate information about sensory quality. Also, it takes into account sources of unwanted error through control of environment and sampling through experimental design and by selecting the most appropriate instruments to make measurements (Lyon *et al.* 1992).

Sensory perception is the most important method for assessing freshness and quality in the fishery sector. Generally, sensory evaluation is carried out in the fish industry from the landing site, processing and marketing by a trained assessor/quality manager of the company. Sensory evaluation measures the freshness quality of the fish, which is dependent on the holding temperature and time of catch. Thus, many quality conscious buyers in fisheries markets demand a documentation of fish quality from the processor and distributor to secure tasty, safe and nutritious products (Huss *et.al.* 1992).

The sensory methods used in evaluating the freshness and quality changes of a fish are Quality Index Method (QIM), Quantitative Descriptive Analysis (QDA) and Torry scores. Regulations in the European Union require freshness grading of most fish to be marketed within the Union [EU 2406/96]. Today, freshness grading of fish relies on a particular EU scheme and is usually carried out in auctions by trained personnel.

2.5.1 *Quality Index Method (QIM)*

The QIM is based on the significant sensory parameters for raw fish when using many quality parameters and score system from 0 to 3 defect points (Martinsdóttir *et.al.* 2001). The table in Annex 1 shows the QIM scheme for the cod (*Gadus morhua*) (Martinsdóttir *et.al.* 2001). Whole and gutted fish are assessed for appearance, odour of skin, outer slime, eyes, gills and belly cavity. Fish are then placed in the grades Extra (E), A, B or Unfit (C) on the basis of schemes for different groups of species. Hence, the QIM is a seafood freshness quality control system that was developed by European Fisheries Research Institute (CXSIRO) in Hobart, Australia (Martinsdóttir *et.al.* 2001).

The scores for all the characteristics are added to give an overall sensory score, the so-called quality index. QIM gives scores of zero for very fresh fish and an increase in total results as the fish deteriorate. The selection of parameters for QIM is determined as a combination of the best descriptors for the spoiling fish, which also fulfil the aim of giving a linear correlation to the shelf life. The remaining shelf life (in days on ice) can be predicted on the basis of this line and knowledge about the corresponding quality index at the time of rejection. The QIM with low scores indicate very fresh and newly caught fish, which may be useful feedback to give to fishermen concerning the quality of their catch, and may result in better handling on board. The direct relationship between QIM scores and storage time makes it easy to calculate shelf life of fresh fish when stored at 0°C as shown in the Figure 2. A straight-line relationship between storage time and QIM score had been determined for many species when stored at 0°C (FETM 2000). For a few fish species, the straight-line relationships have been observed at different storage temperatures as well. The QIM method is a fast and convenient method to determine the freshness of fish. It is very important that assessors (observers, factory staff) conducting the evaluation are properly trained and experienced to guarantee reliable results (Martinsdóttir *et.al.* 2001).

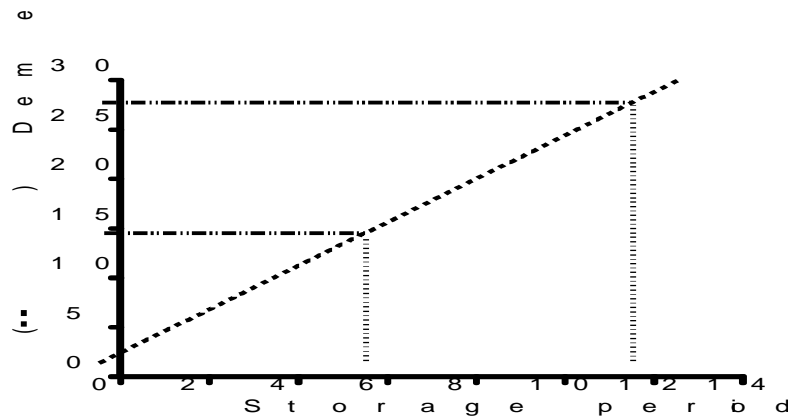


Figure 2: Evolution of sensory scores as determined by a QIM scheme (Source: FETM 2000).

2.5.2 Quantitative Descriptive Analysis (QDA)

Quantitative Descriptive Analysis (QDA) involves the appearance, shape, colour, surface texture, odour character and intensity, flavour character and intensity, texture, initial bite, during chewing, residual, mouth feel, mouth sensation, after-taste linger, and duration character (Stone and Sidel 1998).

The QDA method can be used to describe the sensory characteristics of cooked fish regarding flavour, odour, texture, and appearance properties. With the QDA method a complete description of the sensory properties of a specific product is provided. Each panellist judges each product property separately and the data can be treated statistically (Sveinsdottir *et al.* 2002).

Panellists are trained from a large group based on their ability to distinguish between differences in sensory properties among samples of the specific product type. The panel leader asks like a facilitator, not like an instructor, and has no influence on the decision making of panellists. In a sensory room, there are separate booths for panellists to evaluate products in order to reduce interaction and distraction. Individual score sheets are collected and data are computerized with a card or digital reader directly from the score sheets (Meilgaard *et al.* 1999).

The QDA scale is shown in Annex 2 (Bonilla *et al.* 2007).

2.5.3 Torry Scores Method

The most used scale for evaluating the freshness of cooked fish is the Torry-scores, which is used in the fish industries and by buyer of fish products in some countries (Shewan *et al.* 1953). The Torry Research Station developed the Torry-scores with a descriptive 10-point scale for lean, medium fat, and fat fish species. The scores are given from 10 (i.e. for very fresh in taste and odour) to 3 (spoiled) and description below 3 is considered unnecessary, as the fish is then not good or fit for human consumption. The average Torry-score of 5.5 is used as the limit for consumption. Thus, the sensory panellists detect sour taste and hints of 'off' flavours that indicate spoilage characteristics. The Torry-scores method explaining the freshness of the cooked fish and score sheets for assessment of cooked odours and flavours of iced lean fish is shown in Annex 3.

2.6 Chemical Methods

Chemical methods to measure freshness quality have been considered to be objective methods and therefore superior (less variable) to methods involving sensory evaluation. During post-mortem storage, microbiological spoilage may occur, which cause the formation of volatile bases that can determine indirectly the freshness quality of such seafood. Chemical methods or analysis of fish is to evaluate or measure freshness of raw material of the fish such as TVB-N, trimethylamine (TMA), ammonia, biogenic amines, ethanol, and indol.

The TVB-N remains constant for the first days of storage or increases slowly but rises fast later in the spoilage process. Therefore, TVB-N is a very good indicator of spoilage in fish. The European Commission (Council Regulation No. 95/149/EEC of March 1995) specified TVB-N limits to be used if sensory evaluation indicates doubt about freshness of different fish species. Critical limits of 25, 30 and 35 mg TVB-N/100g were established for different groups of fish species. The methods for determination of TVB-N are by distillation of volatile amines, which involves the direct distillation of sample with MgO. In processed, lightly or semi preserved, seafood levels of TVB-N at sensory product rejection are more variable. The EU Regulations on Foodstuffs that covers the area of chemical analysis for fish and fisheries products is Commission Regulation (EC) No 1881/2006 of 19 December 2006 setting maximum levels for certain contaminants in foodstuffs. Annex 4 shows the EU limits for TVB-N in certain fish products.

2.7 Microbial Methods

During post-mortem storage, microbiological spoilage may occur, which cause the formation of volatile bases that can be determined indirectly in measuring the freshness quality of such seafood. The Commission Regulation (EC) No 2073/2005 of 15 November 2005 on microbiological criteria for foodstuffs is the EU Regulations on Foodstuffs covering the area of microbial analysis for fish and fisheries products.

3 MATERIALS AND METHODS

The sample collection, sensory evaluation, microbial and chemical analysis in this project involves the use of a fisheries laboratory, which is currently not available in Sierra Leone. So, this aspect of the project was done at Eskja Fishing Company and Matís Laboratory in Iceland.

In pursuings of this project, the following activities were undertaken:

3.1 Experimental design

In this experiment, the fish was caught by a long liner at sea in Iceland and was brought to the harbour in Hafnarfjordur, Iceland on the 24th of November 2011 at 10.30am. After that, on-spot check, records of information on the raw fish was recorded in a computer by the quality manager or receptionist at Eskja for record keeping (Quality Check) and this document was sent to the Directorate of Fisheries for approval of the raw material before processing.

A forklift took the raw fish to the weigh house or auction market for weighing before it was stored or taken into the processing plant. At 12.00, the raw fish was transported through a vehicle from the landing site to the Eskja Company for further processing into fillets or flesh salted fish. The fish was immersed in slurry ice and stored in two containers, with one to undergo Super Chilling (SC) processing and the other Non-Chilling (NC) in order to maintain temperature between 1 and 0°C. At the Eskja Fisheries Factory a part of the whole fish was super chilled in the processing hall. Before cooling of the fish, the temperature loggers were placed on the four corners of two containers with role tie on to it for temperature reading of the fish. The non-superchilled fish was iced at 11.30 into a container and did not undergo CBC cooling. Then the other container of fish with ice was transferred into the CBS cooling machine at 12:36. The fish was cooled for 17 minutes at 12:53 and then weighed using the electronic machine, and the weight recorded was 361 kg at around 12:55. At 13:03, the fish sample was transported in a vehicle with cooling system to Matís and stored in cold room for sensory and non-sensory measurements of the whole fish.

Sampling was done on days 1, 4, 6, 11, 14 and 18 post catch. The sensory evaluation was done using QIM Score for the whole fish and the cooked sample was evaluated using the QDA and Torry Methods. The Non Sensory measurements involved the microbiological and chemical analysis for E.coli or total viable psychrotrophic counts (TVC), H₂S producing bacteria and TVB-N.

The experimental groups were as follows:

- A. Super chilled with liquid ice pre-cooling on-board, liquid cooling and combined blast and contact cooling at processing plant, stored at -1°C at Matís.
- B. Not chilled with liquid ice pre-cooling on-board, liquid cooling at plant, stored at -1°C at Matís.

3.2 Temperature Measurements

The fish was immersed in slurry ice and stored in two containers, one for super chilling and the other non-chilling processing to take place in order to maintain temperature between -1 and 0°C. Temperature at the time of packaging was measured with a handheld thermometer, type TFX410 (Ebro Electronic, Ingolstadt, GER), with a resolution of 0.1°C and accuracy of $\pm 0.3^\circ\text{C}$. Seven types of temperature loggers were used for the temperature measurements. Four types of loggers were used for SC fish, 890, 877, 940, 936 and two loggers for NC fish, 414 and 879, for the product temperature inside the wholesale fish container.

Product temperature was measured close to the centre of the whole and fillet stack in each of the one to two boxes of each experimental group that were investigated. Product temperature was recorded at 2-10 minute intervals and read from the loggers at the end of the experiment.

To measure the ambient temperature, four temperature loggers (i.e.858, 906, 435 and 939) for SC and two loggers for NC (i.e. 884 and 740) were used. The 740 and 884 ambient loggers were applied in the NC container and the 858, 906 to the SC container for the whole fish and right after packaging for the fillets, and the 439, 939 loggers to the SC fish and container. Thus, the temperature conditions from packaging during transport to the air climate chambers at Matís were obtained. But two (439, 939) of the six ambient temperature loggers were used for the steady storage temperature groups and dynamic storage temperature groups, respectively. In both cases, the loggers were distributed inside the chamber and container in order to grasp the spatial temperature differences. Temperature was recorded at 1-10 minute

intervals and read at the end of the experiment. After the eighteenth day, the temperature readings of the loggers were taken.

3.3 Sensory Methods

3.3.1 Quality Index Method (QIM)

Thirteen people participated in the sensory evaluation of the whole cod with the QIM scheme. They were employees of Matís, 10 out of the 12 were trained panellists in QIM scheme from Iceland and the thirteenth assessor from Sierra Leone.

Observations of the cod were carried out under standardized conditions at room temperature using electric light and with no distractions in the sensory laboratory and room. Samples of the cod were collected from the ice container/tubs and placed on a table for 30 minutes before the evaluation. Each cod was coded with a random three-digit number unrelated to storage time. Both sample from each group were evaluated with the QIM scheme for cod (Martinsdóttir *et.al.* 2001) on days 1, 4, 6, 11, 14 and 18 post catch. On each storage day, three samples from each group (SC and NC) were evaluated.

3.3.2 Quantitative Descriptive Analysis (QDA)

QDA as described by Stone and Sidel (1998) was used to assess the cooked cod. Six samples with skin were collected from each fish, all from the loin part, collected by cutting from the spine to 2cm below the lateral line. The samples were placed in coil boxes and coded with three random digit numbers. The samples were cooked at 100°C in a pre-warmed oven (RATIONAL Combi-Dampfer CCM, Landsberg, Germany) with air circulation for 6 minutes. The criteria for the selection of attributes, which might be used to discriminate between days of storage, had to be relevant to cod and discriminate clearly between the samples and furthermore, be non-redundant, and unambiguous to the panellists. Specific words were designated to describe the quality parameters appearance, odour, flavour and texture of cooked cod in the QDA (Sveindóttir *et.al.* 2009).

In total, 12 panellists took part in the QDA evaluation. They were selected and trained according to International Standards (ISO, 1993) for the QDA assessment. The assessments were carried out in a sensory laboratory equipped with eight separate booths and a FIZZ sensory registration system (FIZZ Network, Version 1,1 b, Biosystemes, Couternon, France). On day 18, results were obtained from four panellists. This was because the fish was infected with worms, so it was only possible to use a small part of the fillet.

The QDA on the cooked cod was carried out in parallel to the QIM assessment. Each panellist evaluated samples in duplicate, but one by one in a randomised order from the six storage days in total. During data analysis, y-values for each omitted sample was averaged, thus giving an estimate of the prediction variance (Esbensen *et.al.* 1998). The QDA scale is shown in Annex 2.

3.3.3 Torry Method

In addition to the QDA, the panellists assessed the cooked samples according to the Torry score sheet. This was done in parallel to the sensory evaluation using the QDA method in the

sensory room at Matís base on the six sampling days (1, 4, 6, 11, 14 and 18). Also, the Torry scores sheet for lean fish is show in Annex 3.

3.4 Microbiological Analysis

The microbial measurements for this project was based on the tests for total viable psychrotropic counts (TVC) and counts for H₂S on the shelf life of fish that has undergone super chilled and non- super chill cooling system.

Total viable psychrotrophic counts (TVC) and counts of H₂S-producing bacteria were evaluated on iron agar (IA) as described by Gram *et.al.* (1987) with the exception that 1% NaCl was used instead of 0.5% with no overlay. Plates were incubated at 17°C for 5 days. Bacteria forming black colonies on IA produce H₂S from sodium thiosulphate and/or cysteine. Cephaloridine Fucidin Ceftrimide (CFC) agar was modified according to Stanbridge and Board (1994) and used for enumeration of presumptive pseudomonads. Pseudomonas Agar Base (Oxoid) with CFC Selective Agar Supplement (Oxoid) was used. Plates were incubated at 22°C for 3 days. *Pseudomonas spp.* form pink colonies on this medium. Counts of *Photobacterium phosphoreum* were estimated by using the PPDM-Malthus conductance method (Dalgaard *et.al.*1996), as described by Lauzon (2003). In all experiments, cooled Maximum Recovery Diluent (MRD Oxoid) was used for dilutions and agar media were surface-plated.

3.5 Chemical Analysis

The chemical measurements for this project were on TVB-N test and its base on EU Regulations (Annex 3). The materials for this measurements includes; Distillation Flask, Waring blender, Whatman no.3 filter paper, Kjeldahl type distillatory (Struer TVN), pipettes, beakers, condenser, graduated burette, balance scale and timer.

The methods for determination of TVB-N were done by distillation of volatile amines that involves the direct distillation of sample with MgO. Samples were taken at days 1, 4, 6, 11, 14 and 18 for the determinations of TVB-N. The method of and Tao (1987) was used for total volatile bases (TVB-N). TVB-N was measured by steam distillation (Struer TVN distillatory) and titration, after extracting the fish distillate. So, 100g of minced fresh fish fillets from the microbiological lab was mixed with 200 ml of 7.5% aqueous TCA solution and homogenized in a Waring blender. The mixture was filtered using a whatman n^o3 filter paper. 25 ml of the filtrate and 6 ml of 10% NaOH were transferred with a pipette in a distillation flask. Then, a beaker with 10 ml of 4% boric acid and 0.04 ml of methyl red and bromocresol green indicator was placed under a condenser for titration of ammonia. All analyses were performed from the same fish samples stored at 0°C and 8°C. After that, the flask and the beaker were placed in the distillator and distillation was done for 4 minutes. After 15 minutes, the boric acid turned green when alkalinized with distilled TVB-N and was titrated with 0.0364 N H₂SO₄ acid solution using a 0.05 ml graduated burette. Upon addition of a further drop of H₂SO₄ acid at complete neutralization, the colour turned pink. The results for the chemical measurements are shown below.

4 RESULTS

4.1 Temperature measurements

4.1.1 Ambient temperature from processor (Eskja Fishing Company) to Matís.

The ambient temperature measured base on the two different cooling systems with six temperature loggers is shown in Figure 3. The ambient temperature during this period from processor to Matís for the non-chilled (NC) was -1.4°C and for super chilled (SC) -1.3°C . But, the air temperature was not well controlled as shown in Figure 3. As indicated in Figure 3 the short peaks on days 1, 4, 6, 11 and 14 were due to the duration of these short temperature changes.

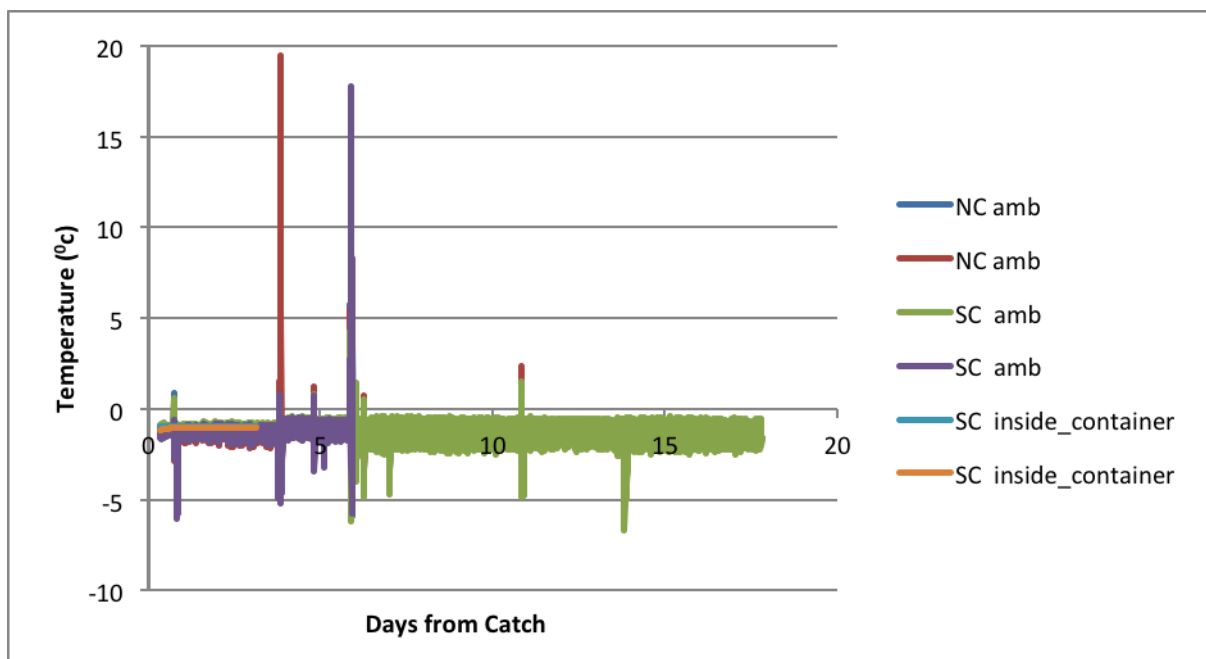


Figure 3: Ambient temperature for SC and NC Cod fish from Processor to Matís.

4.1.2 Product temperature from the processor to Matís.

The product temperature of the two groups SC and NC cod fish is shown in Figure 4. The product temperature for these two cooling systems in the experimental groups at the time of cooling was -0.8 , -1.07 for the SC, and -0.5 , $-0.4 \pm 0.2^{\circ}\text{C}$ for the NC. The mean product temperature over the period from cooling to the end of the experiment was $-1.25 \pm 0.2^{\circ}\text{C}$ and $-1.20 \pm 0.2^{\circ}\text{C}$ for groups SC and NC respectively.

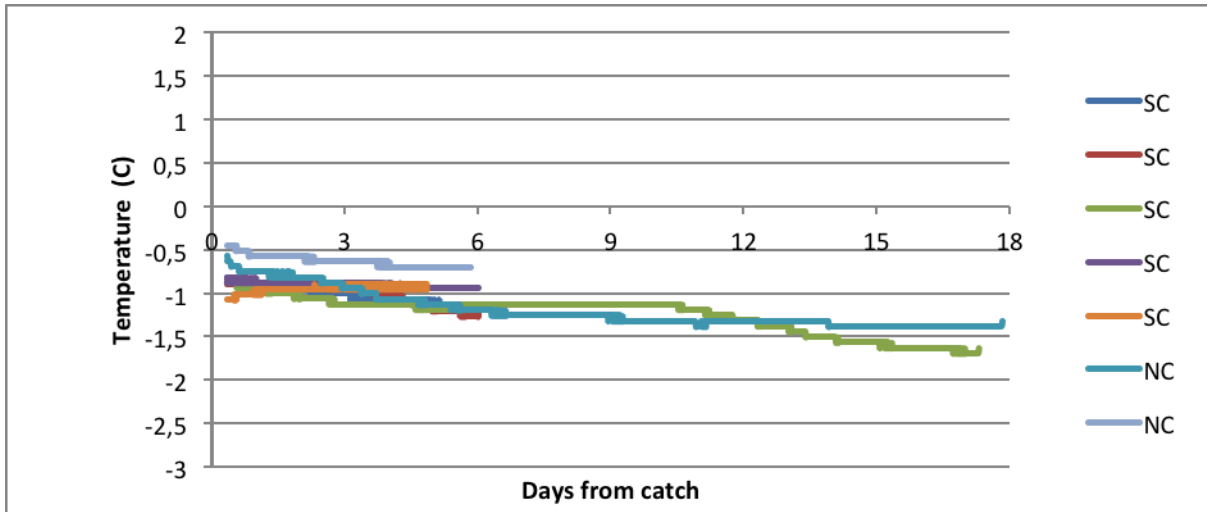


Figure 4: Product temperature of SC and NC Loggers from Processors to Matís.

4.2 Sensory Evaluation

4.2.1 Quality Index Method (QIM)

The results for panellists for the total Quality Index (QI) scores for the SC and NC cod fish is shown in Figures 5, 6, 7 and 8. Figures 5 and 6 show results of thirteen trained panellists. The results in Figures 7 and 8 show the result after removal of three panellists; two due to little experience in the QIM and one due to knowledge on the fish samples.

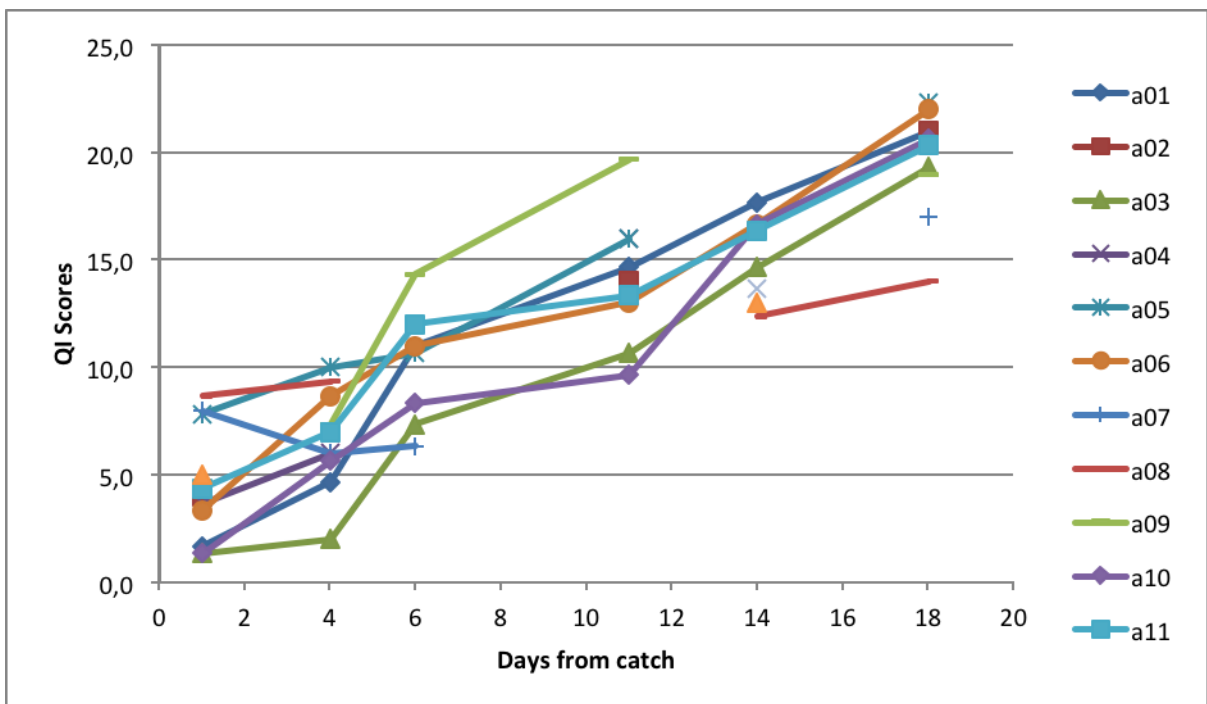


Figure 5: The QI scores by Individual QIM Panellists (a01-a13) for whole SC Cod fish.

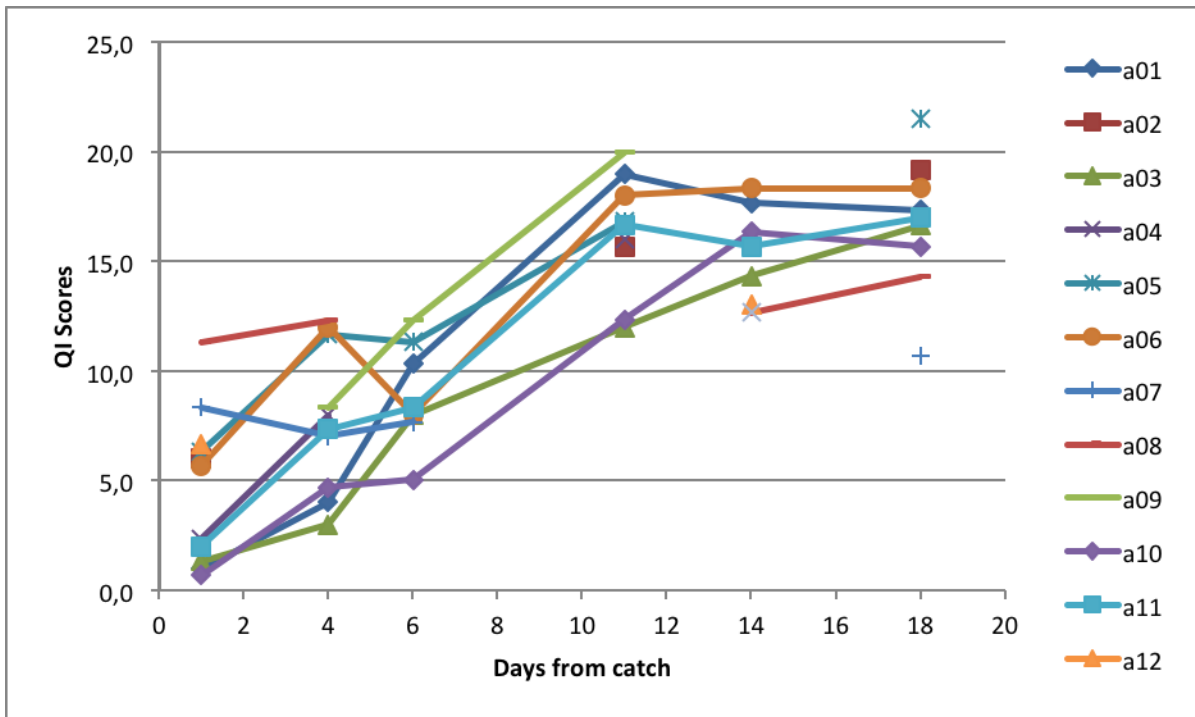


Figure 6: The QI scores by Individual QIM Panellists (a10-a13) for whole NC Cod fish.

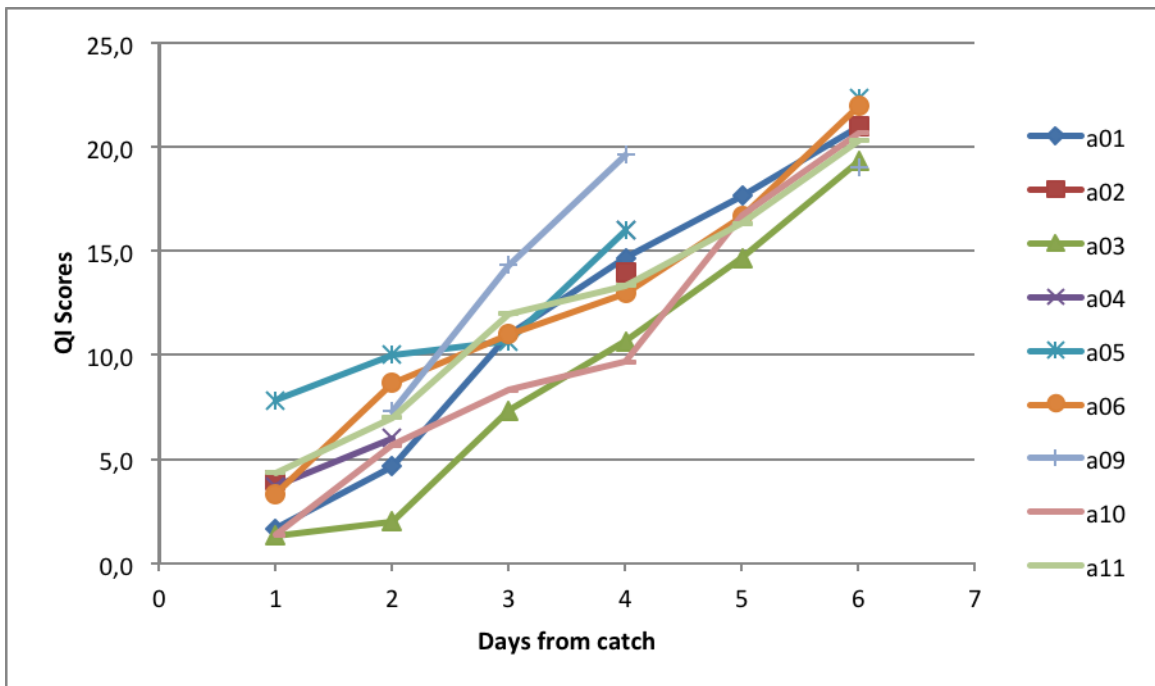


Figure 7: The QI scores for Qualified Panellists (a01-a06, a09-a11) for SC Cod fish.

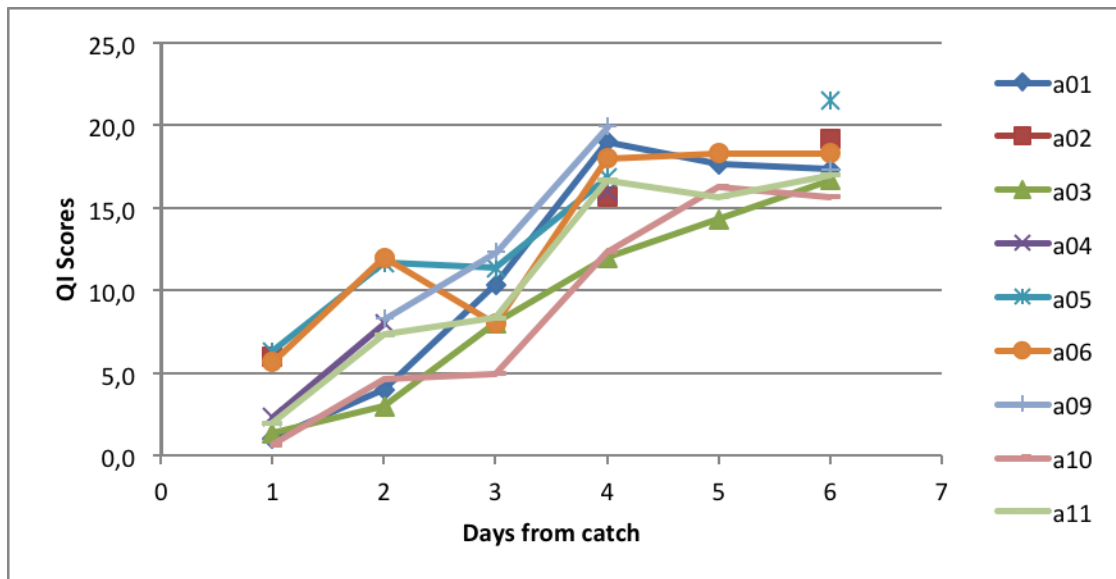


Figure 8: The QI scores for Qualified Panellists (a01-a06, a09-a11) for NC Cod fish.

An increase was observed in individual quality attribute scores with storage time, but to a different extent for different quality attributes, and different patterns were observed for the two sample groups (SC and NC) as shown in Figure 9. Photos of the fish demonstrating the visual aspects of the QIM Scheme, such as appearance of the eyes, gills and skin for SC and NC cod fish are in addition shown in Annex 5. On day 1, the fish showed convex and bulging eyes with bright blackish blue pupil. On day 4 and 6 the eyes of the SC fish became slightly sunken, grey and opaque, and the NC fish shows sunken, grey and opaque eye with brown colour around. On days 11, 14 and 18, the NC fish became sunk, concave, or round and opaque and the eyes of the SC fish were opaque with black spot around the eyes. On storage days 1, 4, and 6 the skin showed bright and blood reddish. On days 11, 14 and 18 the SC fish showed less brown and putrid smells than the NC fish with the gill sheet sunken. On days 1 and 4, the skin of the SC fish was in rigor, bright and tender than the NC fish. On Day 6, the NC fish were in rigor and tender similar to the SC fish. But on day 18, the SC fish decolourized and was in post rigor while the NC fish was still in rigor and less tender. Thus, the changes in the appearance of the eyes, gills and skin depend on the type of cooling system and cooling effects.

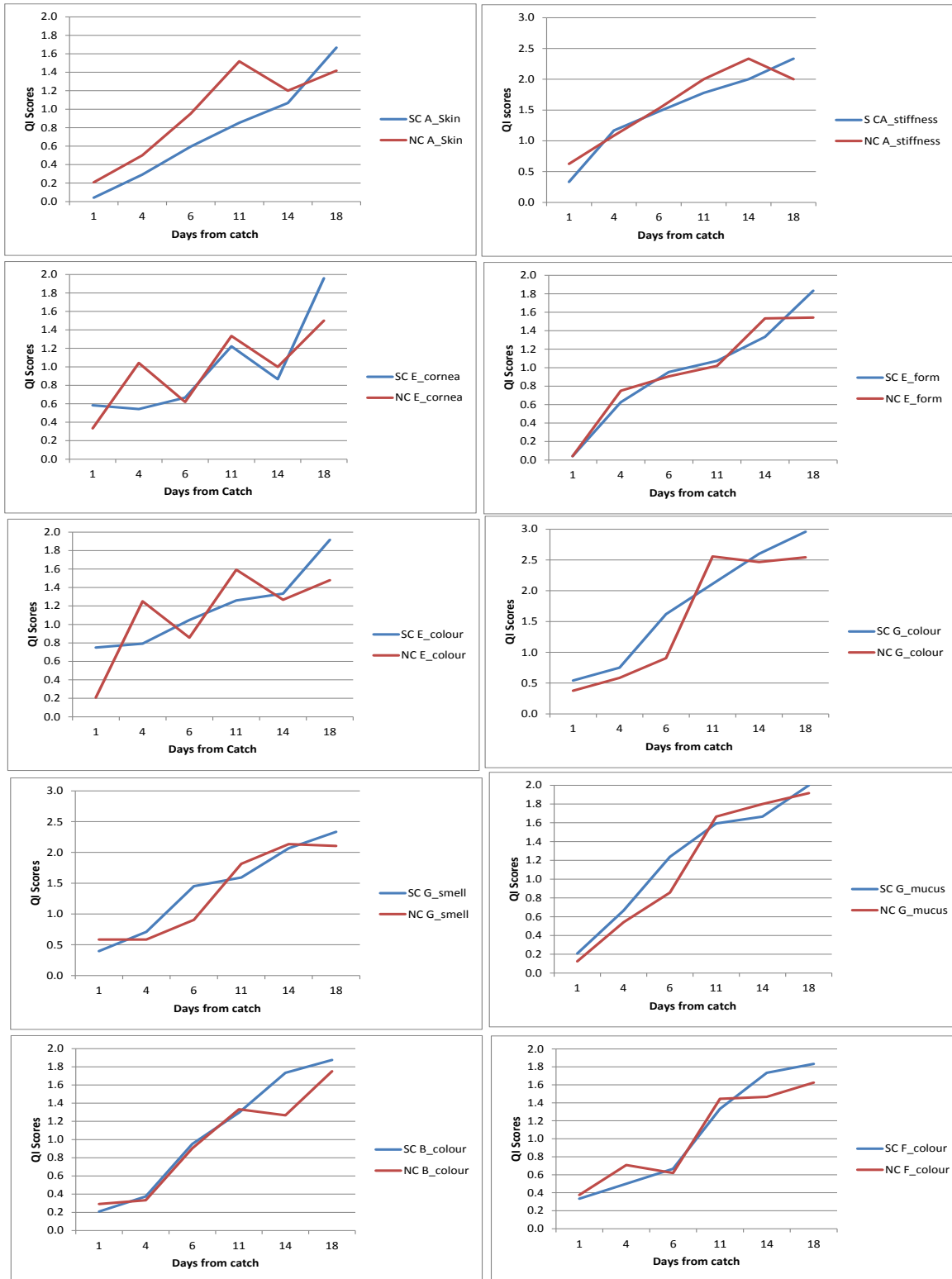


Figure 9: QI scores for each quality attribute (A=appearance, B=Blood, E= Eyes, F= Fillets, G= Gills) with days after catch.

Figure 10 shows the average QI Scores for the two groups (SC and NC) with storage time. The regression lines for the two groups were $y = 0.9856x + 3.0859$ for SC and $y = 0.8962x + 3.6355$ for NC. The QI scores increased linearly with storage time. The slopes are very

similar for SC and NC, which could indicate that there were no significant differences between the two cooling systems and the remaining shelf life (in days on ice) could be estimated on the basis of this trend line and knowledge about the corresponding quality index at the time of sensory rejection.

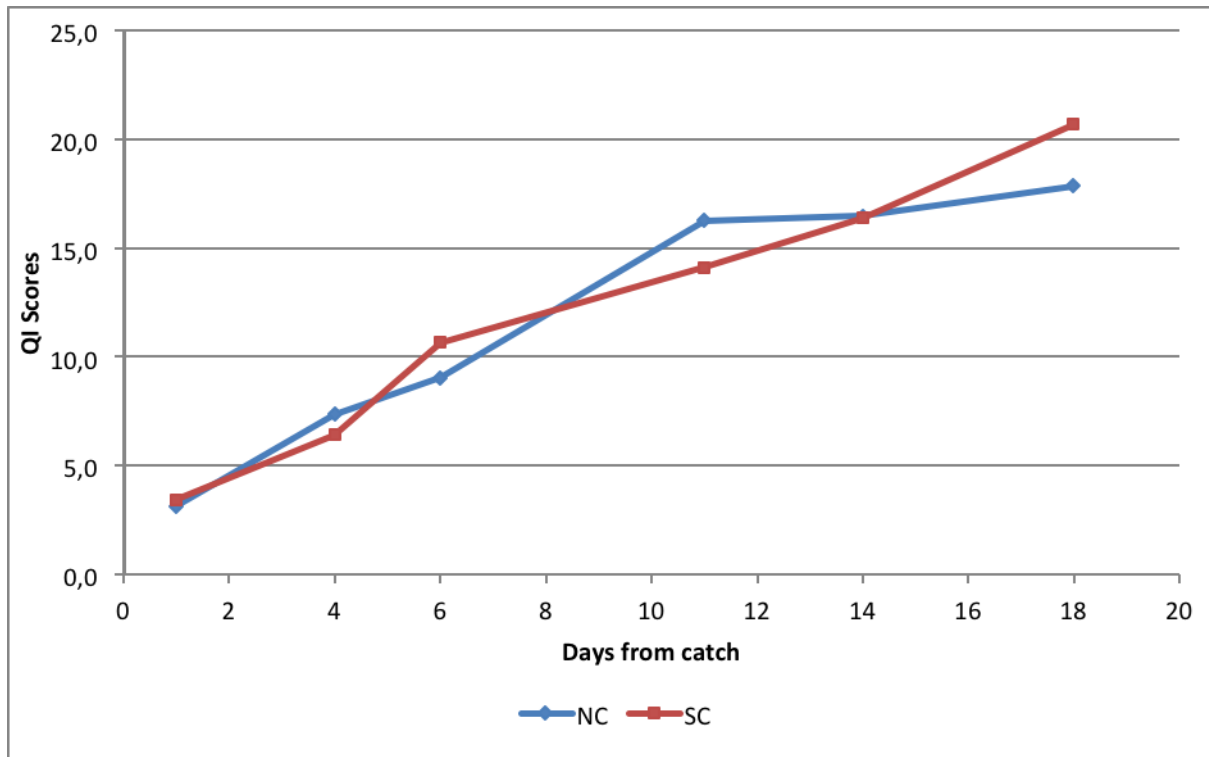


Figure 10: The QI Scores for super chilled and non chilled fish.

4.2.2 Quantitative Descriptive Analysis (QDA)

Figure 11 shows the spoilage (sour, pungent and TMA flavour) and odour (dishcloth, sour and TMA odour) changes with storage time for SC and NC group. Figure 12 shows how the texture attributes change with storage time for the SC and NC groups. Figure 11 shows that at the early stage of storage time of cod fish, there was an increase in QDA scores for flavour and odour for the SC but less for the NC fish. However, in Figure 12, towards the later part of sampling or storage there was an increase in QDA score on texture for meaty, astringent and rubbery for both groups, but more for the NC group than SC, which could be due to the type of storage condition and temperature of the NC fish. Both groups became less soft, juicy and tender with storage time. Both groups become less mushy with storage time.

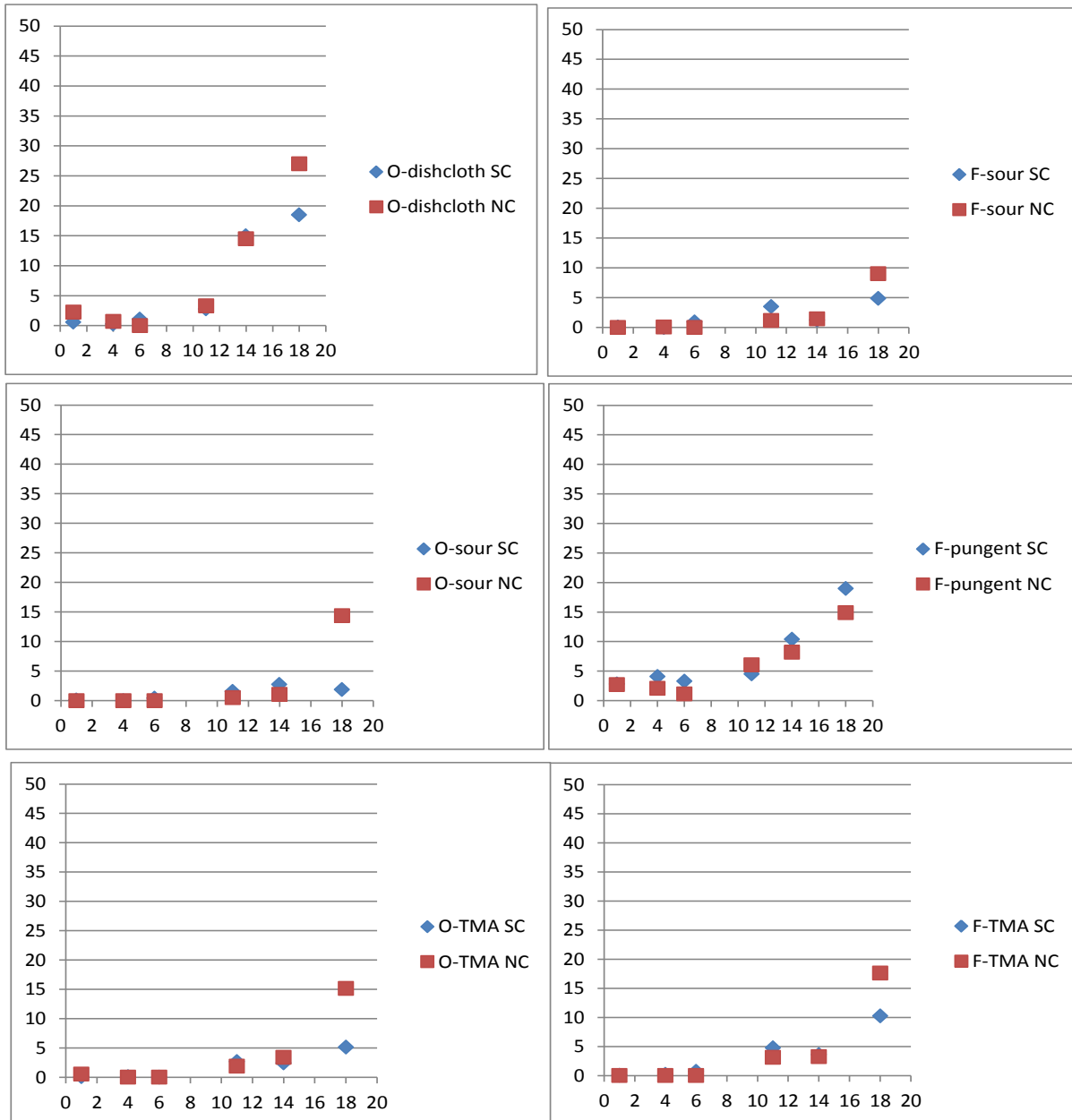


Figure 11: QDA scores (0-100) for odours (O-) and flavour (F-) relating to spoilage for SC and NC Cod fish.

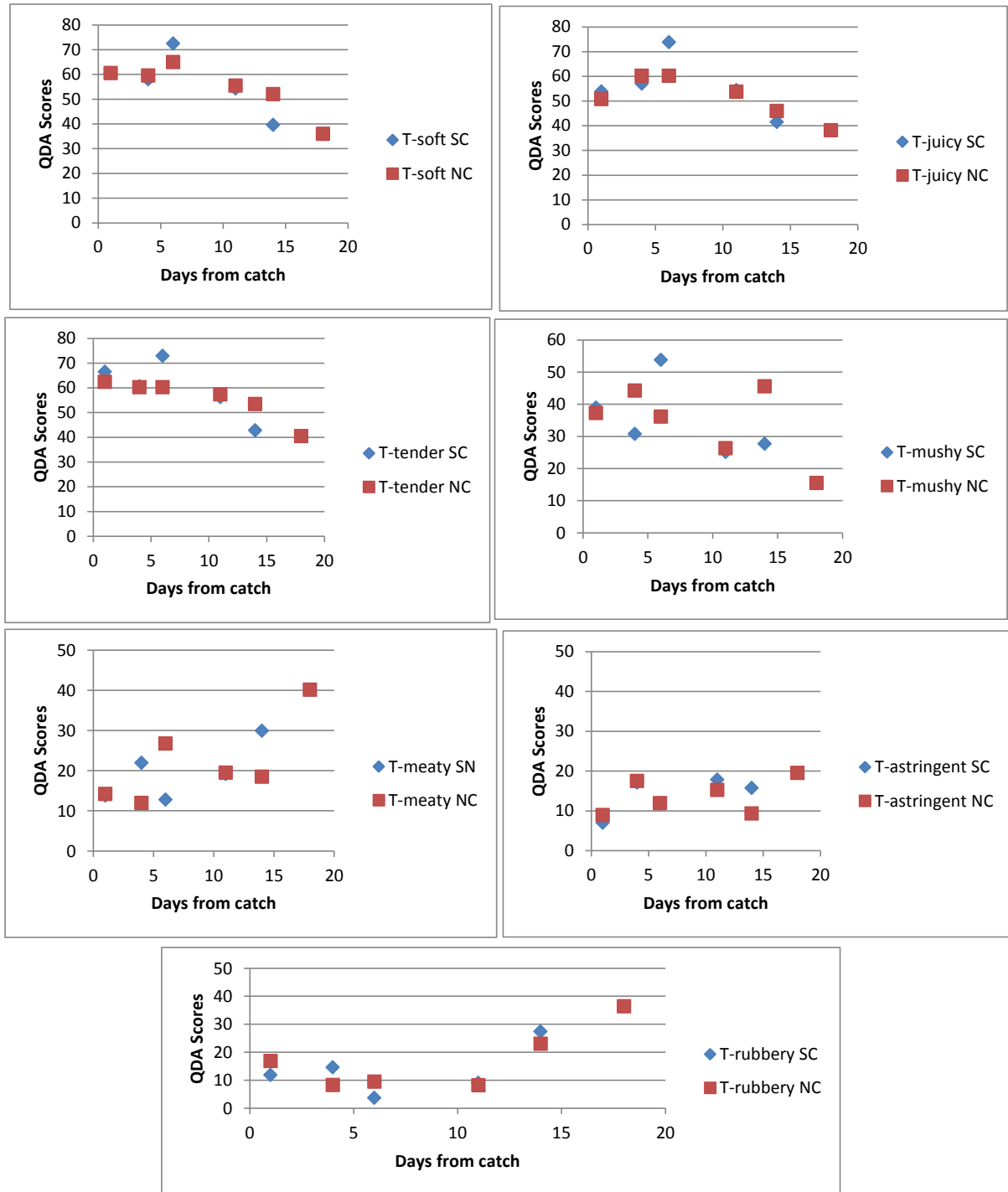


Figure 12: Mean QDA scores (0-100) for texture (T-) of the SC and NC Cod fish.

4.2.3 TorryMethod

The results from the sensory evaluation with the Torry method are shown in Figure 13. The light blue line on the graph indicates the end of shelf life (i.e. Torry Score 5.5) and it is the Torry limit for cod because at this score most of the panellists start to detect spoilage attributes in the fish.

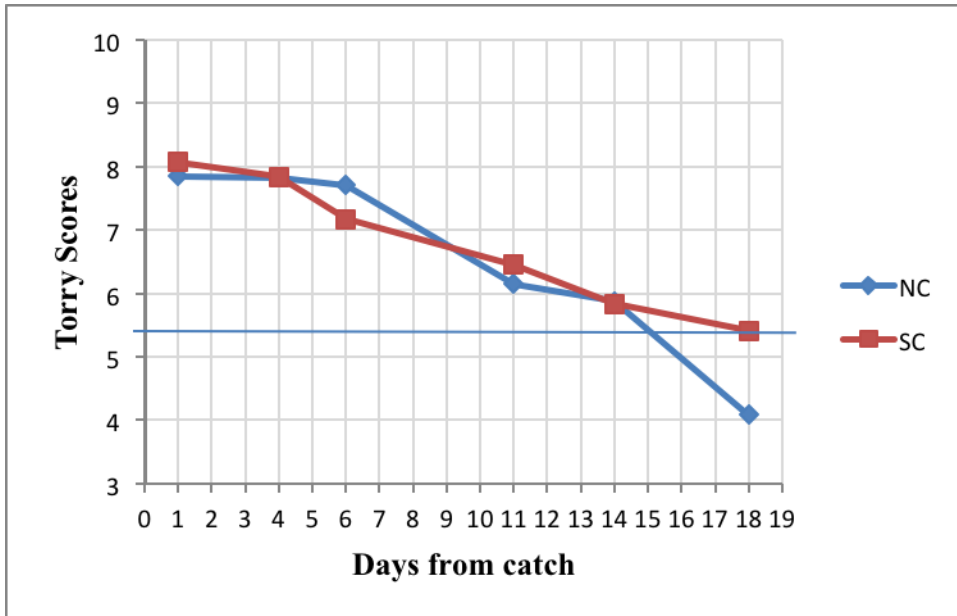


Figure 13: Torry Scores for SC and NC Cod fish with days from catch.

4.3 Microbial analysis

Figure 14 shows the Total Viable Counts (TVC) for SC and NC cod fish and days from catch. Figure 15 shows the growth of H₂S producing bacteria in Cod loins. The H₂S counts were higher for the NC cod fish than the SC cod fish at the end of the experiment (day 18). This could indicate that the SC cod fish has a higher resistance to microbial growth than NC due to its cooling effects and temperature measurements of the fish. Microbial results showed that the total viable counts (TVC) were similar for the two groups at storage day 18, though slightly higher for NC at 6,2 log compared to 5,6 log for SC. At the same time, the number of H₂S producing bacteria were higher for the NC at 5,4 log, compared to 4,5 log for SC.

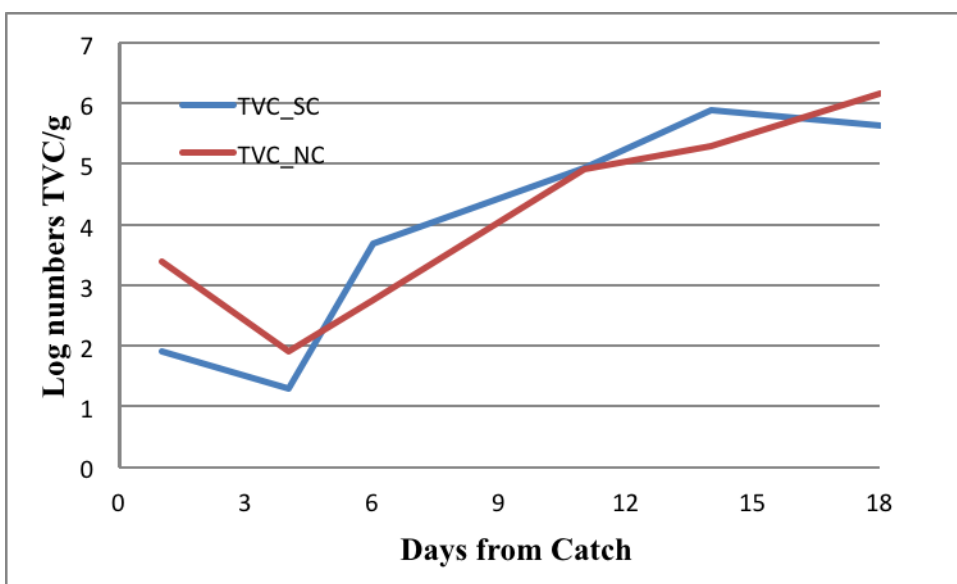


Figure 14: Total viable counts (TVC) for SC and NC Cod fish with days from catch.

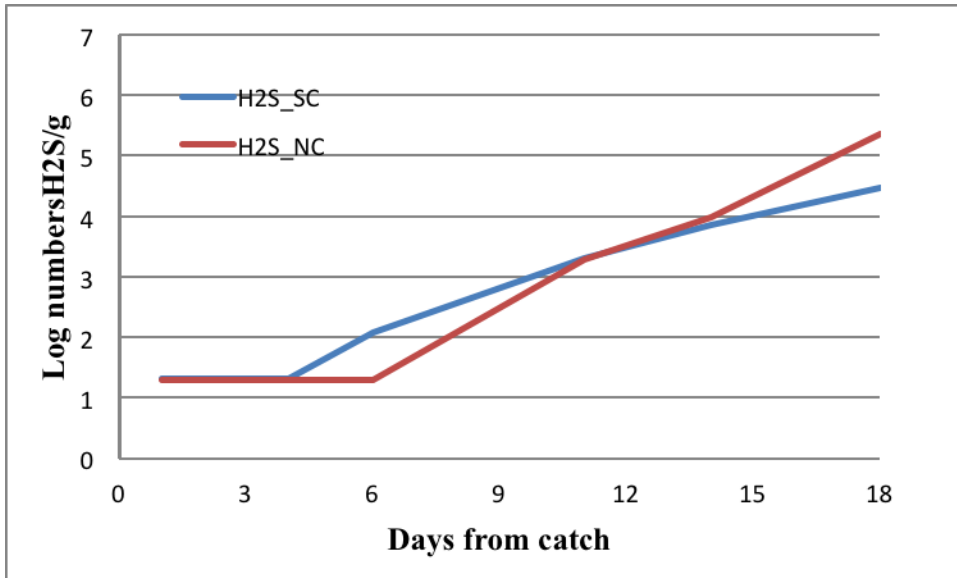


Figure 15: Growth of H₂S-producing bacteria in cod loins for SC and NC Cod fish with days after catch.

4.4 Chemical analysis

As Figure 16 shows, there is a higher increase in TVB-N number for NC cod fish than SC cod fish due to the cooling effects and growth of bacterial and microbes for SC cod fish than NC cod fish. The TVB-N values were higher on storage day 18 in NC.

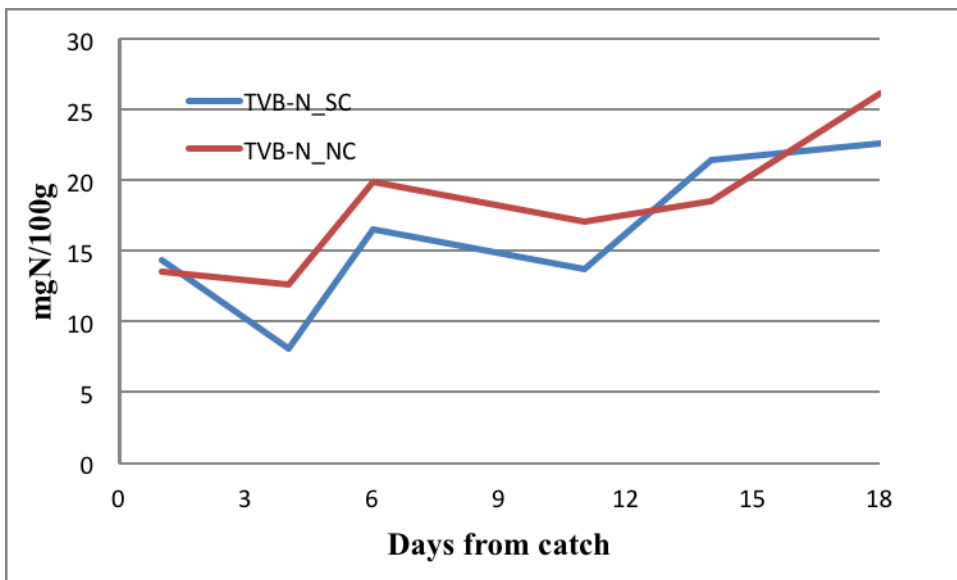


Figure 16: Total Volatile Basic Nitrogen (TVB-N) for super chilled and non-chilled cod fillets.

5 DISCUSSIONS

In this study, discussions are based on temperature measurements, sensory evaluation (such as the QIM scheme, QDA Scale and Torry Score Sheet for cod), and microbial and chemical analysis for SC and NC whole cod fish fillets. The ambient temperature measurement is based on the two different cooling systems with six temperature loggers as shown in Figure 3 and the mean ambient temperature during this period from processor to Matís was -1.4°C for the NC fillets and -1.3°C for SC fillets. The short peaks on days 1, 4, 6, 11 and 14 were due to the duration of these temperature abuses that are short at the time the fish sample was taken for analysis and it has no effect on the product temperature. The mean ambient temperature for the SC whole fish from when it was put inside the container until the end of the experiment was $-1.3 \pm 0.2^{\circ}\text{C}$. This was the average of the two temperature loggers, which were kept within the chamber container of the SC fish. For the product temperature in Figure 4, at the beginning of the cooling, the temperature loggers did not log until after eight hours (i.e. from 13.00 to 21.00) after processing due to technical problems and there was heavy snow on the sampling day at the processing site. At 21.00, the product temperature reading from the loggers for the NC group dropped from -1°C to -0.5°C and the loggers for the SC group dropped from -1°C to -0.9°C maintaining a constant reading with no significance difference.

The QIM results for Figures 5, 6, 7, and 8 show difference in sensory evaluation for the cod fish by the trained panellists, those who are in training and those who have knowledge about the fish. From these results, the three panellists were removed from further analysis, due to little experience in the QIM (panellists in training) and one due to knowledge on the fish samples. The panellists that were dropped were panellists' a08, a07 and a13 and they will have to undergo more training before becoming qualified panellists. These panellists need training on QIM since their scores were very high during evaluation of very fresh fish (e.g. day 1), which means they cannot predict or assess the freshness and quality attributes for the SC and NC cod fish with independent judgements of their sensory characteristics (smell/odour, texture and appearances). It was assumed in the Quality Index Method that the scores for all quality attributes increased with storage time in ice. The scores for skin and stiffness increased faster for NC than SC (Figure 9).

At the beginning of the storage time when the cod was very fresh, the gills odour was described as fresh seaweed or metallic and then the odour became neutral. During the later stages, the odour was described as sour and finally as rotten. The scores for the quality attributes of eyes, skins and gills increased rather constantly throughout the storage time in ice, even though the scores varied somewhat with storage time, especially for form of eyes and cornea for both SC and NC. There was a steeper increase in the scores for skin of NC. Fluctuation in scores for the cornea and colour of eyes was observed, especially for the NC fish. At the end of storage time, the scores reached values close to the maximum score. The assessment of cornea and colour of ice showed considerable fluctuations throughout the storage time for both groups. This could be related to texture, and skin colour appeared to be different with the average quality index scores fluctuating for few quality parameters considerably throughout the storage time for the SC and NC whole fish, which was based on the type of cooling system and the method of handling of the fish from catch to processing and storage.

A regression model based on one individual parameter would be less robust and probably less precise than one based on the QI, because the available values for each parameter in the QIM scheme range from 0 to 3, whereas the full quality index ranges from 0 to 22. The slopes are very similar for SC and NC, which could indicate that the two different cooling systems result in a similar Quality Index. However, taking all evaluated quality parameters into account, the two different cooling systems seem to affect some of the quality parameters differently. The remaining shelf life (in days on ice) could be estimated on the basis of the QI trend line and knowledge about the corresponding quality index at the time of rejection. The QIM scores summarize scores given for each QI quality parameter, and the overall sensory score ranges from zero for very fresh fish and increases with storage time as the fish deteriorates.

Thus, the results and plotted graphs for SC and NC are in line with the QIM scheme for cod fish as written in the Reference Manual for the Fish Sector; Sensory Evaluation of Fish Freshness (Martinsdóttir *et.al.* 2001). The low scores at the beginning of the sampling days in the Figures 2 and 9 indicate the best quality, which is useful to give feedback to fishermen concerning the quality of their catch, which may improve handling on board. Also, the direct relationship between QIM scores and storage time makes it easy to estimate storage time of fresh fish when stored at 0°C. The photos on the visual appearance of the eyes, gills and skin for SC and NC fish is in line with the sensory, chemical and microbial results for the whole cod fish in this project.

The QDA results explain the texture, flavour and spoilage odour of the SC and NC group with regards to the type of storage conditions. On day 11, the SC group had more metallic and sweet odour than NC group with difference in p-value (0.045) for SC than NC group. The dishcloth scores are above 20 for NC, and almost reaching 20 for SC, the other spoilage attributes are around 15 at day 18. This indicates that on day 18 majority of the panellists detected spoilage in the NC group in the flavour and odour characteristics of the fish. The results from the Torry Scores in Figure 13, shows the end of shelf life (i.e. Torry Score 5.5), which is obtained from the screened data from the panellists and the SC group seems to have a longer shelf life than the NC group. The Torry Scores were also in line with the QDA results for SC and NC fish, which indicate that most of the panellists detected spoilage in NC group in the flavour and odour characteristics of the fish. Thus, the Torry Scores for the cod fish on day 18 for SC group is in line with the shelf life limit of Torry Scores sheet for cod, with the SC group above this limit and having a longer shelf life than the NC group.

The microbial measurements for this project was based on the tests for total viable psychotropic counts (TVC) and counts for H₂S on the shelf life of fish that have undergone super chilled and non-super chill cooling system. Microbial results shows that the total viable counts (TVC) were similar for the two groups at storage day 18, though slightly higher for NC at 6,2 log compared to 5,6 log for SC. At the same time, the number of H₂S producing bacteria were higher for the NC at 5,4 log, compared to 4,5 log for SC. But these results were opposite for SC and NC groups for the QI scores at sensory rejection because the scores for the SC group was higher than the NC group.

The TVB-N values were higher on storage day 18 in NC than SC group with NC at 26.5mg/100g compared to SC at 22.5mg/100g and is below the EU limit for TVB-N is 35mg/100g muscle for cod as shown in Annex 4. But, at sensory rejection, the chemical results are opposite for SC and NC since the SC has a higher score in QI than the NC as shown in the QI trend line, QIM photos and individual parameters. The TVB-N values were

higher on storage day 18 in NC. The resulting chemical and microbial measurements shows that there is slight difference between the SC cod fish and NC cod fish in terms of spoilage factor but there is longer shelf or storage life for the SC cod fish than NC cod fish due to the different cooling effects and temperature measurements of the fish.

Thus, the super chilled and non-chilled fish gave differences in characterises as shown in the QIM results sheets, figures and photos in Annex 5. Significant differences were observed in the temperature evolution of the fish stored in ice and super chilled ice. The quality of the fish goes down for both non-chilled and super chilled fish but the storage time of the fish is longer in the super chilled than non- chilled from Torry and QDA results. The spoilage indicators are higher in NC fish than SC group as shown in the microbial and chemical measurements, which affect the shelf life of the fish. But, at sensory rejection the QDA, Torry scores, microbial and chemical results are opposite for SC and NC since the SC has a higher QI score than the NC as shown in the QI trend line, QIM photos and individual parameters, which affects the quality of the fish based on the method of handling. Further, the CBC machine was designed for filleting of the fish not the whole fish. Thus, the type of cooling system can affect the quality in terms of appearance and shelf life of the fish base on the sensory, microbial and chemical analysis of the fish.

6 CONCLUSION AND RECOMMENDATIONS

From the sensory evaluation, microbial and chemical measurements there is slight difference in sensory characteristics and spoilage indicator for both SC and NC cod fish. The QIM results showed differences in sensory evaluation for the cod fish by the trained panellists, those in training, and those who with prior knowledge about the fish. This aspect of training of panellists is very important because in the sensory evaluation of the QIM scheme, the results depend on the reliability of trained panellists, as they should be able to give correct information on the freshness and different quality attributes of the fish as shown in figure 9. Also, the difference in trend line between SC and NC group is determined by panellists through the average mean QI and storage time of the fish as shown in Figure 10. The different patterns in the QI scores for the appearance of the skins, eyes, gills, blood and blood fillet is determined by the evaluation of the trained panellists and that is why it is important for fisheries industries that are doing QI scheme for different fish to train their panellists well especially when they may have only few panellists. The results from the QIM scheme for total scores for quality attributes (QI) gave a linear relationship with storage time in both super chilled and non-chilled fillets. The QI could therefore be used to estimate the remaining storage time in ice and at 0°C temperature.

The QIM method offers a fast and reliable procedure to evaluate the freshness of cod, providing information about its quality and the remaining shelf life. The QIM is a fast and convenient method to determine the freshness of fish. It is very important that assessors (observers, factory staff) conducting the evaluation are properly trained and experienced to guarantee reliable results (Martinsdóttir *et.al.* 2001).

Thus, the results and plotted graphs for SC and NC were in line with the QIM Scheme for cod fish as written in the Reference Manual for the Fish Sector; Sensory Evaluation of Fish Freshness (Martinsdóttir *et.al.* 2001). The low scores at the beginning of the sampling days in the Figures 2 and 9 indicate the best quality, which is useful to give feedback to fishermen concerning the quality of their catch, which may improve handling on board. Also, the direct

relationship between QIM scores and storage time makes it easier to estimate storage time of fresh fish when stored at 0°C.

The QDA results explain the texture, flavour and spoilage odour of the SC and NC group with regards to the type of storage conditions and temperature effects of the fish. Results from the QDA indicate that on day 18, majority of the panellists detected spoilage in NC group in the flavour and odour characteristics of the fish. The Torry Scores showed the end of shelf life 5.5 of the cod on day 18, which was in line with the shelf life limit of Torry Scores sheet for cod, with the SC group above this limit and having a longer shelf life than the NC group. Also, the Torry Scores showed that the type of storage condition for the SC cod group is of higher quality than the NC group and the quality changes is also reflected in the sensory evaluation for QIM, QDA, chemical and microbial measurements of the fish from the six sampling days (i.e. 1, 4, 6, 11, 14 and 18) in this study.

Microbial results showed that the total viable counts (TVC) were similar for the two groups at storage day 18, though slightly higher for NC at 6,2 log compared to 5,6 log for SC. At the same time, the number of H₂S producing bacteria were higher for the NC at 5,4 log, compared to 4,5 log for SC. The TVB-N values were higher on storage day 18 in NC. Thus, microbial results showed an increase in numbers for iron agar for total viable counts and H₂S counts for the NC group than the SC group. This means that the SC fillets had a high resistance to microbial growth than NC due to its cooling effects and temperature measurements of the fish. Also, results from chemical measurements showed an increase in TVB-N number for NC cod fish than SC cod fish due to the cooling effects and growth of bacteria and microbes.

Thus, according to sensory, microbiological and chemical analysis, the combined blast and contact (CBC) cooling for SC group clearly resulted in longer freshness period and shelf life extension in comparison with the NC group where this technique was not applied. Temperature was lower in SC than NC group at processing since chilling was not applied to NC group at processing and during the storage period. Also, the results from the microbial and chemical measurements for SC and NC fish clearly showed that the SC cooling system was of higher standards for preservation of freshness of the whole fish and fillets than the NC cooling system.

This study will serve as a guide and could be useful to evaluate the freshness of the fish, in terms of product development, using parameters other than handling (i.e. sensory evaluation QDA and Torry methods) for the fisheries industries in Sierra Leone. The QIM method is a fast and convenient method to determine the freshness of fish. It is very important that assessors (observers, factory staff) conducting the evaluation are properly trained and experienced to guarantee reliable results. Also, this study will give valuable information on how to train assessors and develop QIM-schemes for other species and the Torry Scheme can actually determine the end of shelf life of the fish with reference to the type of cooling systems, which is important in the safety and quality of the fish for export and import purposes in the channel of trade.

Such a guide will be of great importance for producers in Sierra Leone to meet the EU markets requirements based on the compliance with quality attributes, Sanitary and hygiene standards of the fish and fishery products. Also, it could be used for training and awareness raising both the industrial and artisanal fisher folks in basic fish handling, processing, storage, hygiene and sanitation practices.

Hence, we can recommend that the super-chilling of fish could be more useful than non-chilling cooling systems due to its freshness and shelf-life characteristics, based on the microbial analysis. Also, this study will be able to improve the quality control and safety assurance measures using the Quality Index Sensory methods and trials on microbiological and chemical analysis method of a fish for Fisheries Industries in terms of fish quality, food safety and export promotion in Sierra Leone and other countries.

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APPENDIX

Annex 1: Quality Index Method (QIM) Scheme for COD (Gadusmorhua)

Date: _____ Name: _____

Quality parameter Point	Description	Point
General appearance	Surface appearance	0 - 3
	Skin	0 - 1
	Slime	0 - 3
	Stiffness	0 - 1
Eyes	Clarity	0 - 2
	Shape of pupil	0 - 2
Gills	Colour	0 - 2
	Smell	0 - 3
	Slime	0 - 2
Flesh colour	Open surfaces	0 - 2
Blood fillet	Blood In throat cut	0 - 2
Sum of demerit points		

Annex 2: The QDA Scale.

sensory attribute	short name	scale	definition
sweet	O-sweet	none much	Sweet odour
shellfish, algae	O-shellfish	none much	Shellfish, algae, characteristic fresh odour
vanilla	O-vanilla	none much	Vanilla, sweet heated milk
boiled potatoes	O-potatoes	none much	Reminds of whole warm boiled potatoes
boiled potatoes	O-dishcloth	none much	Reminds of a dishcloth (damp cloth to clean kitchen table, left for 36 h)
TMA lykt	O-TMA	none much	TMA odour, reminds of dried salted fish, amine
spoilage sour	O-sour	none much	Sour odour, sour milk, spoilage sour, acetic acid
sulphur	O-sulphur	none much	Sulphur, matchstick
colour	A-colour	light dark	Left end: light; white colour. Right end: dark; yellowish, brownish, grey
heterogeneous white precipitation	A-discol.	homogenous heterogeneous	Left end: homogeneous, even colour. Right end: heterogeneous,
flakiness	A-flakes	none much	White precipitation on the sample surface The fish portion slides into flakes when pressed with the fork
salt	F-salt	none much	Salty taste
metallic	F-metallic	none much	Characteristic metallic flavour of fresh cod
sweet	F-sweet	none much	Characteristic sweet flavour of fresh (boiled) cod
pungent	F-pungent	none much	Pungent flavour, bitter
spoilage sour	F-sour	none much	Sour taste, spoilage sour
TMA	F-TMA	none much	TMA flavour, reminds of dried salted fish, amine
putrid	F-putrid	none much	Putrid
soft	T-soft	firm soft	Softness in first bite
juicy	T-juicy	dry juicy	Dry - draws liquid from the mouth
tender	T-tender	tough tender	Evaluated after chewing several times
mushy	T-mushy	none much	Mushy texture, puree
meaty mouth feel	T-meaty	none much	Meaty texture, meaty mouth feel, crude muscle fibers
astringent	T-astringent	none much	Astringent, dry red wine, tannin
rubbery	T-rubbery	none much	Rubbery texture, springy

Annex 3: Torry Freshness Sheet For Iced Lean Fish (cooked).

Score	Odour	Flavor
10	Initially weak odour of sweet, Boiled milk, starchy followed by Strengthening of these odours	Watery, metallic, starchy. Initially no sweetness but meaty flavours with slight sweetness may develop
9	Shellfish, seaweed, boiled meat	Sweet, meaty characteristics
8	Loss of odour, neutral odour	Sweet and characteristic flavor's but reduced in intensity
7	Woodshavings, woodsap, vanillin	Neutral
6	Condensed milk, boiled potatoes	Inspid
5	Milk jug odours, boiled clothes-like	Slight sourness, trace of 'off flavours'
4	Lactic acid, sour milk TMA	Slight bitterness, sour, 'off-flavours', TMA
3	Lower fatty acids (e.g. acetic or butyric acids) composed grass, soapy, turnipy, tallow	Strong bitter, rubber, slight sulphide













Session 1, sample nr	Odour	Flavour













Session 2, sample nr	Odour	Flavour













Annex 4: The table below shows the EU limits for TVB-N in certain fish products:

Species	TVB-N Limits
Sebastes sp. (e.g. Redfish), Helicolenusdactylopterus(e.g. Bluemouth), Sebastichthyscapensis	25 mg /100g muscle
Pleuronectidae (e.g.flatfish, Halibut) With the exception of Hipoglossussp Salmon salar(e.g. Salmon) Merluccidae(e.g. Hake)	30 mg/100g muscle
Gadidae(e.g. Cod and Haddock)	35 mg/100g muscle

Annex 5: QIM Photos on the eyes, gills and skins for SC and NC Cod fish base on sampling days 1, 4, 6, 11, 14 and 18.

Type of Cooling System	Super Chilled	Non- Chilled
Day 1		
Day 4		
Day 6		
Day 11		
Day 14		
Day 18		

Type of Cooling System	Super Chilled	Non- Chilled
Day 1		
Day 4		
Day 6		
Day 11		
Day 14		
Day 18		

Type of Cooling System	Super Chilled	Non- Chilled
Day 1		
Day 4		
Day 6		
Day 11		
Day 14		
Day 18		

ANNEX 6: Photos showing the experiment design from catch, processing and storage of cod fish, sensory evaluation, microbial and chemical analysis.



Fish boat brought to Harbour at Hafnarfjordur . Fish is fort lifted from boat to landing site.



Cod Fish is weighed at Auction Market. Temperature Measurement taken after gutting of cod fish.



Temperature Loggers in fish during icing(Non-chilled).CBC Machine used during super chilling.



Icing of fish with loggers after chilling.Storage of Non-chilled and Super chilled fish at Matís.



Sensory Evaluation of Cod fish by QIM Scheme at *Matís*.



Microbiological Measurement of fish sample at *Matís*.



Chemical measurement of fish sample at *Matís*.