UNITED NATIONS UNIVERSITY

unuftp.is Final Project 2018

IMPROVEMENT OF POST-HARVEST HANDLING OF AQUACULTURE FISH IN MYANMAR

Nyo Nyo Thant
Department of Fisheries
West Gyogone, Bayint Naung Road, Yangon, Myanmar
nyo151@gmail.com

Supervisors:
Prof. Hjörleifur Einarsson (hei@unak.is)
Arnheiður Eyþórsdóttir (arnh@unak.is)
Faculty of Natural Resource Sciences
University of Akureyri

ABSTRACT

The aim of this study was to identify the main steps where action can be taken to prolong shelf life and improve quality in Rohu processing in Myanmar. To gain basic information on quality parameters, a shelf life study was performed with farmed Arctic Char stored under two different conditions, in ice and at 10 ˚C. Quality was assessed by microbial counts and sensory analysis. Arctic Char kept for 4 days at 10 ˚C, but for 11 days in ice. The results, as well as literature data were used to predict shelf life of Rohu in different handling scenarios, using the Food Spoilage and Safety Predictor (FSSP). Results show that keeping low temperature of fish during harvest and transport improves quality and prolongs shelf life of Rohu. Handling of farmed Rohu can be improved at many processing steps to ensure quality and longer shelf life, as well as preventing contamination.

Key words: Rohu, Arctic char, storage temperature, quality index method, shelf life prediction.

This paper should be cited as:
Thant, N. 2019. *Improvement of post-harvest handling of aquaculture fish in Myanmar.* United Nations University Fisheries Training Programme, Iceland final project. http://www.unuftp.is/static/fellows/document/Nyo18prf.pdf

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1 INTRODUCTION

1.1 Background

Myanmar has a total marine shelf area of 51.000 km^2 and an Exclusive Economic Zone of 497,442 km^2. The continental coastline is 1,650 km (FAO, 2012). In Myanmar, the fisheries sector is vital for national food security, income generation and export earnings. Myanmar´s population is 53 million. It is estimated that aquaculture and fisheries directly employ more than 3 million people and that between 12 and 15 million people benefit from the aquaculture sector (World Fish Center, 2016). Fish and fishery products are nutritious foods and are the most important sources of animal protein in the country.

Aquaculture in Myanmar has grown rapidly in the last decades and plays an increasingly important role in national fish supply (Belton, Filipski, & Hu, 2017). Aquaculture production was reported slightly over one million tons in 2016 which is around a 2% increase from the previous year. (World Bank, 1960 - 2016). The farmed finfish species are freshwater fish that includes Rohu (*Labeo rohita*), Carfu (*Cyprinus carpio*), Mrigal (*Cirrhinus* spp), Katla (*Catla catla*), Pangasius (*Pangasius* spp), Puti (*Puntius* spp) and Tilapia (*Oreochromis* spp). Rohu is typically 70-85% of the population in the pond, while the other species may each be 5-10 % of the total population (Ministry of Agriculture, 2018). There is an interest in increasing the export of fish from Myanmar to the EU. In order to do so, the fish must be of the highest quality. Handling, transporting, processing and storing of fishery products, must, therefore, follow proper procedures in terms of hygienic issues and temperature control to ensure quality according to requirements. Total aquaculture export was around 67,000 metric tons in 2016-2017 (Ministry of Agriculture, 2017 a).

Fish is generally both wholesome and safe. However, it spoils rapidly if not kept chilled and it can be contaminated during growth and after harvest. The quality depends on the qualities and condition of the raw material, as well as on factors such as controlling of temperature, relative humidity of air, hygiene and handling. Fish spoilage is mainly due to enzymatic activity, microbial growth and lipid oxidation resulting in loss of positive sensory attributes (Valtysdottir, Margeirsson, Arason, Lauzon, & Martinsdóttir, 2010). Fish can also be contaminated with chemicals (e.g. pesticides, herbicide, antibiotic and heavy metals) and other hazards (e.g. virus and parasites) during growth and by bacteria and chemicals during post-harvest handling resulting in an unsafe product (Huss, 1995).

Furthermore, if the fish is handled roughly, mechanical or physical damage will result in poor external appearance. Rough physical handling will cause some cells to rupture, leaving the enzymes free to react with other substances. Mechanical damage, therefore, gives good conditions for some enzymatic activities. The micro-organisms come into the fish flesh and allow faster spoilage of the fish (Huss,1995). It is known that both enzymatic and microbiological activity are significantly affected by temperature, thus temperature control is of crucial importance (Huss, 1995).

Temperature plays a vital role in the deterioration of the aquaculture fish quality after harvesting. Usually, the temperature during transportation to the processing plant should be lower than 4°C in order to slow down the microorganism multiplication which can cause fish spoilage. However, due to lack of facilities, temperature rises rapidly after harvesting and during transport in most aquaculture farms in Myanmar, resulting in fish spoilage problems. Moreover, keeping the harvested fish (postmortem) in the nets or open air at a high temperature for a long time may result in the rapid decline of the fish quality. As soon as the fish dies, spoilage begins. The fish body becomes stiff and rigid caused by rigor mortis. This type of spoilage can take place 1-7 hours after fish dies (Germano & Pantanella, 2016).

The materials that come in contact with the fish are also an important factor in avoiding fish spoilage during harvest and transport such as ice, transportation boxes, and vehicles. Generally, well-protected insulation boxes with sufficient crushed ice or flake ice are recommended to be used in order to keep the temperature below 4℃ for decelerating not only enzymatic reaction but also the rate of bacterial growth and lipid oxidation. Therefore, the use of improper containers that can be seen in some of Myanmar's aquaculture farms, such as plastic baskets or broken insulation boxes, are another cause of the decline of post-harvest fish quality.

Moreover, landing site conditions could be another concern for fish spoilage and lead to a decrease in product quality. In Myanmar, most auction markets usually leave the whole fish on the tray without covering with ice to maintain the low temperature. Furthermore, the lack of pest control may accelerate the microorganism growth.

1.2 **Rationale**

Development of the aquaculture sector in Myanmar has led to international export of some products, and there are plans to export more. The poor post-harvest handling of fish and interruption of the cold chain on the way to the processing plant has been a major problem for the sector. This leads to faster spoilage, lower safety and in the end lower value of the products.

To improve the situation, the Department of Fisheries has implemented the "National Residue Monitoring Plan" to manage risks of chemical contamination of products (Ministry of Agriculture, 2018). Part of the programme requires fishery inspectors to inspect aquaculture farms to make sure the farmers comply with good aquaculture practices and inspect post-harvest handling to ensure good manufacturing practices. In 2017, a total of 186 samples of fish, shrimp and soft-shell crabs were tested for residues of veterinary medicines and environmental contaminants and 95% were found in compliance with legal requirements. The results and experiences from this year, as well as the previous 4 years, have been used in the development of the National Residue Monitoring Plan in 2018-2019 (Ministry of Agriculture, 2017b).

1.3 **Goal**

The aim of this project is to study the effect of some post-harvest handling variables on quality of aquaculture fish.

1.3.1 *Objectives*

The overall objective is to identify the main processing steps of aquaculture fish in Myanmar where quality losses occur and to make suggestions so that aquaculture fish exports from Myanmar can fulfil relevant international requirements (e.g. of the EU). More specific objectives are:

1: To make a detailed flowchart of fish handling from pond to processed fish (frozen) in Myanmar

2: To collect temperature data from Myanmar

3: Measure changes in quality (bacterial load/numbers and QIM) during transportation of fish from farm to processing

4: To simulate the effect of temperature fluctuation on quality in fish during transport (Food Spoilage and Safety Predictor)

5: To identify and rank weak points in the process

6: Make suggestions on how international quality requirements can be achieved

2 LITERATURE REVIEW

2.1 Post-harvest losses

Annual landing of fish and other aquatic animals in the world is around 160 million metric tonnes (m.m.t) (FAO, 2016) . Approximately 90 m.m.t come from capture fisheries and the rest, (approx. 70 m.m.t) comes from aquaculture. This makes fisheries an important contributor of animal proteins, micronutrients, minerals and essential fatty acids of many communities in both the industrial and developing world (Getu, Misganaw, & Bazezew, 2015). However, a substantial part of the annual catch (35%) never reachs the plates of consumers due to waste (Gustavsson, Cederberg, Sonesson, Otterdijk, & Meybeck, 2011). Loss has been defined as the “decrease in edible food mass throughout the part of the supply chain that specifically leads to edible food for human consumption” and can occur at production (harvest), post-harvest and at processing. While waste rather occurs toward the food chain, e.g. at retailers and at home. For fish, losses include discard, spillage, spoilage and waste (Gustavsson, Cederberg, Sonesson, Otterdijk, & Meybeck, 2011).

There are five categories of post-harvest losses of fish: nutritive losses, physical losses, quality losses, economic losses and traditional processing losses (Getu, Misganaw, & Bazezew, 2015). Nutritive losses included discard of fish after harvesting due to spoilage or bad handling which could lead to loss of its nutritional value during the storage or lower economic returns because of its low price. Physical losses are the wasting or throwing out of fishes after harvesting or landing. These losses can occur because of fish spoilage and inadequate handling processing. Quality loss relates to fish that has undergone changes due to spoilage or physical damage and has suffered quality deterioration. Economic losses are the result of the changes in market demands due to oversupply or lower demand. Finally, processing losses are the result of using improper techniques in traditional fish processing might give negative impacts on the nutritional value of fishes.

As noted, post-harvest fish loss occurs during pre-processing, processing, storage and transportation of fishery products. This is summarized in Table 1 (Getu, 2015).

Table 1. Summary of causes of post-harvest fish losses from (Getu, 2015).

Stage	Cause	Loss Type
During the harvesting	Falling from the net or discarded after harvest	Physical
	Setting a fishing net for long periods, causing fish to spoil.	Quality, Physical
Holding fish on the boat	Delay in landing after fishing and exposure of fish.	Quality, Physical
	Failure to gut (when feasible), wash and chill the fish on the boat	Quality
	Stepping on fish, causing physical damage	Quality
	Keeping the temperature high	Quality
Landing site	Poor hygienic practices causing contamination	Quality
	Fish falling from the basket on to the Physical landing theft at the landing site during offloading of fish	Physical
	Keeping the temperature high	Quality
Fish market	Inadequate ice and no insulated car used	Quality, physical
	No contact to or lack of marketing information, with an excess of market	Market, Quality
	Careful delay in purchasing the fish by traders	Quality
	Keeping the temperature high	Quality
During processing and packaging	Processing of already damaged/poor-quality fish	Quality, physical
	Processing fish under unhygienic conditions, allowing insects infestation	Quality, physical

	Damage of inadequate packaging method and materials	Quality, physical
	Keeping the temperature high	Quality
During storage	makes the fish damp	Quality
	Insects consume fish during storage	Quality, physical
	Discolouration owing to chemical changes	Quality
	Inadequate storage facilities	Quality, physical
	Damage to fish during transportation	Physical
	Keeping the temperature high	Quality
During marketing	Postponements in selling	Quality
	Inadequate cold-storage facilities, warehouses and inadequate of ice	Quality, physical
	Supplying the market at the “wrong time.”	Market
	Poor purchasing power of buyers/consumers	Market

2.2 Post-mortem changes in fish (fish spoilage)

After harvest and death, fish undergoes several changes that result in a product that is no longer fit for consumption. These post-mortem changes can be classified post-mortem into four categories: sensory changes, autolytic changes, bacterial changes and lipid oxidation and hydrolysis (Huss, 1995).

Fish Quality loss refers to changes in the fish flesh after death. Fish spoilage can be caused by chemical reactions, physical damage, and microbial growth. Chemical reactions, through enzymatic activity in muscles of the fish and external microbial activity, produce changes in the proteins and lipids in the fish flesh, resulting in degeneration in sensory quality, loss of nutritional value and physical properties. The rate of these changes depends on the nature of the fish species, size, lipid content, the status of capture, nature of the microbial load and storage temperature (Sravani, 2011).

2.2.1 *Sensory changes*

Sensory changes are changes in appearance, odour, texture and taste. Initially, the most important change is related to rigor mortis. The rigor mortis changes can be divided into three phases, namely pre-rigor, during rigor and post-rigor mortis changes. Pre-rigor mortis changes starts immediately after the death of fish. While fish muscle relaxes and becomes elastic for some hours. Then muscle will start to contract in rigor mortis phase. At this phase, fish muscle becomes hard and stiff, and whole fish body becomes inflexible. After few hours, flesh will become firm, succulent, and elastic in the post-rigor mortis phases. The rate of rigor mortis changes varies from species to species. It is also affected by temperature, handling, size and physical condition of the fish. Rigor mortis starts immediately or shortly after the death of the fish when it is starved, and the glycogen reserves are depleted, or if the fish is stressed (Huss ,1995).

The method used for stunning and killing the fish also influences the onset of rigor. This includes hypothermia (the fish is killed in iced water) which induces the fastest onset of rigor, while a blow on the head gives a delay of up to 18 hours before rigor mortis starts (Huss ,1995).

The technological importance of rigor mortis in fish processing relates to filleting before or in the rigor state. Rough handling can contribute to gaping. However, if the fillet is removed from the bone, the pre-rigor of the muscle can contract freely, and the filleted fish shorten after the rigor start. The dark muscle may shrink up to 52 % while white muscle up to 15 % of the original length. In addition, if the fish is cooked in pre-rigor state, the texture becomes very soft and pasty. On the other hand, when cooked in rigor state, the texture will become tough. Post rigor, flesh becomes firm, succulent and elastic (Huss ,1995).

2.2.2 *Autolytic changes*

Autolysis means self-digestion. There are two types of fish spoilage: bacterial and enzymatic. Enzymatic changes can be identified before and unrelated to changes in the microbiological quality. For some species, these changes dominate the spoilage of chilled fish, but in others they are a part of the overall quality loss in addition to the microbially mediated process (Huss, 1995).

TMAO-ase or TMAO demethylase is the enzyme responsible for splitting trimethylamine oxide (TMAO) into dimethylamine and formaldehyde, which can result in formaldehyde-induced toughening. This is mostly found in gadoid fishes (cod family). The TMAO demethylase enzymes have been reported to be membrane-bound and normally becomes effective when cell membranes are interrupted by slow freezing, fluctuating temperature in cold stores or detergent solubilization. (Huss, 1995).

In a living organism, a series of reactions take place to retrieve energy from organic molecules (cell respiration), which ultimately produce carbon dioxide (CO_2), water, and the energy-rich organic compound adenosine triphosphate (ATP). This process can occur in two stages, depending on the continued presence of oxygen (O_2) which is only available from the circulatory system. ATP is the energy supplying compound, but it also acts as muscle plasticiser. Glycolysis is a potential pathway to produce energy when the heart stops beating. Lactic and pyruvic acids are products of these reactions. ATP is generated from glycolysis, but the glycolytic end products are oxidized aerobically in the living animal. The anaerobic muscle cannot maintain its normal level of ATP after death. Therefore, due to the intracellular decline, the muscles transition into rigor mortis. There is a reduction of pH of the muscle as a result of post-mortem glycolysis that accumulates on lactic acid. The pH drop in marine animals is however smaller than observed in post-mortem mammalian muscle (Huss, 1995).

2.2.3 *Bacterial changes*

Microbial food spoilage is a global concern for all food products. Preventing the activity of spoilage microorganisms in seafood and other foods is crucial for the development of preservation techniques and consequent reduction of losses due to spoilage. Bacterial growth can cause off-odour and changes in flavour. In a living fish, microbes are found on gills, skin and in intestines and not in the flesh. Raw fish is highly perishable due to the intrinsic properties of the product which favour microbial activity. With high temperature, the freshness of fish is reduced due to bacterial growth, evident when microbial counts are $10^6 – 10^7$ CFU/g (Gram & Dalgaard, 2002). The bacterial counts can, therefore, be used to assess the quality of fish.

Microbial activity plays a vital role in the shelf life of fish as gram-negative and fermentative bacteria (such as *Vibrionaceae*) spoil unpreserved fish and psychrotolerant gram-negative bacteria (*Pseudomonas spp* and *Shewanella spp*) continue growth in the chiller. Poor storage and bad handling of fishery products may cause the growth of spoilage bacteria such as *Lactobacillus spp* and *Proteus spp* (Tahsin, Soad, Ali, & Moury , 2017). Even though 10^7 CFU/g has generally been considered as a maximum acceptable microbial load for fish sensory rejection has typically been found at microbial levels between 10^6-10^9 CFU/g (Kuuliala, et al., 2018). Microbial spoilage of fish can take diverse forms which manifest in the sensory indication such as flavour, slime formation, largely visible pigment or non-pigment colonies, production of gas and discolouration (Gram & Huss, 1996). As a result of microbial metabolism, volatile organic compounds are often produced, which leads to the production of characteristic off-odours and off-flavours. Odour is one of the important quality factors for determining fish freshness (Olafsdottir et al., 2005). Typical compounds associated with fish spoilage include acids, alcohols, aldehydes, amines, ketones and sulfides (Gram, 2002).

Specific Spoilage Organisms (SSO) are a fraction of the initial microbial community, but their outgrowth leads to the rejecting of products quality (Gram, 2002). Hydrogen sulphide (H_2S)

producing bacteria grow rapidly post-capture during storage and processing (Svanevik, Roiha, Levsen, & Lunestad, 2015). The spoilage potential of SSOs is characterized by their qualitative ability to produce off-odours, whereas spoilage activity refers to the quantitative ability to produce spoilage metabolites (Gram, 2002). The shelf life of fish is influenced by several factors such as storage temperature, fish species, microbial contamination and packing condition (Sivertsvik, Jeksrud, & Rosnes, 2002). The kinetic models of spoilage organisms grown in substrates can be used for prediction of shelf life. This requires that specific spoilage organisms are known and that growth kinetic parameters can be estimated accurately (Dalgaard, 1995).

Trimethylamine oxide (TMAO) is the part of the NPN (Non-Protein Nitrogen) fraction and is found in marine and freshwater fish. TMAO is known to cause a high (positive) redox potential (Eh) in the flesh of fish. The spoilage of fresh fish is influenced by the TMAO, as it can serve as the terminal electron acceptor in anaerobic respiration. It produces off-odour and -flavour due to the formation of trimethylamine (TMA) (Gram, 1996). Accordingly, TMA levels can be used to determine microbial deterioration leading to fish spoilage. Bacteria, for instance, *Shewanella putrifaciens*, *Aeromonas* spp., psychrotolerant *Enterobacteriacceae*, and *Vibrio* spp. can get energy by reducing TMAO to TMA producing the ammonia-like off-flavour and spoilage compounds (Getu, 2015). Another method is to test for total volatile basic amines (TVB-N), including ammonia and TMA.

2.2.4 *Lipid oxidation and hydrolysis*

The major concern of the freshness of commercial products is represented by the rupture of proteins and lipids. Preservation of freezing storage is demanded to change synthetic or natural preservatives for control of lipid oxidation and microbial growth in fish during storage. These preservatives and refrigeration reduce the process of spoilage. Fish spoilage is a result of lipid oxidation and protein degradation as well as loss of other valuable molecules during the composition changes (Ghaly, Dave, & Budge, 2010). This results in character changes in the sensory attributes.

2.3 **Microbiological and chemical hazards (contamination)**

2.3.1 *Microbial hazards*

Foodborne diseases are caused by different types of pathogens, including bacteria. Bacterial contamination in aquaculture products, as well as other food products, can be caused by inadequate hygienic conditions and bad handing during processing (Yucel & Balci, 2010). Pathogenic bacteria can be divided into three general groups in fish and fishery products. Indigenous bacteria that can be included in the natural micro-flora of fish (*Clostridium botulinum*, pathogenic *Vibrio* spp., *Aeromonas hydrophila*); enteric bacteria (non-Indigenous bacteria) that are present due to fecal contamination (*Salmonella* spp., *Shigella* spp., pathogenic *Escherichia coli*, *Staphylococcus aureus*); and bacterial contamination during processing, storage or preparation for consumption (*Bacillus cereus, Listeria monocytogenes, Staphylococcus aureus, Clostridium perfringens, Salmonella* spp.) (Elhadi, 2016).

Many foodborne pathogens spread through the faecal-oral route, hence, strict rules concerning hygiene must apply to all food producers. *L. monocytogenes*, however, occurs naturally in various environments and could, therefore, follow the fish during the production line. Other bacteria, such as *Staphylococcus aureus* and *Salmonella*, are more often associated with cross-contamination during production (Svanevik, 2015).

Taking this into consideration, prevention of pathogens in fish products is important to ensure food safety. *Salmonella* has been found in cultured rohu from Myanmar, but neither *Listeria* nor *Vibrio* species were isolated (Elhadi, Aljeldah, & Aljindan, 2016). The lowest number of *Salmonella* isolates were isolated from rohu fish compared to other fish in the study.

2.3.2 *Chemical hazards*

Fish products from the aquaculture sector are sometimes associated with food safety issues from chemical and biochemical agents (Obasohan, 2009). These include agrochemical veterinary drug contamination and heavy metal pollution. This has been as a result of inappropriate fish handling practices, environmental pollution and cultural habits of food preparation and consumption.

Chemical contaminants in aquatic ecosystems with potential for toxicity include inorganic chemicals such as heavy metals (Cd, Hg, Se, Pb etc), as well as mycotoxins, dyes, organic compounds such as polychlorinated biphenyls, dioxins, insecticides (chlorinated hydrocarbons) and contaminants related to aquaculture and farming activity such as antibiotics, anaesthetics and hormones (Obasohan, 2009).

2.4 **Factors affecting quality changes**

The factors involved in food spoilage, especially microbiological spoilage, can be classified into four categories: intrinsic factors, processing, extrinsic factors and implicit factors (Adams, Moss, & McClure, 2016). Intrinsic factors refer to the chemical and physical properties of the product, the processing is any modification of the intrinsic factors, extrinsic factors are the conditions in the product’s environment (temperature, composition of air and humidity of atmosphere in storage), while implicit factors are mutual influences of the other factors.

The spoilage of fish is influenced by the status of processing and preservation, storage temperatures, and level of cross contamination. These factors can affect microbial and biochemical spoilage or a combination of both (Dalgaard, 1995). The processing factors such as drying, smoking, chilling, and salting, which greatly minimize the spoilage, also needs to be monitored and the processes understood. The quality and safety of perishable food products are dependent on an unbroken cold chain. In a cold chain, the temperature is managed and monitored at every stage, which is a requirement to ensure quality and safety of food products. Maintaining the cold chain involves control of the environmental temperature during and after the production, transporting and sale processes.

2.5 **Importance of temperature**

Fish spoilage starts immediately after death. Spoilage is caused by a combination of microbial, chemical and autolytic reactions. These are accelerated by temperature, physical damage of the fish, pollution and contaminations. Temperature is the most important factor in the fish spoilage. The microbial growth, enzymatic reactions and chemical reactions need an optimal temperature range. If the temperature is beyond the optimal level, fish spoilage rate will be accelerated (FAO, 2014).

2.5.1 *Temperature variation during distribution*

As fish freshness is affected by temperature, spoilage can be controlled by reducing the temperature, which is commonly done to keep fish fresh. The colder the temperature, the longer it will take for the fish to spoil. Temperature is then kept under control at all stages from delivery, during storage, and on display. Raised temperature increases the rate of bacterial growth, enzymatic activity, and oxidation, leading to rapid spoilage, reduced shelf-life and likely food safety risks. Accordingly, poor temperature controls lead to increased waste and loss of value, affecting the business’s success (Edirisinghe, Wansapala, & Wickramasinghe, 2018).

Temperature requirements vary among food items, whether frozen or chilled. Categories of refrigerated foods have sometimes been defined as freezer storage temperature – 18˚C or below; chilled temperature 0 ˚C to 1 ˚C, medium-chilled at 5°C and exotic-chilled at 10 ˚C to 15 ˚C (Ndraha, Hsiao, Vlajic, Yang, & Lin, 2018). Even a short period of exposure, such as a few hours, of extreme changes in temperatures can cause a marked decrease in quality and shelf life. This leads to faster bacterial spoilage and muscle degradation, affecting both sensory and nutritional qualities. Temperature is the most important single factor affecting the quality of fish (Ndraha, 2018).

2.5.2 *Predicting bacterial growth (Seafood Spoilage and Safety Predictor - SSSP)*

Predictive microbiology represents a proactive approach to food quality and safety by accumulating information on bacterial responses related to environmental factors and by summarising the responses in databases and mathematical models (Østergaard, 2014). Mathematical models for growth, survival or inactivation of microorganisms can be valuable tools to assess safety and shelf-life of food. Such models are used to identify the relationship between a controlling factor in foods and growth of spoilage microorganisms and/or pathogens. These models can be used to predict the shelf life of fish (Dalgaard, 2014). Models to predict food safety include those that predict histamine formation in marine fin fish.

2.6 **Quality Assessment of Fish**

Quality of fish can be assessed by several different methods. The most important of these are sensory, chemical, physical and microbiological methods (Huss, 1997). They can be performed either instrumentally or by observations (sensory).

2.6.1 *Sensory methods*

Sensory evaluation is the scientific discipline that measures, analyses and interprets human reaction. In food science, this evaluation describes the perceived senses of sight, smell, taste touch and sound characteristics of food. Sensory evaluation is a systematic assessment of the odour, flavour, appearance, and texture. The method to conduct sensory evaluation is to establish a sensory panel, or trained inspectors within the fish sector, to perform sensory analysis on daily production. Sensory evaluation of raw fish flesh are important indices for the consumer to evaluate the freshness and product shelf life. It is also a key factor in the fish industry and inspection in the EU scheme according to the council regulation (European Union, 2019).

Spoilage of fish and loss of freshness are complicated processes. There is no single spoilage or freshness indicator for fish that can be used, but a combination of selected indicators representing the different changes occurring during spoilage. Sensory assessment of the outer appearance, odour and texture of fish and evaluation of cooked fish is the most convenient method for freshness of fish assessment (Odoli, Odote, Ohowa, & Onyango, 2013).

There are three major schemes of sensory assessments to measure fish freshness. These are the EU scheme, Torry system, and the Quality Index Method (QIM) (Tahsin, Soad, Ali, & Moury, 2017). QIM essentially evaluates sensory parameters and attribute changes over time (Huss, 1995). The quality index is the score for all the quality parameters and sensory attributes combined to give overall score. QIM gives a score of zero for fish fresh and increases as fish freshness deteriorates. QIM scores and storage time determine the shelf life of fish products (Martinsdóttir et.al., 2001).

2.6.2 *Chemical methods*

The freshness and quality of fish stored at different temperatures can be assessed using Total Volatile Basic Nitrogen (TVB-N) analysis. TVB-N appears as one of the most common chemical indicators of fish spoilage. The European Union directive on fish hygiene specifies that if the organoleptic examination shows any doubt as to the freshness of the fish, inspectors must use TVB-N as a chemical check (European Union, 2019). The TVB-N analysis involves distilling an extract deproteinised by perchloric acid, alcalinized, followd by a titration with hydrochloric acid.

Total volatile bases (TVB) is a group of biogenic amines formed in non-fermented food products during storage. The combined total amount of ammonia (NH_3), dimethylamine (DMA) and trimethylamine (TMA) in fish is called the total volatile base (TVB) nitrogen content of the fish. (Jinadasa, 2014).

2.6.3 *Microbiological methods*

Microbiological methods assess presence of bacteria or microorganisms of relevance to public health. The number of specific spoilage bacteria gives information of remaining shelf-life. Microbiological measurements are used to determine the number of specific spoilage organisms (SSO) or total viable counts (TVC) measurements that can be determined by agar plating or direct microscope count (Olafsdottir et al., 1997). The iron agar media can be used to detect spoilage bacteria that produce H_2S as they form black colonies on the agar media. Black and white colonies are noticed and counted. The black ones are described as spoilage bacteria, but the total (black and white) represent total count of bacteria.

2.7 **Quality assurance programs for fishery products**

Fishery products are meant for human consumption and as such need to pass regulation or control systems to give the consumer confidence in the products. There are several control systems in the seafood industries, including GMP and Hazard Analysis Critical Control Points (HACCP).

Myanmar is an exporting country; therefore, all exported seafood products need to meet this control system. In 2009 Myanmar was certified to export wild catch fisheries products to the EU market. As such, it is very important to assess the fishery control system.

2.7.1 *Formal Requirements (e.g. EU law and regulations, FDA/USDA)*

Regulation (EC) No 2074/2005, states that “unprocessed fishery products shall be regarded as unfit for human consumption where organoleptic assessment has raised doubts as to their freshness” and chemical checks exceed the specified TVB-N limits. Critical limits of 25, 30 and 35 mg nitrogen/100g have been established for different groups of fish species. Depending on the establishment of specific European Commission legislation, member states may set limits at a higher level for certain species. (European Commission, 2008)

The British Retail Consortium (BRC) Global Standard for Food Safety lays down requirements for a quality management system (QMS) that producers must fulfil to establish their ability to produce safe and legal food products. BRC Global Standards now exist for storage and distribution, packaging and packaging materials and consumer products also food safety. Food standards are now often a conditional requirement of suppliers to the UK and worldwide retailers. The food standards cover key areas within a business, including: management commitment and continuous improvement, HACCP, quality management systems, site standards, product and process controls and personnel (Seafood Scotland, 2019).

The International Standard Organisation (ISO) has developed over 20,000 standards, including the widely used ISO 9001 for QMS. This standard gives requirements for quality assurance in design, development, production, installation and servicing. ISO 9001 can be certified by an external agency. It is important to note that the ISO 9001 standards relate to quality management with customer satisfaction as the end point and that they do not specifically refer to technical processes (Huss, 2003).

2.7.2 *Border rejections/notifications (EU and USA)*

EU controls carried out in the context of drawing up or updating lists of non-EU countries from which imports of products of animal origin are permitted. These controls consider past experience of marketing of the product from the third country and any existing import control measures. The importer must present import documents before the border inspection port checks begin. A document check includes the examination of the veterinary health certificates. Border Inspection port authority are carried out to check compliance with EU regulation 882/2004 on animal health and welfare. If there is a serious risk, the consignment is rejected. In 2014, one Rapid Alert System for Food and Feed (RASFF) notification was issued by EU due to detection of chloramphenicol in dried shrimp in Myanmar. An investigation was carried out by the Competent Authority at the processing plant and the follow-up measures were presented to the audit team. As a result, the operator was suspended from EU export certification and de-listed (Directorate-General for Health and Food Safety, 2019).

The United States Food and Drug Administration (USFDA) is a part of the United States Department of Health and Human Services, authorised to oversee the manufacturing and distribution of food, pharmaceuticals, medical devices, tobacco and other consumer products and veterinary medicine. The FDA also oversees the development of biological products such as vaccines, products that treat allergies and cosmetics. This is to keep public health in check to ensure safety, good health (FDA, 2019).

According to the FDA website, it has issued 5 Import Alerts in 2018-2019, that concern fish/seafood producers in Myanmar. These five issues included improper labelling, decomposition, violation of HACCP system, un-eviscerated fish and *Salmonella* as noted in the red list to this import alert (FDA, 2019).

2.7.3 *Good Manufacturing Practices (GMP)*

Good Manufacturing Practices of Fishery Products covers the basic requirements necessary for fish processing establishments to prevent cross contamination onto the products. This document is also applied as a guideline in facility inspection of export-orientated frozen, canned and traditional fishery products. Requirements cover the following sections:

1) Building design and construction
2) Employee health
3) Personal hygiene
4) Process control
5) Prevented adulteration
6) Pest control
7) Maintain facilities and equipment
8) Training (FAO, 2019)

2.7.4 *Hazard Analysis Critical Control Point (HACCP)*

This standard sets out the requirements for HACCP of Fish and Fishery Products which includes essential needs in managing hygienic controls of food processing, determination of food safety hazards relating to products and processing, and appropriate control measures for identified hazards. A hazard analysis is the identification of any hazardous biological, chemical, or physical properties in raw materials and processing steps, and an assessment of their likely occurrence and potential to cause food to be unsafe for consumption. HACCP plan, when a hazard analysis reveals one or more food safety hazards that are reasonably likely to occur, must include:

Principle 1: Conduct a hazard analysis
Principle 2: Determine the critical control points (CCPs)
Principle 3: Establish critical limits
Principle 4: Establish monitoring procedures
Principle 5: Establish corrective actions

Principle 6: Establish verification procedures

Principle 7: Establish record-keeping and documentation procedures (FDA, 2019).

2.8 The situation in Myanmar

The EU performed an audit focused on the organisation and performance of the Competent Authority of the EU export certification procedure in Myanmar in 2016. The audit evaluated how official control system covering production, processing, and distribution stages functioned when producing fishery products to be exported to the EU and certification the procedure (Directorate-General for Health and Food Safety, 2019). The audit team observed that the raw materials placed in plastic barrels under ice were without drainage holes to allow melted water out. The recorded temperature was less than 4°C in the barrels, but some of the products showed up to 15°C after auction, but before transport. The Competent Authority has already taken measures as a reaction to this audit. The observed non-compliances were related to the quality of ice, storage conditions or product in the vessel holds at the landing site. Poor temperature control, cold stores, traceability issues, incomplete HACCP plans, sourcing of ice from non-approved producers, and the use of non-approved cold stores contributed to non-compliances. Inspection reports were available with non-compliances recorded. Corrosion of equipment and high temperatures of the product during sorting and sizing were most of the non-compliances issues at the auction hall (Directorate-General for Health and Food Safety, 2019).

In 2018, the EU evaluated the follow up measures implemented regarding the recommendations of the audit DG(SANTE)/2016-8864 on the official controls of fishery products intended for export to the European Union market. According to follow up audit, EU audit team certified that all corrective measures have been successfully followed and implemented in accordance with the EU requirements in 2016. However, some systemic weaknesses were not solved, including poor temperature control in cold store, traceability issues, incomplete HACCP plans, the source of ice from non-approved factory and the use of unapproved cold store (Directorate-General for Health and Food Safety, 2019).

In Myanmar, the quality of aquaculture fish production needs to be assessed throughout the long value chains. The fish farms are located within the main swathe of ponds that runs within 25–50 km of Yangon, from Northeast to Southwest. Larger farms transport fish by boats and cars. Fish passes through many steps before it gets to the final consumers. This includes harvesting, transporting, handling, processing, packing and storage. To ensure that quality is maintained at each step of the chain, attention must be paid to factors that will lead to fish spoilage and find safety precautions to prevent it.

As noted, rohu (*Labeo rohita*) is the most preferred fish in Myanmar and contributes to foreign exchange earning of the economy of Myanmar. Therefore, the quality of this species needs to be properly assessed to derive benefits from it. The most important method of preserving fish and fishery products include icing and freezing. Proper cooling during the whole value chain is a key factor in maintaining maximum quality if possible. The quality of fish also depends on the impact of fish handling, processing, storage and logistics on fish. Therefore, proper handling at all stages during processing is necessary to ensure the highest quality and obtain the most possible valuable products (Sravani, 2011).

2.9 Quality and shelf life of char and rohu

Arctic char (*Salvelinus alpinus*) is one of the aquaculture species produced in Iceland. It is highly demanded and reared in land-based aquaculture farms under excellent conditions. The fish have high nutritional value, including omega-3 fatty acids and vitamin D. It is characterized as sweet in flavour (Matis, 2019).

Different types of chilling agents and packaging methods are used to keep the temperature low. One of them is super chilling, which has been shown to reduce growth rate of spoilage bacterial significantly, but it can have negative effect on texture and drip, at least in some species. This is probably due to formation of large ice crystals inside the muscle cells, increasing rupture of the cell membranes. As a result, higher enzymatic activity can lead to negative changes in such as increased drip, protein denaturation and oxidation, affecting texture, juiciness, flavour, and odour of the fish. Combining super chilling by CO_2 (dry ice) and ice packs could be effective to improve storage condition (Bao, Arason, & Porarinsdottir, 2007). CO_2 dissolves in the muscle and lowers the pH. Activity of microorganisms and enzymes, as well as physiochemical reaction are altered by the lower pH (Bao, Arason, & Porarinsdottir, 2007). The extension of shelf-life of fresh fish and fishery products is important for marketing. Ice is the most important and best chilling medium used to preserve fresh fish in both tropical and temperature climates. In a study on effect of storage temperature on quality of arctic char by Cyprian et al. (2008), rapid spoilage and shorter shelf life was observed at ambient storage whereas chilled storage resulted in prolonged shelf life.

Rohu *(Labeo rohita)* is a freshwater fish which is highly abundant in the Indian subcontinent. The fish is used as aquaculture species and is cultured in ponds. Rohu is good of a source of omega- 3 fatty acids, trace minerals like zinc, iodine, calcium, selenium, etc (Khan, 2019). The harvested fishes are stored with the chilling and icing method. These methods reduce the microbial load in the fish and extend their shelf life (Dhanapa, Sravani, Balasubramanian, & Reddy, 2013). Freezing is an effective form of long-term preservation. Fish can be kept frozen for three months (Gandotra, Sharma, Sharma , & Kumari , 2017). Delayed icing is an important issue which is responsible for shorter shelf-life of fishes. The effect of delayed icing on rigor mortis, shelf-life and bacteriological changes have been found to affects the quality and commerciality of the fresh water fish (Nabi, Islam, & Kamal , 2001).

3 METHODOLOGY

3.1 Storage experiment

Twenty (20) individuals of Arctic char was provided by Samherji. The fish was kept in ice until setup of the experiment and then it was divided into three groups as follows:

1. Three fishes served as the initial sample, sampled at day 0.
2. Group 1 was stored at 10°C, in an insulated box, kept in a chiller. Temperature in the box was checked daily. This was kept for ten days and sampled at day 3, day 6 and day 10.
3. Group 2 was stored in ice, kept for 14 days and sampled at day 3, 6, 10 and 14. Ice was added onto the fish daily.

3.1.1 *Microbial analysis*

Fish was handled on a disinfected surface. One whole side of the fish was disinfected with cotton wool soaked in 70% ethanol. With sterile knife and forceps, a cut was made through the fish skin and pieces of the flesh cut out to make up 25 g into a stomacher bag. Butterfield's buffer was added to make a total of 250g and mixed in a stomacher for 1 minute This was diluted in 10-fold dilutions as required. Samples were surface plated on Iron Agar (Lyngby) and incubated at 15°C for 48 h. All colonies were counted (both white and black) and reported as "black count" and total count (black and white).

3.2 Sensory Evaluation

Quality Index Method (QIM) was used in the study to evaluate the whole fish. The QIM is based on evaluating certain quality parameters of the raw fish, characteristic of appearance (eyes, gills, flesh and blood), odour and texture. A scoring system with 0 to 3 demerit points for each parameter is used for the evaluation and the scores are summarised to the overall score (Martinsdottir, Sveinsdottir, Luten, Schelvis-Smit, & Hylding, 2001). Three panelists participated in the QIM.

3.3 Collection of temperature data

Inspectors visiting fish farms make observations regarding general conditions but also, they record handling times and temperatures.

3.4 Simulation of bacterial growth

FSSP (Food Spoilage and Safety Predictor) was used to predict the growth of spoilage and pathogen microorganisms in food. The software uses mathematical models to estimate the growth of spoilage and pathogenic microorganisms in food under constant or changing temperature storage conditions and accordingly predicts the product’s shelf-life.

4 RESULTS

4.1 Flowchart of rohu handling in Myanmar

The main aquaculture production of fish in Myanmar, including rohu, takes place in an area approximately 25 to 50km west and south west of Yangon-city. The area has numerus ponds of different shapes and sizes. From the ponds, the fish is transported either by boat or car to a “landing” and auction site in Yangon. From there, the fish for export is transferred to a factory in the city, as seen in Figure 1 (Belton, et al., 2015).

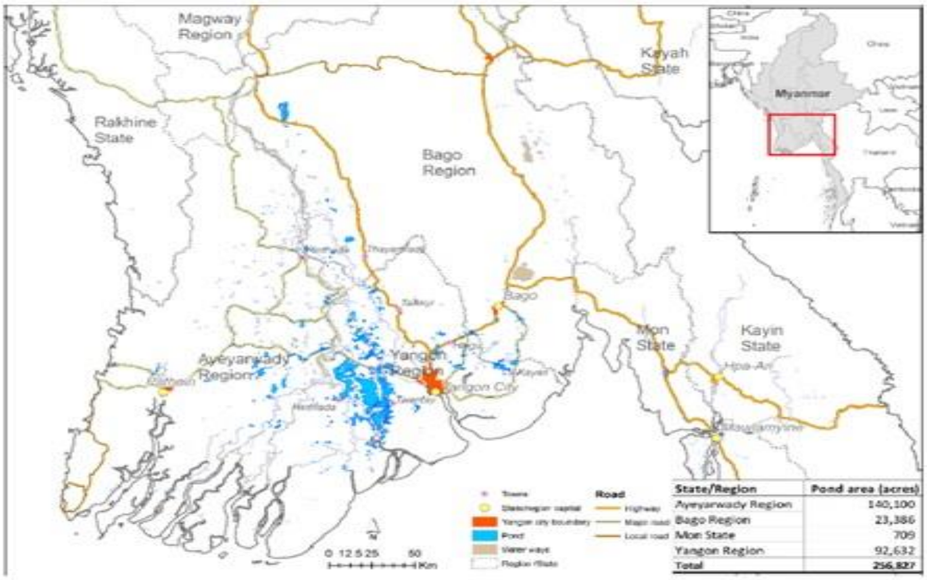

Figure 1. Fish pond in lower Myanmar (Belton, 2015)

In order to identify the steps where quality losses could possibly take place from harvest to factory a flow chart was constructed and is shown in in Figure 2.

No.	Step	Typical time	Reasons for quality losses /
1	Harvest at farm ⇩	Harvest time 2h-3h	-physical damage -microbiological contamination -chemical contamination
2	Transport by boat or insulated car ⇩	3h by car 6h by boat	inadequate ice / bacterial growth fish not washed with treated water /contamination - fish contact surface not clean / contamination
3	Landing Site ⇩	Unloading and display time 3h	fish unloaded on the floor /contamination inadequate ice /bacterial growth
4	Auction ⇩	Auction time 2h	transport not by an appropriate car microbiology hazard
5	Transport from Auction to factory	Transport 1h	inadequate ice /bacterial growth
6	⇩ Reception (at plant)	unloading stage delay time is 1 hour	fish unloaded on the floor /contamination inadequate ice / bacterial growth
7	⇩ Processing ⇩	Processing time 2 hr	contamination (exposure to flies, contamination, dirty surfaces and equipment) growth of bacteria
8	Freezing ⇩		Contamination (poor freezing and chilling conditions)

Figure 2. Flow chart showing the main steps of handling of rohu in Myanmar from farm to factory, typical times at each step and possible causes of quality losses at each step.

Fish harvesting is usually done by men who use nets and dugout canoes as major equipment. Fish farmers spend about two to three hours to harvest the fish. Fish harvesting can be associated with physical damage caused by poor fishing techniques and equipment. If chemicals (e.g. mycotoxin, heavy metals) have been used during the growth period, the fish can be chemically contaminated at this stage. After harvesting, the fish is brought to shore where it is put in insulated boxes with some ice, however the fish is not washed. After, the fish is either loaded to a van or a boat that transports the fish to an official landing- and auction- site. The boat trip can take approximately 6h while the van transport is about 3h. The long transport times (3- 6 hours) and little ice on the fish can decrease the quality of the fish.

At the landing/auction site, the fish is unloaded onto the floor. This poor handling can cause quality losses. Also, due to the open nature of the landing site, unloaded fish are exposed to flies and insects. Sometimes, price bargaining can take about an hour this also can affect the quality of the fish because there is inadequate ice on the fish. At the fish auction, buyers inspect the fish before paying. From the auction, the fish is transported to the fish processing plant where the fish is unloaded onto the floor. This can cause contamination from dust and insects, which will affect the quality of the already low-quality raw materials. In the processing plant there are several places where the fish can become contaminated, including on dirty weighing scales. This is a result of irregular cleaning of the scales which many people touch. Some may use the scale without washing their hands at the same time touch the fish. Also, improper sorting, grading and gutting fish contribute to fish contamination. Many processors do not clean the surface of the tables or wash their hands regularly when grading, sorting and gutting. Sometimes the quality of the water used to wash fish cannot be trusted as the tap water sometimes is not clean. The fish is laid into trays, the surfaces of which are not regularly cleaned. This is another potential source of contamination, as the trays are not maintained and may be corroded. Delay before freezing can further lower the quality of the fish.

The flow chart (Figure 2) shows that the total time from harvest to factory can take from 12 to 15 hours and during a large part of that time the fish can be in little or no ice.

4.2 Temperature data from Myanmar

Inspectors visiting fish farms make observations regarding general conditions but also, they record handling times and temperatures. Results from such observations are given in Table 2. Harvesting takes 2 or 3 hours and the range of temperature in ponds is from ~ 29°C ˚C to ~33°C. Driving time from ponds to where the fish are loaded to landing site is from 2 or 3 hours. When the fish leaves the pond area to the landing/auction the product temperature is from ~ 5°C to ~15°C.

Table 2. Time - temperature data from Myanmar

Harvest time	Pond Temperature	Time (Departure from the pond area) hr	Product temperature °C	Driving Time (Pond to landing site)
11.50 to 15.20	31.2	15.50	15.4	2.30 hr
11.00 to 13.00	30.5	13.20	15.4	2.50 hr
10.25 to 11.50	29.6	12.20	6.0	2.00 hr
12.00 to 13.30	33.2	15.50	5.4	2.00 hr
13.05 to 15.00	31.6	13.20	8.2	2.20 hr
13.20 to 15.30	32.0	17.50	14.9	3.00 hr
12.00 to 13.30	30.0	13.50	11.0	2.20 hr
13.50 to 16.35	32.8	16.50	8.2	2.00 hr
12.20 to 14.30	26.6	2.50	10.2	2.30 hr
11.50 to 13.30	30.0	14.00	15.1	3.00 hr
11.40 to 13.15	28.6	13.25	14.2	2.30 hr
11.25 to 13.15	32.0	13.40	14.7	2.00 hr
14.05 to 15.45	30.2	16.10	15.7	2.50 hr
11.50 to 14.50	31.8	15.10	12.9	2.00 hr

11.35 to 14.20	33.2	14.40	14.8	2.20 hr
11.30 to 15.30	30.2	15.50	13.3	2.00 hr
11.45 to 15.15	31.0	13.40	11.2	2.00 hr
13.20 to 14.50	30.0	15.15	9.9	2.00 hr

4.3 Quality changes in char

The fish, Arctic char, arrived very fresh to the laboratory one day after slaughter in good condition. It was packed in an insulated box with ice and cooling gel mats. Temperature in the box at opening was -1°C.

4.3.1 *Bacterial changes*

The changes in bacterial numbers in arctic char stored in ice and at and 10°C respectively, are shown in Figure 3. The temperature of the fish that arrived at the laboratory was close to 0°C however when put in ice the temperature during the rest of the storage time was approximately 3°C. The initial total number of bacteria was low, less than 10/g. Black colonies were absent (below detection limit) in the fresh fish. As expected, the bacteria grew faster in fish stored at 10°C than in iced fish. At 10°C the black colonies (presumptive spoilage bacteria) grew at the same rate as the total number and there was no apparent lag-phase. However, in ice the black colonies had a lag-phase of three days where after they grew rapidly. Number of black colonies reached 100.000/g (5 on the log-scale) after 4 days but at day 14 in the fish stored in ice.

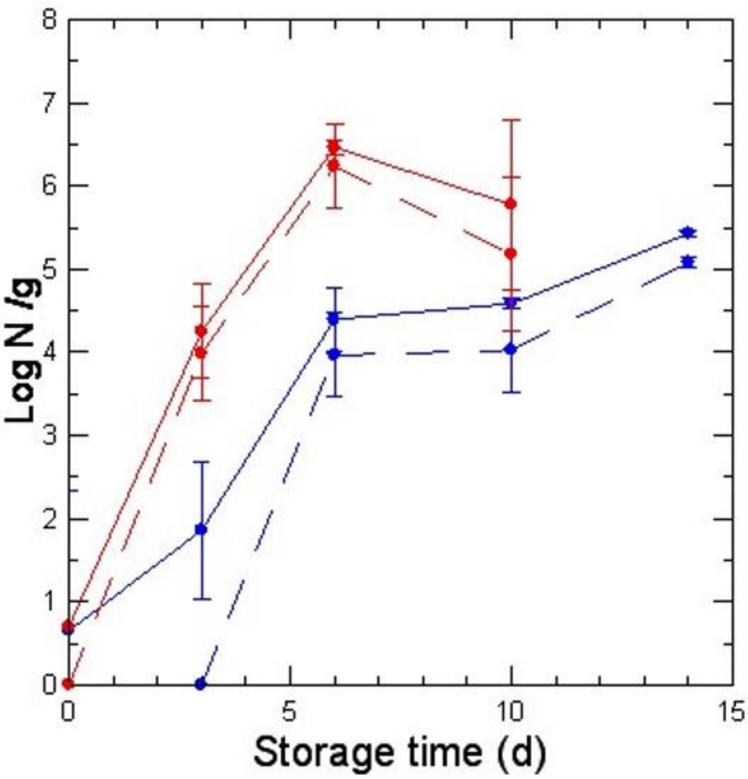

Figure 3. Bacterial numbers (log N/g on Iron Agar for 48h at 15°C) in Arctic char stored at two different conditions, 10°C (red) and in ice (blue). Solid line: Total number (black and white); dashed line: Number of black colonies (presumptive spoilers). Error bar =SD, n=2).

4.3.2 *Sensory Changes*

The changes in sensory quality as determined using Quality Index scheme are shown in Figure 4. The initial QI was low, or 3, but increased rapidly in fish stored at 10°C but more slowly in fish stored in ice. In this study, the "cut value" for the freshness of fish was set to QI score 15. Using the cut value, the shelf life of fish in 10°C is estimated to be 4 days but 11 days when stored in ice. The rise in QI is almost linear at 10°C up to QI 20 but somewhat curved for the fish in ice.

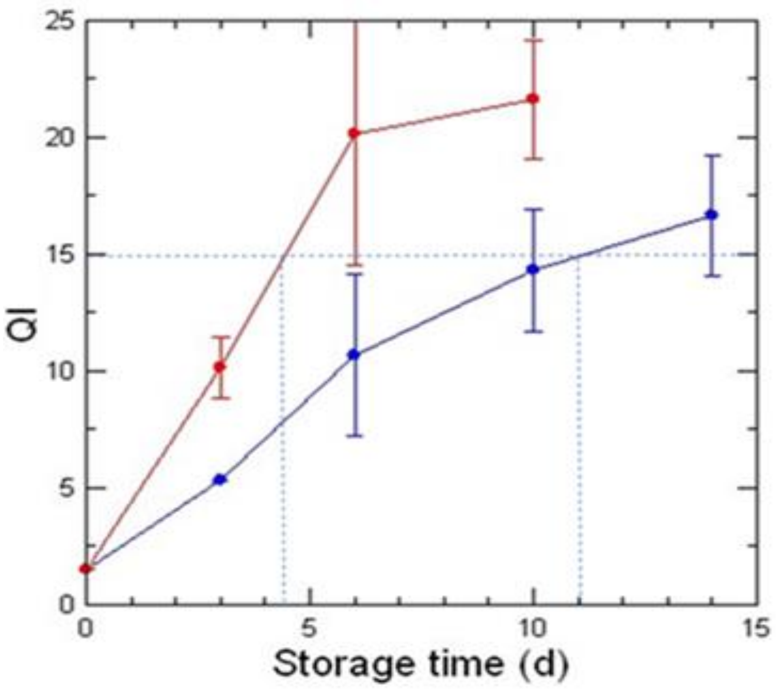

Figure 4. Changes in QI in Arctic Char stored at two different conditions, 10°C (red) and in ice (blue). (Error bar =SD, n=6)

4.4 **Simulation of quality changes**

In order to estimate the effect of different storage time and temperature combinations on shelf-life of rohu and Arctic char, the Food Spoilage and Safety Predictor programme was used. The inputs for the calculations were taken from information in Myanmar (Figure 2 and Table 2), from this study and literature (Table 3). Table 3. shows that estimated shelf-life of rohu at 30°C (ambient temperature) is 12h and in ice from 13 to 17days. The shelf-life of Arctic char has been found to be 4 days at 10°C, 11 days at 3°C and 15 days at 0°C.

Table 3. Shelf-life of rohu and Arctic char found in literature and this study

<table>
<tr><th>Fish</th><th>Temperature (0°C)</th><th>Shelf-life</th><th>Reference</th></tr>
<tr><td rowspan="4">Rohu</td><td>30</td><td>12 hr</td><td rowspan="2">Sravani, (2011)</td></tr>
<tr><td>Ice 0</td><td>17 days</td></tr>
<tr><td>Ice 0</td><td>13 days</td><td rowspan="2">Joseph, Surendran, & Peigreen, 1988</td></tr>
<tr><td>Ice 0</td><td>15 days</td></tr>
<tr><td rowspan="2">Arctic Char</td><td>10</td><td>4 days</td><td rowspan="2">This study</td></tr>
<tr><td>3</td><td>11 days</td></tr>
<tr><td rowspan="2">Arctic Char</td><td>0</td><td>15 days</td><td rowspan="2">Cyprian, Sveinsdóttir, Magnússon, & Martinsdóttir, (2008)</td></tr>
<tr><td>24h at 18°C and then 0°C</td><td>13 days</td></tr>
</table>

This table shows that rohu stored at 30°C has shelf life of ~12 hours, while kept in ice it will last for up to 17 days. The values of 13, 15 and 17 days depend on the fish size. The shelf life of Arctic char at 0°C is 15 days and if initially stored at 18 ˚C for 24 hours followed by 0°C, the shelf life will drop to 13 days.

Table 4. Calculated loss of shelf-life of rohu and Arctic char stored at different times and temperatures. The calculations assume that shelf-life of rohu is 17 days at 0°C and that of Arctic char 15 days at 0°C.

Fish	Scenario	Time	Temperature (°C)	Loss of Shelf-life
Rohu	1	6 hr	30	9 days
	2	3 hr + 3 hr	30 + 10	5 days
	3	2 hr+ 4 hr	30 + 10	3.6 days
	4	1 hr+ 5 hr	30+10	2.2 days
	5	0.5 hr + 5.5 hr	30+10	1.5 days
Arctic Char		4	10	0.66 days
		2+2	10-0	0.41 days
		4	0	0.16 days

In scenario 1 it is assumed that the fish will not receive any ice (chilling) during the entire journey from pond to auction in a van. During that time (6h) the fish will lose 9 days, or almost half of the shelf life compared to storage at 0°C. In scenario 2 it is assumed that the fish is put in ice in the van and transported in ice to the auction. Here the loss of shelf life is 5 days, or three hours in ice will give shelf life gain of 4 days compared to no ice. In scenario 5 it is assumed that the fish is iced at pond and kept in ice during the whole transport to the auction. This will result in “only”1,5 days loss in shelf-life.

If the fish is never iced from pond to factory (12-15h) the whole shelf life will be lost.

The three different storage temperature scenarios for arctic char are based on assumed shelf-life of 15 days at 0°C. These scenarios are derived from observations in this study (Table 4). Storing the arctic char at 10°C for 4 hours is equal to shelf-life loss of 0.66 days. However, if the fish is chilled from10°C to 0°C in 2 hours the shelf-life loss is 0.41 days.

4.5 Identification and ranking of weak points

Regarding spoilage, it is clear from the results above that lack of proper chilling at harvest and at ponds is a weak point in the whole transport and storage chain. The transportation step is also shown to be a critical control point. Fish is not properly iced or chilled which affects the quality of the fish during transport. Also, as seen from the flow chart, while transporting the fish, the insulated containers are not monitored to control the temperature. This can invite rapid bacterial growth. One of the major contaminations include the insulated containers, which are not properly cleaned.

5 DISCUSSION

The aim of this study was to identify the main processing steps where quality losses take place in the handling of rohu in Myanmar. Also, to see if lessons could be learned from the handling of aquaculture fish in Iceland.

Aquaculture is an important sector in Myanmar fisheries sector. Its production was about one million tons in 2016. It is 70 % to total national fish production in 2016. Rohu is dominant aquaculture species in the aquaculture. Post-harvest losses are big problem in the aquaculture sector.

Aquaculture products value chain start from harvesting in the farms and end with export final products. Harvest from the farm to the processing industry is an important part of the value chain. A total of eight steps were identified that describes the handling of rohu from harvest to the freezing pan of the factory. It has shown that icing (chilling) is inadequate in many of the steps. Simulations showed that icing at harvest is the most effective way of reducing quality losses as if temperature is brought below 10°C quality changes are very slow. It takes 12 to 15 hours to reach to processing plant. Transportation is an important step, which consumed 3-6 hours in the process. The transportation temperature varies in boat transportation and insulated vehicle transportation, while transportation duration also short in the insulated vehicle method. Temperature of fisheries product in the insulated vehicles is lower than the boat transportation method. The temperature of fisheries products is ranged between 5°C to 16°C in insulated vehicle transportation. The boat temperature is higher than this range. These temperatures of storage and duration of transportation likely negatively impact the fish shelf life.

The very low initial total counts in Arctic char are because the flesh of newly caught fish is sterile, due to the defence system of the fish. However, when the fish dies, the immune system and other defence mechanisms breakdown and during storage, bacteria invade the flesh.

The results (Figure 2) show that bacterial numbers respond as expected to the storage temperature and time. In the experiments, Arctic char was kept in two different temperatures, 3°C and 10°C for up to 14 days. On the first day, very low amounts (less than 10/g) of bacteria were found at both temperatures. But the number of bacteria increased with the storage time in both temperatures. The increase was higher at 10°C than at 3°C. The result shows the importance of temperature for growth of microorganisms. As microorganisms are responsible for post-mortem spoilage of fish, the results underpin the importance of low temperature storage of fish.

Quality Index (QI) of Arctic char kept at two different temperatures, 3°C and 10°C, was determined by three panellists. The average QI was calculated, and graphs has plotted QI vs storage time. High level of correlation (r^2=0.9918) was found in 3˚C. The results (Figure 3) show that slope of the 10°C was higher than the 3°C. It reveals that the 10°C storage temperature quality index values are higher than 3°C over the storage time. The quality index values are directly proportional to spoilage rate of the fish. The relationship suggests that fish in the 10°C storage temperature spoil more quickly than 3°C. The QI values increase with the storage time. Therefore, spoilage rate is affected by both storage temperature and storage time.

The storage experiments with Arctic char showed, as expected, that proper chilling effectively slows quality losses. In this study, the shelf life at 3°C was found to be 11days and 4 days at 10°C. Using that for simulations, the estimated shelf life of Arctic char at 0°C is estimated to be 16 days or a day longer than found by Cyprian et al (2008). The results (Table 4) indicate that shelf life of Arctic char is affected by the storage temperature. The results also show some similarities with Sravani (2011) studies on rohu. The low storage temperature helps to reduce the spoilage rate and keep the fish fresh longer.

These results can be applied to the Myanmar fisheries sector. The Myanmar pond water temperature is about 30°C throughout the year. After the harvest, farmers transport their harvest by fishing boat or insulated vehicles to the landing site and auction. But due to inadequate chilling facilities, the temperature is high. Boat transportation takes longer than insulated vehicles. The temperature of the fish in insulated vehicles is between 5°C to 15°C, and the transport time is shorter than for the boat transport. Based on the simulation results, fish in boats is likely to spoil more quickly than in insulated vehicles as the temperature in boat transportation is higher and transportation duration longer. Therefore, considering the results of this study, it is highly recommended to reduce the transportation time and use effective chilling methods to keep the fishes at low temperature. It will keep the fish in good quality for more days.

This study focused on time and temperature aspect. However, another important aspect is chemical contamination as the use of the chemicals in aquaculture has increased. Also not included but important is contamination by pathogenic bacteria in aquaculture products.

6 CONCLUSION

The aim of this study was to identify the main processing steps where quality losses take place in the handling of Rohu in Myanmar.

Temperature is very important for the quality of the fish. During processing, it is important to cool the fish from start to finish. The study also shows that boat and van travel time contribute to fish spoilage. The shorter the travel period with lower temperature, the higher the quality of fish. Prevention of contamination in the flow chart is very important to minimize the fish spoilage.

To draw parallels, microbiological and Quality Index analysis were done to evaluate the spoilage rate of Arctic char at two different storage temperatures. The results revealed that fish spoilage is higher at high temperature and longer storage time. In the high temperature, microorganisms grow rapidly and spoil the fish quickly which then reduces shelf life. In experimenting, the Arctic char was properly chilled and stored under iced conditions and 10^{o}C. Bacteria grew at a lower rate in the iced condition. In 10^{o}C, samples were kept for 10 days, when it was realised that the spoilage and bacteria growth were high.

Fresh fish cannot be kept for long without serious loss of quality. Fresh fish is normally preferred by consumers. In transporting fish from a long-distance additional ice is required by vans and trucks with cooling devices. It may not be economically feasible to transport fresh fish unless economies of scale can be achieved through high-volume.

7 RECOMMENDATIONS

To ensure the safety and quality assurance of post-harvest handling of fish in Myanmar, the following actions should be taken as possible as:

- Transporting should be as early as possible from pond to processing plant.
- Time and temperature control need to be monitored in the pond to processing plant.
- Quality control on ice plants and ice used needs to be done for fish hygienic conditions.
- Required training manuals such as Good Aquaculture Practices, Good Manufacturing Practices and Good Hygiene Practices for fish farmers to upgrade their knowledge.

ACKNOWLEDGEMENTS

First of all, I would like to express my sincere and heartfelt gratitude to my supervisors Prof. Hjorleifur Einarsson and Arnheidur Eyporsdottir, University of Akureyri, for their invaluable advice, kind guidance and assistance.

I express my deepest appreciation to the staff of UNU-FTP, Iceland; Director, Dr. Tumi Tomasson, Deputy Director, Mr. Thor Asgeirsson, Project Managers Mary Frances Davidson and Stefan Ulfarsson, and Administrative Manager Julie Ingham for giving me the opportunity to participate in the programme and their continued assistance, support and guidance during the six-month period of the training programme.

Special thanks also go to my Director-General Khin Maung Maw and Deputy Director-General Myint Zin Htoo of Ministry of Agriculture, Livestock and Irrigation, Department of Fisheries for giving me this opportunity to participate in the UNU-FTP in Iceland.

Finally, I would like to thank all the UNU-FTP fellows for their help during my study and stay in Iceland.

REFERENCES

Adams, R., Moss, O., & McClure, P. (2016). Food Microbiology 4th Edition. UK: The Royal Society of Chemistry.

Bao, H. N., Arason, S., & Porarinsdottir, K. A. (2007). Effects of Dry Ice and Superchilling on Quality and Shelf Life of Arctic Charr (Salvelinus alpinus) Fillets. *International Journal of Food Engineering 3 (3), Article 7*.

Belton, B., Filipski, M., & Hu, C. (2017). *AQUACULTURE IN MYANMAR: FISH FARM TECHNOLOGY, PRODUCTION ECONOMICS AND MANAGEMENT.* Myanmar: Research Paper 52 .

Belton, B., Hein, A., Htoo, K., Kham, L., Nischan, U., Reardon, T., & Boughton, D. (2015). *AQUACULTURE IN TRANSITION: VALUE CHAIN TRANSFORMATION, FISH AND FOOD SECURITY IN MYANMAR ,INTERNATIONAL DEVELOPMENT WORKING PAPER 139.* USA: the Department of Agricultural, Food, and Resource Economics and the Department of Economics, Michigan State University, East Lansing, Michigan 48824-1039 .

Cyprian , O., Sveinsdóttir , K., Magnússon , H., & Martinsdóttir , E. (2008). Application of Quality Index Method (QIM) Scheme and Effects of Short-Time Temperature Abuse in Shelf Life Study of Fresh Water Arctic Char (Salvelinus alpinus) . *Journal of Aquatic Food Product Technology,17:3*, 303-321.

Dalgaard, P. (1995). Modelling of microbial activity and prediction of shelf life for packed fresh fish. *International Journal of Food Microbiology, 26(3)*, 305-317.

Dalgaard, P. (2014). Food Spoilage and Safety Predictor (FSSP) Software. 31.

Dhanapa,K, Sravani, K., Balasubramanian, A., & Reddy, G. (2013). QUALITY DETERMINATION OF ROHU (Labeo rohita) DURING ICE STORAGE. *Tamilnadu J. Veterinary & Animal Sciences 9 (2)*, 146 - 152.

Edirisinghe, K., Wansapala, J., & Wickramasinghe, I. (2018). Review of marine fishery status along the supply chain in Sri Lanka. *International Journal of Food Science and Nutrition 3 (4)*, 10-23.

Elhadi, N., , Aljeldah, M. , & Aljindan, R. (2016). Microbiological contamination of imported frozen fish marketed in Eastern Province of Saudi Arabia. *International Food Research Journal , 3*, 2723-2731.

European Commission. (2008). *COMMISSION REGULATION (EC) No 1022/2008- amending Regulation (EC) No 2074/2005 as regards the total volatile basic nitrogen (TVB-N) limits.* European Commission. Official Journal of the European Union. Retrieved 01 25, 2019, from https://www.fsai.ie/uploadedFiles/Reg1022_2008.pdf

European Commission, Directorate-General for Health and Food Safety. (2019, 02 21). *Final report of an audit carried out in Myanmar, Evaluation the control system in place governing the production of fishery products intended for export to the European Union*. Retrieved from European Comission: http://ec.europa.eu/food/audits-analysis/audit_reports/details.

European Union. (2019, 02 23). *EC No 2406/96, COUNCIL REGULATION, laying down common marketing standards for certain fishery products*. Retrieved from European Union: https://publications.europa.eu/en/publication-detail/-/publication

European Union. (2019, 02 23). *Official Journal of the European Union*. Retrieved from REGULATION (EC) No 854/2004 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL, laying down specific rules for the organisation of official controls on products of animal origin, the organisation of official controls on products of animal origin: https://eur-lex.europa.eu/LexUriServ/LexUriServ

FAO. (2012, February). *FAO Fisheries statistics*. Retrieved from FAO: www.fao.org/fishery/facp/MMR/en

FAO. (2014). *Assessment and management of seafood safety and quality* . Rome: FAO Fisheries and Aquaculture Technical Paper 574.

FAO. (2016). *THE STATE OF WORLD FISHERIES AND AQUACULTURE.* Rome: Contributing to food security and nutrition for all. Rome. 200 pp.

FAO. (2019, 02 21). *Code of Practice for fish and fishery products*. Retrieved from FAO: www.fao.org/fao-who-codexalimentarius

FDA. (2019, 01 23). *FDA (U.S. Food and Drug Administration)*. Retrieved from FDA: https://searchhealthit.techtarget.com/definition/FDA-US-Food-and-Drug-Administration

FDA. (2019, 02 16). *U.S. Department of Health and Human Services*. Retrieved from U.S. Food & Drug Administration: https://www.fda.gov/food/guidanceregulation/haccp/ucm2006801.htm#princ

FDA. (2019, 01 23). *U.S. FOOD & DRUG ADMINISTRATION*. Retrieved from U.S. Department of Health and Human Services: https://www.accessdata.fda.gov/cms_ia/country_MM.html

Gandotra, R., Sharma, S., Sharma , M., & Kumari , R. (2017). Effect of two different storage temperatures (-12 ºC and -20 ºC) on the proximate and microbial quality of Labeo rohita muscles. *International Journal of Fisheries and Aquatic Studies, 5(3)*, 435-439.

Germano, R., & Pantanella , E. (2016). *Best Management Practices for Fish Handling and Small-scale Processing* . Myanmar: Italian Agency for Development Cooperation.

Getu, A., Misganaw, K., & Bazezew, M. (2015). Post-harvesting and Major Related Problems of Fish Production. *Fisheries and Aquaculture Journal 6 (4)*, 1-5.

Ghaly, A., Dave, D., & Budge, S. (2010). Fish Spoilage Mechanisms and Preservation Techniques: Review. *American Journal of Applied Sciences, 7*, 859-877.

Gram, L., & Dalgaard, P. (2002). *Fish spoilage bacteria-Problem and solution.* Genmark: Department of Seafood Research, Danish Institute for Fisheries Research 13 (3), 262–266.

Gram, L., & Huss , H. H. (1996). Microbiological spoilage of fish and fish products. *International Journal of Food Microbiology, 33 (1)*, 121-137.

Gustavsson, J., Cederberg, C., Sonesson, U., Otterdijk, R., & Meybeck, A. (2011). *Global Food Losses and Food Waste.* Rome, Italy: FAO, 16-17.

Huss , H. H. (1995). *Quality and quality changes in fresh fish.* Rome: FAO Fisheries Technical paper-348.

Huss , H. H. (1997). Control of indigenous pathogenic bacteria in seafood. *Food Control* , 91-98.

Huss, H. H. (2003). *Assessment and Management of Seafood Safety and Quality.* Rome: FAO-444.

Imteaz A Khan. (2019, 01 23). *Is rohu fish healthy*. Retrieved from quora: https://www.quora.com/Is-rohu-fish-healthy

Jinadasa, B. (2014). Determination of Quality of Marine Fishes Based on Total Volatile Base Nitrogen test (TVB-N). *Nature and Science, volume 12(5)*, 106-109.

Joseph, J., Surendran, P., & Peigreen, P. (1988). *Studies on ice storage of cultured Rohu (Labeo rohita).* Cochin: Central Institute of Fisheries Technology, 35- 682 029.

Kuuliala , L., Hage, Y., Ioannidis, A., Sader, M., Kerckhof, F., Boon , N., . . . Devlieghere, F. (2018). Microbiological, chemical and sensory spoilage analysis of raw Atlantic cod (Gadus morhua) stored under modified atmospheres. *Food Microbiology , 70*, 232-244.

Martinsdottir, E., Sveinsdottir, K., Luten, J., Schelvis-Smit, R., & Hylding, G. (2001). *Sensory Evaluation of Fish Freshness.* Iceland.

Matis. (2019, 01 23). *Iceland Arctic Charr*. Retrieved from Matis: http://old.matis.is/english/iceland-arctic-charr/

Ministry of Agriculture, L. a. (2017 a). *Fishery Statistics.* Republic of the Union Myanmar.

Ministry of Agriculture, L. a. (2017 b). *National Residues Monitoring Plan for Aquaculture Products Progress Report.* The Republic of the Union of Myanmar.

Ministry of Agriculture, L. a. (2018). *National Residues Monitoring Plan for Aquaculture Products Annual Plan.* Myanmar.

Nabi, M., Islam, M., & Kamal , M. (2001). Effect of delayed icing on quality changes and shelf-life of some freshwater fish from Bangladesh . *Department of Fisheries Technology, Bangladesh Agricultural University, 5 (2)*, 181-188 .

Ndraha, N., Hsiao, H.-I., Vlajic, J., Yang, M.-F., & Lin, V. H. (2018). Time and Temperature abuse in the food cold chain: Review if issues challenges and recommendations. *Food Control 89*, 12-21.

Obasohan , E. (2009). Pollution in aquaculture: chemical health concerns of aquaculture systems in Nigeria. *African Scientist 10 (2)*, 117-122.

Odoli, C., Odote, O., Ohowa, B., & Onyango, S. (2013). *Evaluation of fish handling techniques employed by artisanal fisher on quality of lethrinids and siganids fish genera at landing time along the Kenyan coast using sensory and microbiology methods.* Kenya: Kenya Marine and Fisheries Research Institute 13, 5.

Olafsdottir, G., Jonsdottir, R., L.Lauzon, H., Luten, J., & Kistbergsson, K. (2005). Characterization of Volatile Compounds in Chilled Cod (Gadus morhua) Fillets by Gas Chromatography and Detection of Quality Indicators by an Electronic Nose. *J. Agric. Food Chem*, 10140–10147.

Olafsdottir, G., V, V.-B., Luten, J., Dalgaard, P., Careche, M., Martinsdottir, E., & Heia, K. (1997). *"The need for methods to evaluate fish freshness"Methods to determine the freshness of fish in research and industry. Processing of the Final Meeting.*

Østergaard, N. (2014). Predictive Food Microbiology. *PhD thesis, Dauian Technical University ,National Food Institute*, 32.

Seafood Scotland. (2019, 01 22). *Quality & Standards*. Retrieved from Seafood Scotland: http://www.seafoodscotland.org/en/quality-standards/brc-global-food-standards.html

Shawyer, M., & Pizzali, A. (2003). *The use of ice on small fishing vessels.* Rome: FAO FISHERIES TECHNICAL PAPER 436.

Sivertsvik, M., Jeksrud, W., & Rosnes, J. (2002). A review of modified atmosphere packaging of fish and fishery products – significance of microbial growth, activities and safety. *International Journal of Food Science and Technology, 37*, 107-127.

Sravani. (2011). *Qulaity Assessment of Rohu (Labeo Rohita) Stored at Different Temperature.* India: Department of Fish Processing Technology, SRI VENKATESWARA VETERINARY UNIVERSITY.

Svanevik, C. S., & Lunestad, B. T. (2011). Characterisation of the microbiota of Atlantic mackerel (Scomber scombrus). *International Journal of Food Microbiology*, 164-170.

Svanevik, C. S., Roiha, I. S., Levsen, A., & Lunestad, B. T. (2015). Microbiological assessment along the fish production chain of the Norwegion Pelegic fisheries sector result from a spot sampling programme. *Food Microbiology , 51*, 144-153.

Tahsin, K. N., Soad, A. R., Ali, A. M., & Moury , I. J. (2017). A Review on the Techniques for Quality Assurance of Fish and Fish Products. *International Journal of Advanced Research in Science, Engineering and Technology , 4 (7)*, 201.

Valtysdottir, K., Margeirsson , B., Arason , S., Lauzon , H., & Martinsdóttir , E. (2010). *Guidelines for precooling of fresh fish during processing and choice of packaging with respect to temperature control in cold chains.* Reykjavik: Matis.

World Bank. (1960 - 2016). *Myanmar Agricultural Production and Consumption.* Retrieved from https://www.ceicdata.com/en/myanmar/agricultural-production-and-consumption

World Fish Center. (2016). *Improving Research and Development of Myanmar's Inland and Coastal Fisheries*. Retrieved from World Fish Center: https://www.worldfishcenter.org/content/improving-research-and-development-myanmars-inland-and-coastal-fisheries-myfish

Yucel, & Balci. (2010). Prevalence of Listeria, Aeromonas and Vibrio Species in Fish Used for Human Consumption in Turkey. *Journal of Food Protection 73,2,* 380-384.