The United Nations University

FISHERIES TRAINING PROGRAMME

ANALYSIS OF QUALITY DETERIORATION AT CRITICAL STEPS/POINTS IN FISH HANDLING IN UGANDA AND ICELAND AND SUGGESTIONS FOR IMPROVEMENT

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ABSTRACT

In this report, fish handling steps prior to processing in Uganda and Iceland were studied empirically. The effects of fish age (post-catch days) and mechanical load on the sensory, microbiological and chemical qualities of cod (*Gadus morhua*) were also investigated. The effects of mechanical load were investigated by subjecting one lot of fish to mechanical load for seven days and the quality was then compared to the other lot without load. Sensory results of post-catch days analysis showed increased quality deterioration of cod on post-catch days 7-11 than post-catch days 1-7. Fish subjected to mechanical load exhibited more sensory quality loss and higher total microbial counts in the flesh and lower counts on the skin surface as opposed to fish that was not exposed to mechanical load. TVB-N was also slightly higher in fish with load. The overall results suggested that fish quality deterioration in Uganda is mostly due to bacterial growth. It is thus recommended that fish shouldn't be kept beyond six hours at ambient temperature before it is iced if its shelf life is to be maintained to meet the market's quality demands.

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1   INTRODUCTION

Currently, Uganda's major source of foreign exchange comes from fish exports of Nile perch (*Lates niloticus*) and to a lesser extent Nile tilapia (*Oreochromis niloticus*) exported mainly to the European Union (EU). Fisheries annual production amounts to approximately 371,000 metric tonnes with approximate exports worth USD 100 million, with over one million people directly or indirectly involved in fishing, transportation, processing or employed as resource managers (FAO, Year of fishery statistics 2007).

The main sources of fish for fish processing plants in Uganda are landing sites on the islands of Lake Victoria. Kalangala district is one of them (a unique district in Lake Victoria composed of 84 isolated islands) with about 2500 operational fishing boats. On average, 40 kg per boat valued at 2400 Ugshs (about USD 1.3) per kg are landed on a daily basis.

However, not all fish landed end up in factories, about 10-30% are regarded as "rejects" both at landing sites and in fish processing factories. The rejected fish is either of deteriorated quality or to a lesser extent under sized, which fetches only about a quarter of the price. However, rejected fish always finds its way to local or regional markets, and is often processed locally by frying, smoking or salting and drying to minimise further spoilage during distribution.

EU regulation (EC) No852/2004, demands imported foods from exporting countries to be of at least the same hygienic standards as food produced within the EU . Iceland has more contacts with the EU as it is a member of the European Economic Area (EEA) and also an exporter of fishery products to the EU market. Therefore, a study of fish handling practices in Iceland is of paramount importance for improving fish handling practices and fish quality in Uganda.

First class products can never be produced from defect raw materials. Therefore, a study of the fish handling chain from catch prior to processing and factors for the best storage conditions in insulated fish transport boats to maintain quality of fish for 2-7 days was conducted. The objectives of the study were to:

- Identify major causes of fish quality deterioration in the handling chain in Uganda.
- Study fish handling practices in Iceland that can potentially be applicable in Uganda to improve fish quality.
- Analyse the quality of fish at each step in Iceland.
- Come up with recommendations of both Good Hygiene Practices (GHPs) and Sanitation Standard Operating Procedures (SSOPs) for fish handling prior to processing in Uganda.

2   LITERATURE REVIEW

Fish are recognised as being highly perishable, having a relatively short shelf life, which is defined as the length of time from the day of catch that fresh fish can be in the marketplace unspoiled (Regenstein and Regenstein 1991). Therefore fish requires proper handling and preservation to increase its shelf life and retain its quality and nutritional attributes. Quality is defined as the aesthetic appearance and freshness or degree of spoilage which the fish has undergone (FAO). Immediately as fish is caught, it looses its natural resistance to attack by microorganisms and also starts to undergo both physical and chemical changes that in return bring changes in appearance, taste, smell and texture.

2.1   Forms of fish spoilage

"Spoilage" can be defined as a change in fish or fish products that renders them less acceptable, unacceptable or unsafe for human consumption (Hayes 1985). Fish undergoing spoilage has one or more of the following signs: slime formation; discolouration; changes in texture; off-odours; off-flavours and gas production. The development of these spoilage indicators in fish and fish products is due to a combination of microbiological, chemical and enzymatic and physical phenomena (Huis in't Veld 1996).

2.1.1   Microbiological spoilage

Live fish is normally considered to be sterile, but microorganisms are found on all the outer surfaces (skin and gills) and in the alimentary tract of live and newly caught fish in varying numbers. A normal range of 10^2-10^7 cfu (colony forming units)/cm^2 on the skin and between 10^3 and 10^9 cfu/g in the gills and intestines has been observed (Liston 1980). When fish dies, its entire body resistance mechanisms breakdown, giving way to microorganisms or the enzymes they secrete to invade or diffuse into the flesh where they react with the complex mixture of natural substances present. During storage a characteristic flora develops, but only a part of this flora, known as the specific spoilage organisms (SSO), contribute to spoilage. The SSO counts reach a minimal spoilage level where the fish is sensorially rejected (Figure1). Temperate fish have psychrotrophic (cold-tolerant) bacteria of the genera *Pseudomonas, Moraxella, Acinobacter, Shewanella Flavobacterium, Vibrio, Photobacterium* and *Aeromonas* as part of their natural flora whereas tropical fish normally have non-psychrotrophic (mesophilic) spoilage bacteria that make tropical fish spoil much faster than temperate water fish in the absence of ice.

Pseudomonas and *Altermonas putrefaciens* are probably the major bacterial species that cause fundamental spoilage of usually iced fish. These can use the non-protein nitrogen compounds present in the fish such as trimethyl amine oxide (TMAO) that result in several volatile odoriferous compounds such as trimethyl amine oxide, TMA (Regenstein and Regenstein 1991). These volatile compounds are responsible for the off-odours and off-flavours characteristic of spoiled fish. In several studies, *Photobacterium phosphoreum* and *Shewanella putrefaciens* have been found in packed cod with the former most likely the SSO of packed cod stored on ice (Dalgaard 1995).

Bacteria are able to decompose proteins, other nitrogen containing compounds to ammonia, hydrogen sulphide, which produce an unpleasant and disgusting flavour (Herbert and Shewan 1975). Trimethyl amine oxide (TMAO), mostly found in marine fish, is broken down to trimethyl amine (TMA), dimethyl amine (DMA) and ammonia (NH3), which are responsible for off-odours in fish undergoing spoilage.

The main spoilage test of metabolite(s) produced during fish storage or distribution to obtain a quantitative fish quality index is total volatile bases (TVB). It measures the total content of TMA+DMA+ ammonia plus other basic nitrogenous compounds associated with fish spoilage. TVB and TMA values of 30 mgN and 15 mgN/100 g are the rejection spoilage levels respectively (Regenstein and Regenstein 1991). The fishy odour of TMA when it reacts with lipid is generally detectable when the TMA level reaches 4-6 mgN/100 g.

Microbiological quality evaluation of fish aims to quantify the hygienic quality of fish, including temperature abuse and the possible presence of pathogenic microorganisms in the fish. Total aerobic bacteria, also called total plate count (TPC); specific spoilage organisms (SSO) and various pathogenic bacteria are examined using appropriate agar media. Quality levels are based on the plate counts for acceptance or rejection of fishery products for human consumption. With representative sample units not less than five, plate counts below 5×10^5 are considered of good quality; between $5 \times 10^5 \, and \, 10^7$ marginally accepted quality (sample units with plate counts between 5×10^5 and 10^7 not exceeding three) and plate counts at or above 10^7 are considered unacceptable in quality (ICMSF 1986).

2.1.2   *Chemical oxidation*

Chemical spoilage processes are changes taking place in the lipid fraction of the fish. Lipids are oxidised to peroxides, aldehydes, ketones and lower aliphatic acids. The hydro-peroxides are tasteless but can cause brown and yellow discolouration of the fish tissue. The degradation of hydro-peroxides gives rise to the formation of aldehydes and ketones that result in rancid off-flavours. All the chemical by-products eventually reach a level where the fish is rejected (Figure 1).

High temperatures are partly responsible for the speed of the oxidation processes. In addition, direct sunlight, wind, heat, light (especially UV-light) and several organic and inorganic substances may also accelerate oxidative processes.

Living cells in fish have enzymatic protection mechanisms against lipid oxidation by having an enzyme, glutathione peroxidase, which acts by reducing hydro-peroxides in cellular membranes to corresponding hydroxyl-compounds. This reaction requires a supply of the enzyme in a reduced form and thus the reaction stops when the fish die.
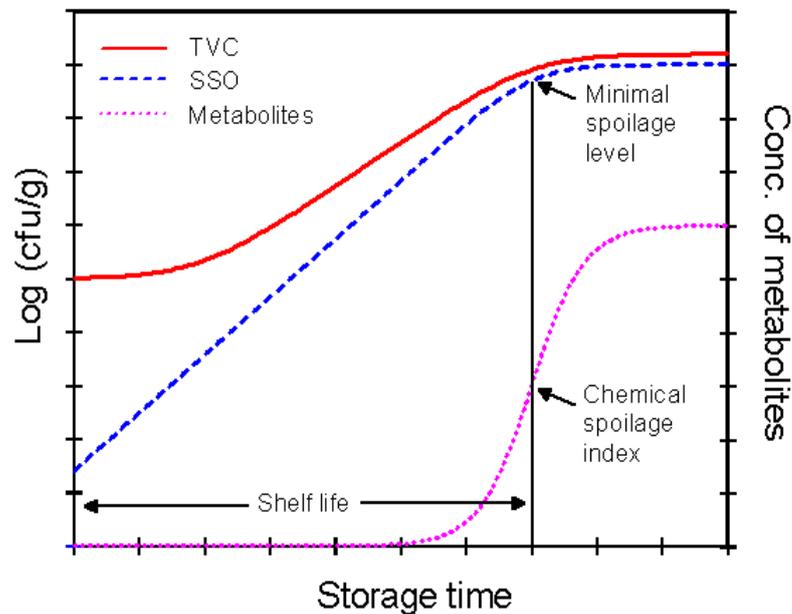
Figure 1: General pattern of microbial spoilage changes in total viable count (TVC), specific spoilage organisms (SSO), and chemical spoilage indices during chilled storage of a fish product (adapted from Dalgaard 1993).

2.1.3 Autolytic spoilage

As fish dies, its enzymatic activity doesn't stop immediately but continues resulting in proteolytic changes that are responsible for early quality loss in fresh fish. The more these enzymes get in contact with the fish's flesh the greater the spoilage. Adenosine triphosphate (ATP) is broken down through a series of products such as adenosine diphosphate (ADP), inosine monophosphate (IMP), inosine and hypoxanthine (HX) as: $ATP \rightarrow ADP) + energy \rightarrow IMP + I \rightarrow HX$.

IMP and HX may be responsible for the sweet and mild tastes in the later stages of shelf life and these products accumulate especially when the respective step is rate-limiting (Regenstein and Regenstein 1991). From previous studies, these changes precede microbiological spoilage and have been seen to contribute very little to spoilage of chilled fish and fish products (Huss 1994).

2.2 Factors that influence the rate of fish spoilage

2.1.4 Effects of time/temperature conditions on microbial growth

The most crucial factors determining the quality of fishery products are time and temperature tolerance. Proliferation of microorganisms requires appropriate high temperatures, while at lower temperatures close to 0ºC, their activity is reduced, thereby extending the shelf life of fish products. Temperature is the single most important factor affecting post-harvest quality of the products. It is often critical to reach the desired short-term storage temperature rapidly to maintain the highest visual quality, flavour, texture, and nutritional content of fresh fish.

The rate of spoilage is dependent upon the holding temperature and is greatly accelerated at higher temperatures, due to increased bacterial action.

The shelf life at different storage temperatures ($t^{\circ}C$) has been expressed by the relative rate of spoilage (RRS), defined by the equation (Spencer and Baines 1964):

$$\text{Relative rate of spoilage} = \frac{keeping\ time\ at\ 0^{\circ}C}{keeping\ time\ at\ T^{\circ}C}$$

$$Shelf\ life = \frac{Final - initial\ level\ of\ a\ quality\ indicator}{Rate\ of\ spoilage\ at\ the\ actual\ storage\ conditions}$$

2.1.5 Effects of hygiene on fish quality during handling

Apart from the microorganisms that fishes have at the time of capture, more is added via unhygienic practices and contaminated equipment such as storage facilities. This was demonstrated by studies that compared the quality and storage life of completely aseptically treated fish (aseptic handling), washed fish, iced in clean plastic boxes, with clean ice (clean handling) and with un-washed fish, iced in old, dirty wooden boxes (normal handling). A considerable difference was found in the bacterial contamination of the three batches, the latter heavily contaminated with a reduction in storage life compared with the other samples (Huss *et al.* 1974).

The design of a fish hold is of great importance as far as hygiene in the hold is concerned. Hold design should enable the purge (drip loss) to be collected easily. The amount of purge was suggested to be higher at 5-7ºC; at which temperature there is greater spoilage since the purge is a very good medium for bacterial growth (Hermansen 1983).

2.1.6 Rough handling

Rough handling will result in a faster spoilage rate. This is due to the physical damage to the fish, resulting in easy access for enzymes and spoilage bacteria. Physical mishandling in the net, such as very large catches, fishermen stepping on fish or throwing boxes, containers and other items on top of the fish, may cause bruises and rupture of blood vessels.

When fish is in rigor mortis (a complicated series of chemical changes that result in stiffening of the fish's muscle shortly after death), rough handling can cause gaping (Huss 1995).

2.1.7   Initial bacterial load

The microflora on tropical fish often carries a slightly higher load of Gram-positives and enteric bacteria but otherwise is similar to the flora on temperate-water fish (Liston 1980). Basically, bacteria populations on temperate fish are predominantly psychrotrophic reflecting water temperatures of about 10°C while fish from the tropics have largely mesophilic bacteria (Gram and Huss 1996).

2.1.8   Methods of capture

The fishing gear and method employed determines the time taken between capture and death. Fish caught in gillnets struggle much to escape, and in so doing, they are bruised by the net which increases exposure to microbial entry and subsequent deterioration. Fish caught by hook and line methods, on the other hand, die relatively quickly and therefore bruises and stresses are likely to be minimal. Physical mishandling in the net due to long trawling nets and very large catches accelerates spoilage. The large catches in the net are compacted against each other resulting in the fish getting bruised and crushed (especially small sized fish) by the heavy trawl net.

2.1.9   Mode of storage

In bulk-storage, the weight of the pile may crush the fish at the bottom, leading to a loss of weight (yield) as well as other physical damage. It has been reported that when haddock is kept in a short, deep pile of about 3 ft, the bottom fish lose 15% of their weight compared to a normal weight loss of 3-8%, which is entirely due to biochemical changes that cause a loss of water holding capacity leading to drip (Regenstein and Regenstein 1991). Crushing of the fish by ice or other fish can seriously affect the quality of fish by releasing enzymes from the gut into the fish muscle thereby accelerating autolytic processes.

3   MATERIALS AND METHODS

3.1   Fish handling steps in Uganda and Iceland

Using the author's own experience, observation and previous studies, the fish handling steps in Uganda were critically reviewed and described, pointing out major practices that are likely to be responsible for fish quality deterioration, with an emphasis on those that can potentially be improved. In Iceland, the same handling steps were studied through study visits to a fish harbour and auction market in Dalvik and the factory reception area at Brim factory limited so as to have a comparative view.

3.2   Effects of post-catch storage time on fish quality

In an effort to have an insight into the degree of GHPs and SSOPs employed in fish handling in Iceland, the sensory, microbiological and chemical quality parameters of gutted iced cod of different post-catch days were evaluated. Five individual whole cod of different post-catch days (PDs) 1, 7, and 11 were randomly picked from their respective tubs in the reception area of fresh fish from vessels landing at Brim factory limited. The fish sampled were from a trawler (Arbakur RE 205). The core temperature of the fish at the time of sampling was -0.4^{o}C and the ambient temperature was -0.5^{o}C to -0.2^{o}C in the reception area.

3.3   Effects of mechanical load on fish quality

In order to observe the effects of mechanical load (pressure) on bottom fish in a big fish hold for several days, as is the case in Uganda, the approach used aimed at assessing the effects of mechanical load on fish quality deterioration in fish that is heavily loaded in a fish hold (container). Thirty-five individual whole gutted cod (*Gadus morhua*) of one day post-catch (approximately 1 kg in weight per fish) from Brim factory limited were used for the study.

Five individual fish were sensorially analysed and the other three fish samples iced in polystyrene box and transported to the laboratory at the University of Akureyri, for biological and chemical analysis in order to get the original quality of the fish.

Twenty whole fish were then weighed into two lots of 13.4 and 13 kg and then handled under two different treatments:

Treatment one: One lot of 13 kg was properly iced in a fish-tub with a storage capacity of 300 kg, with proper drainage from the tub .The tub was then kept at 0-2ºC (temperature in the reception room) for seven days.

Treatment two: The other lot weighing 13.4 kg was iced in the same way as the first lot . Unlike the other treatment, several layers of salmon bags filled with clean portable water were added on top of the ice layer above the fish, which acted as fish, alternating with ice layers until the tub was full. The approximate weight above the fish layer was 200 kg. The second tub was kept in a similar environment for the same period of time after which the sensory, microbiological and chemical parameters were analysed.

3.4   Sensory evaluation

Freshness is to a certain degree subjective but it can be "measured" against an agreed scale by assessment of appearance, odour and taste. Sensory quality attributes of five whole cod fish samples were evaluated by the author using the quality index method (QIM) where each quality attribute was rated on a 0-3 demerit point score (with 0 being the highest and 3 the lowest) with a total score of 0-18 for cod fillets and 0-23 for whole cod (Larsen *et al.* 1992 and Bonilla *et al*. 2007) as shown in Appendix 1 and 2. Scores from each individual fish were added and the sum of the individual fish averaged to give the overall sensory score (quality index) of the fish from the same post-mortem age (post-catch days).

3.5   Microbiological evaluation

Three fish samples of 1, 7 and 11 post-catch days and three fish samples from each treatment were iced in different polystyrene boxes and immediately taken to the microbiological laboratory of the University of Akureyri for analysis. Bacterial counts were made from the skin and flesh separately as follows:

Skin: An area of 20 cm^2 was marked on the skin surface of each fish, swabbed clearly several times and the swabs mixed thoroughly in 20 ml of buffer solution. Ten-fold serial dilutions were made from 1 ml of the mixture, and 0.1 ml from each dilution spread on prepared iron agar plates in duplicate and the plates incubated at 22ºC for 72 hours and thereafter the total viable bacteria were enumerated using the total plate count method (TPC).

Flesh: The skin from individual fish was carefully removed, pieces cut from the flesh and minced in a blender. Twenty-five grams (25 g) of the minced fish were weighed in a stomacher bag, 225 ml of buffer solution added and the contents homogenised for 60 seconds in a laboratory stomacher-400 model. Serial ten-fold dilutions were made from 1 ml of the homogenate and 0.1 ml of each dilution spread on iron agar in duplicate and the plates incubated at room temperature (22ºC) for 72 hours.

3.6   Chemical analysis

The same fish samples that remained after the microbial analysis were used to determine the total volatile bases-nitrogen (TVB-N) of the initial quality of the fish before treatment. Fish sample (100 g) was weighed and the corresponding 200 ml of 7.5% aqueous trichloroacetic acid solution added and the mixture homogenised in a waring blender for 60 seconds. The mixture was then filtered through a white-filter paper.

To 25 ml of filtrate in a distillation flask was added 6 ml of 10% sodium hydroxide (NaOH) and the mixture steam- distilled against a beaker containing 10 ml of 4% boric acid solution and 0.04 ml of methyl red and bromocresol green indicator using a Kjeldahl-type distillator until the solution in the beaker rose to the 50 ml mark. Then the alkalised boric acid solution was titrated with aqueous 0.025 M sulphuric acid solution (H_2SO_4 (aq)). Complete neutralisation was obtained when the green colour turned pink on the addition of a further drop of sulphuric acid.

4   STUDY RESULTS

4.1   Fish handling steps in Uganda prior to processing

Three major methods of fishing are used namely, gillnetting, long-lining and hook and line. The complex chain through which the catch flows from fishing boat to the fish processing plant is summarised in Figure 2. Fish for industrial processing is transported by insulated boats from landing sites in the islands of Lake Victoria, and from landing sites along the shores by insulated trucks. The time taken for catch to reach processing plants ranges from 3-8 days for coming from the islands.

4.1.1   On the lake

For gillnetting, fishermen from fish landing sites go offshore (by motor or manual propulsion) and cast their nets at around 4-5 pm. Hauling of nets starts at about 2 am and landing of the catch (un iced) from 6 am onwards depending on the prevailing lake weather conditions. The major reason why fishermen land un-iced fish is that there is no ice plant in the district. Even the insulated fish transport boats have to get ice from factories, which are far from the landing sites. On the other hand, long-lines are set very early in the morning, hauled in the afternoon and catches landed in the evening. Assuming that the first fish gets caught in the net at 6 pm, hauled from the net at 3 am, transported and received by the container at the landing site at 8 am, this means the fish would have spent about 14 hours from the time it got caught in the net. This time interval may be responsible for most of the fish being rejected at the first landing sites as a result of bacterial growth. This factor is exacerbated where landed fish is not immediately iced but collected by "middlemen" and kept for an additional 1-3 hours before it is transferred to the container to be iced.

4.1.2   Landing sites on the islands

On landing, fish is sorted out of the nets, graded, weighed and sold to supplier/factory agents. During removal of the fish from nets, fish is simply thrown into the boat haul with little or no care. The rough handling can cause internal bruising and bleeding that becomes visible either when the fish is filleted or eaten by the consumer. Such fillets in factories are rejected or trimmed causing financial losses in terms of labour and yield.

In most landing sites, there are middlemen locally referred to as "kachanga" who are given money at landing site by suppliers or factory agents to buy and collect the fish from different landing boats. They sometimes use unhygienic collection points such as dirty, dilapidated boats. Thereafter, the fish is conveyed to the respective container owner who gives them a commission based on kg of fish bought. It is at this point that fish of low quality end up in the container and at factories because the middlemen strive to get more fish by mixing in fish of different quality levels. Based on studies conducted on the use of fish holds with different degrees of cleanliness (Huss *et al.* 1974), it is this step that poses the greatest potential danger to fish quality deterioration due to bacterial contamination from dirty, unclean and un-disinfected contact surfaces (dilapidated boats at landing sites).

4.1.3   Landing sites and containers on the islands

Fish gathered from boats is in some cases dragged through landing site water and thrown on to an insulated container (always anchored on the lake). This practice leads to fish being contaminated in the unclean landing site water and the throwing further damages the fish's skin because of sharp points of the container, making entry by bacteria easy. However, lack of landing site facilities such as floating jettys/docks makes transfer of fish from landing sites to containers difficult and thus fishermen to behave in this way.

The size of the fish hold is so big that the person icing the fish stands on the fish as he loads and ices it in the fish hold. The person and his boots may damage the fish and also the overall weight of the person may cause the fish to "burst". In addition, the many layers of fish and ice can also cause crushing of fish especially on the bottom layers. Another critical source of fish spoilage lies in the design and conditions of the container where some are poorly designed and cannot allow proper cleaning and drainage of purge. These factors promote contamination and growth of bacteria.

Buying and loading fish in the container is done by mixing fish of different post-catch days. One of the disadvantages associated with this practice is that grading of fish at the next landing site or factory reception area for size, species and degree of freshness is considerably problematic and time consuming. From the first landing site, the boat leaves for another established landing site on the mainland or in Kalangala district, or directly to a factory on the mainland. The tonnage of the container can be 1-6 tonnes of fish depending on: days spent buying, capacity of the container, availability of fish, finance and amount of ice.

4.1.4   Loading in trucks both on the islands and the mainland

At the second landing site, fish is removed from the container, evaluated and quality fish is re-iced in an insulated truck which buys and loads fish (for 2-3 days in the case of Kalangala) and finally it is taken to the factory. De-icing and evaluation are done on display tables and floors which are provided with a shade. The hygiene and cleanliness of these contact surfaces is critical in the contamination of the fish. The duration of transporting fish from the original landing site to next landing takes 2-6 hours depending on the distance and speed of the engine. The kind of loading in the truck is bulky massive stowage where fish of different post-mortem days, sizes and qualities are mixed. As said before, this makes grading fish at the factory difficult. Improper icing, conditions of the truck insulation and the effects of mechanical load are likely to affect the quality of the fish.

4.1.5   Processing plant

In order to identify fish that don't meet the quality demands of processing plants, fish are informally inspected at landing sites by buyers and at factories by factory inspectors through organoleptic assessment of gill colour, skin texture, eye colour and general appearance, with much emphasis on gill colour.

One of the weaknesses at this step is how well the fish is removed from insulated-compartmentalised vessels (containers) to the factory's raw material reception area. Sometimes these boats may take several days to be off-loaded, without having and considering the history of the fish, such as: post-mortem days, core temperature of the fish, amount of ice used, general conditions of the container, and so on. This practice contributes to fish spoilage rates especially if fish from the source was inadequately iced. This affects the fishermen and factory suppliers since this culminates in more fish being graded as "rejects". In addition, there may be a lack of well trained technical expertise (fish inspectors) that may grade quality fish as "rejects" or allow deteriorated raw materials into the processing chain which could result in low prices for exports. It is therefore important that, in the factory's hazard analysis critical control point (HACCP), the first critical control point for quality assurance should be the control of raw materials so as to avoid substandard raw materials entering the processing chain.
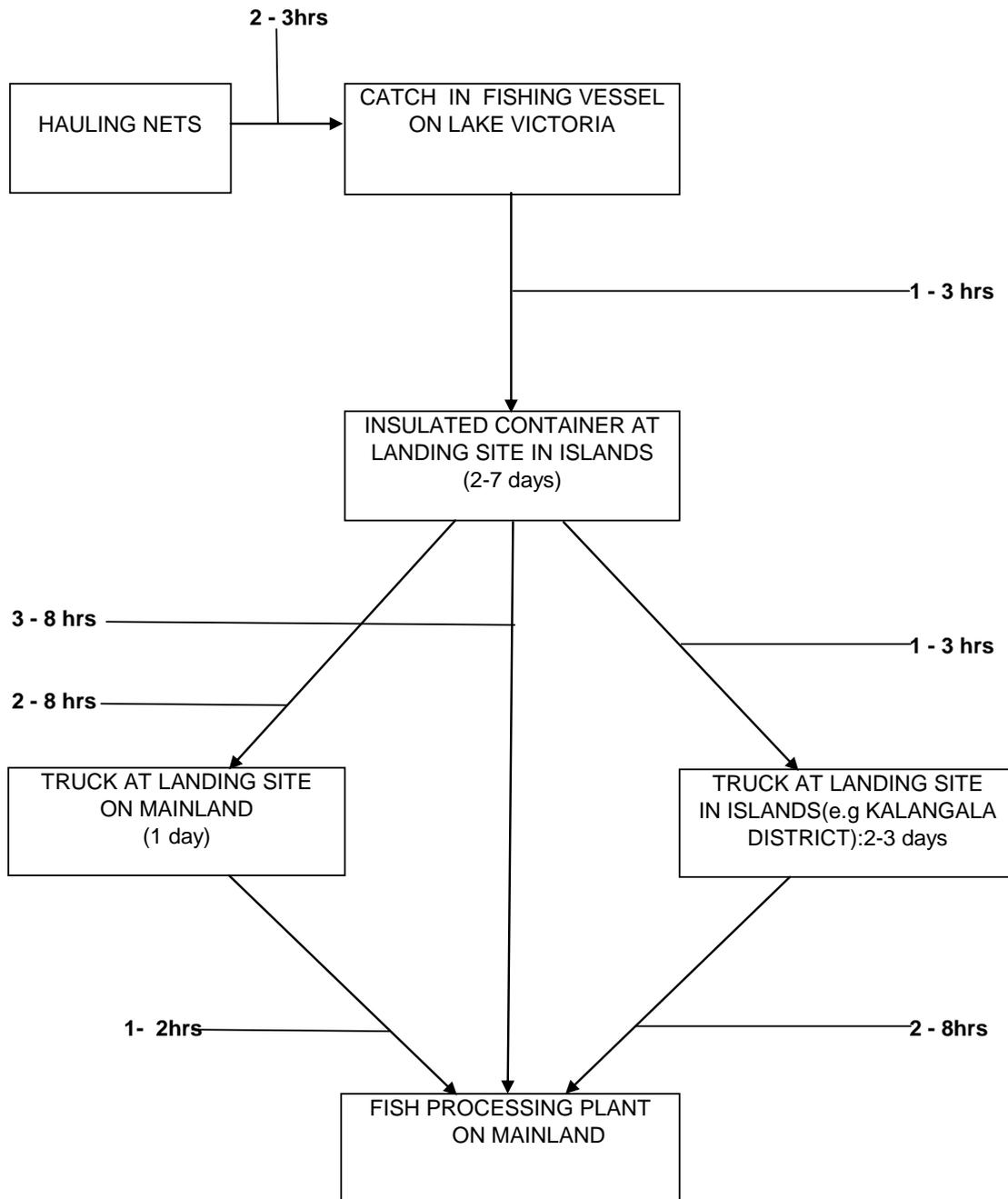
Figure 2: Flow diagram of fish catch from fishing boat to factory.

In sum, there are "dangers" that are responsible for a cumulative reduction in the original quality of fish at every step, which are accelerated by the practices employed in handling the fish (Table1) and need to be corrected or avoided.

Table 1: A summary of what can go wrong at each of the handling steps.

Handling step	Potential danger (Hazard)	Source of danger
On lake to landing site	Growth of bacteria	Exposure to sun and wind
	Contamination	Leaking of boat
	Bruises	Rough handling
		Prolonged stay of fish in nets
At landing site	Growth of bacteria	Delayed icing
	Contamination	Landing site water
Insulated container	Contamination	Poor drainage in container
		Transportation with cargo
	Growth of bacteria	Improper icing
		Poor insulation of container
	Fish crushing	High mechanical load
		Standing on fish (during icing)
Insulated truck	Growth of bacteria	Delayed re-icing
		Poor insulation of truck
		Improper icing
	Fish crushing	Mechanical load
At factory	Substandard raw material entering processing	Delayed off-loading
		Poor inspection

4.2   Fish handling in Iceland

Iceland is among the world's 15 largest fishing countries and fisheries are Iceland's most important foreign exchange industry. Fish and fish products constitute more than 60% of Iceland's exports. Iceland's average annual total production is approximately 1.74 million tonnes with exports worth USD 1.8 billion in 2004 from 1.98 million tonnes in 2003 (FAO, year of fishery statistics). The most commercially exploited fish species include cod, haddock, seithe, and capelin.

The major markets for the different seafood products produced by private-licensed companies are mainly the European Union (EU), United States of America (USA), and Asian countries and to a less extent Africa (especially dried heads to Nigeria). In addition, a number of people are employed in the industry. The fishing and fish processing activities have gradually been dominated by automation. Unlike in Uganda, Iceland has both land-based fish processing plants which are all located on the shores and processing on board factory trawlers.

4.1.6   Handling of catch on board

The Icelandic fishing fleet consists of medium sized vessels whose operations are basically conducted on a daily basis and big trawlers whose fishing trips take several days. The major methods of fishing are long-lining, trawling, gillnetting and purse-seining. Catch from the gear is graded into respective sizes (small, medium and large), bled gutted, washed, chilled and stored ready for transportation to a landing harbour (Figure 3). It is mandatory that fish of the same catching day are stored in their own tub and therefore fish of different post-mortem days are never mixed in the same tub. The catch handling time is accelerated by employing equipment and handling procedures that eliminate, among others, rough handling of fish.
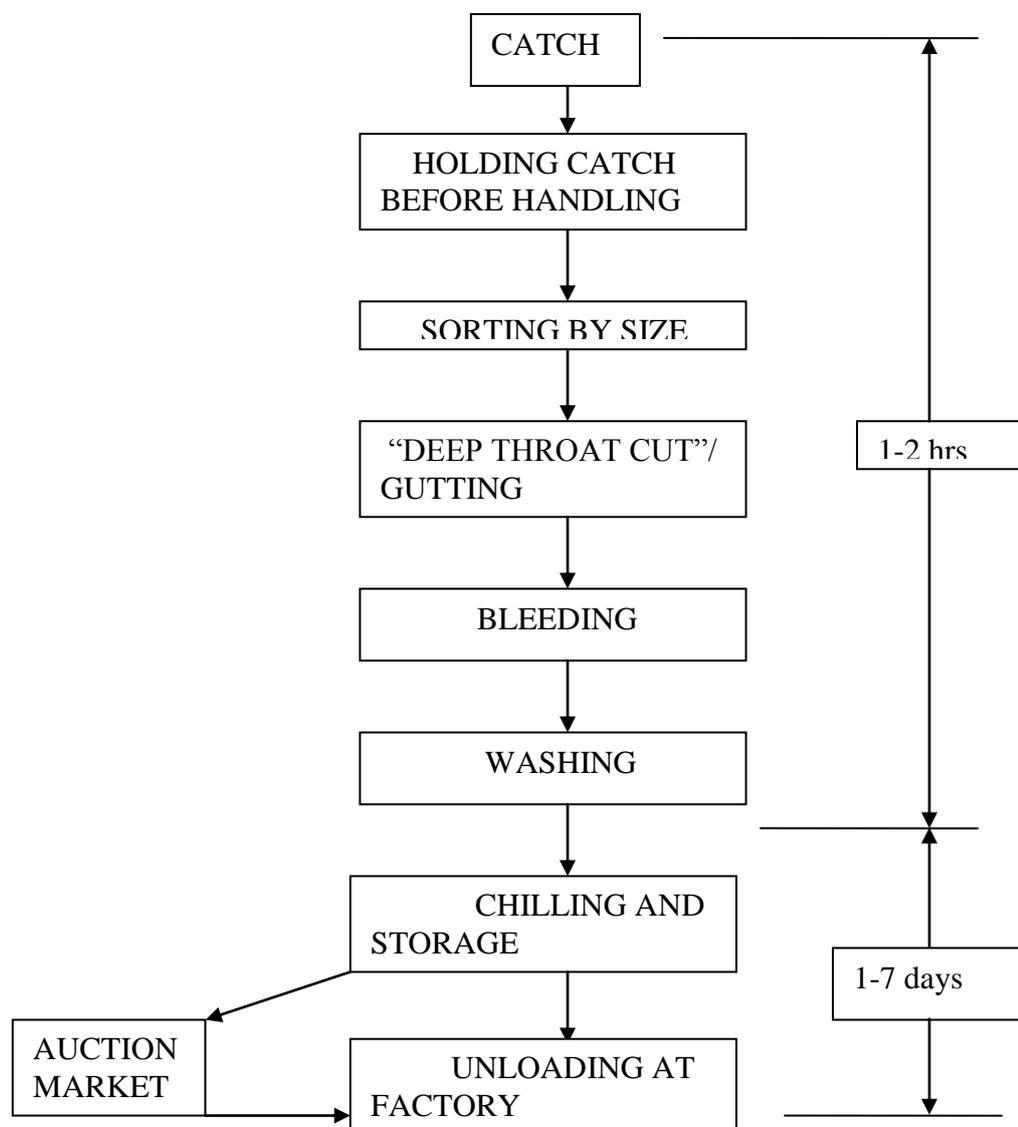
Figure 3: Raw material handling of demersal fish.

4.1.6.1 Bleeding

In an effort to obtain optimal white fillets, (generally higher in value, white-fleshed fish species) fish is bled by cutting the arteries just behind the gills and in front of the heart. Bleeding is normally done when the fish is still alive in order to yield quality white fillets. Therefore, the time between deaths and bleeding is vital. Some fishermen make a "deep cut", gut and then bleed the fish for 12-20 minutes, while others first bleed for the same period and then gut the fish. This seems to complicate the work and delay the chilling process. Red fish, pelagic fish and many flatfishes are commonly not bled or gutted at sea.

However, previous studies have questioned the necessity of handling the fish in a two-step procedure involving a special bleeding period. These studies have shown that the time elapsed between deaths and bleeding is more vital for the overall quality than the bleeding method (Valdimarsson *et al.* 1987 and Botta *et al.* 1986). Efficient removal of blood was found to be dependent on muscle contraction, gravity and vasodilatation in peripheral tissues of fish (Lambooij *et al.* 2004). Huss (1995) suggested blood to drain more easily from muscle during the on set of rigor mortis since rigor would act as "a sponge" and, in so doing physically squeeze blood out as the muscle contracts. Contrary, other results showed that blood drain easily before the on set of rigor mortis and recommended bleeding and gutting to be done at the same time in order to save time, space and investments (Roth *et al.* 2005).

4.1.6.2 Gutting

Fish after feeding normally has a lot of viscera that contains various hydrolytic (digestive) enzymes. Lean fish caught by large trawlers are usually gutted at sea manually or by machines, the aim being to eliminate the potential contamination of the edible flesh by the enzymes and also to prevent the inoculation of the flesh by microbial populations found in the intestines. Gutting is done by cutting fish from either the fish's gill cleft to the anus or from the anus to the gills and then tearing ("ripping") out the viscera (guts), leaving no blood or viscera in the body cavity. When un-gutted fish is mishandled, bile from the gallbladder may be released which can cause a conspicuous discolouration referred to as "belly burn" that gives fish a bitter flavour. The length of the belly cut is vital, and should be smooth and not excessively long.

4.1.6.3 Chilling

Chilling reduces the activity and reaction rates of enzymes normally present in the gut and tissues of fish and slows down the rate of microbial activity, though a population of cold-tolerant bacteria can still thrive (Liston 1980). Ice keeps fish moist, has a large cooling capacity, is safe, and is a portable cooling method that can be easily stored, transported and used by distributing it uniformly around fish. Fish storage and chilling are achieved through the use of plastic tubs with an average capacity of 300-400 kg fish. Once fish is iced in the tubs, unloading fish from tubs only takes place in the factory when taken for processing (in case of trawlers). This eliminates constant handling of the fish that would result in fish bruises and exposure to risks of contamination. Efficient cooling with ice depends on the weight of fish, species, fish temperature, environmental temperature and the amount of ice.

4.1.7   Receiving, storage and quality assessment of fish at factory

Trawlers on arrival at the factory are unloaded from the fish tubs with a crane and then carried by a fork-lift to the factory reception area. The removal of containers in this way and refitting the trawler with clean iced containers allows a quick return of the fishing vessel and also reduces the labour required for unloading. In the vessel, the tubs are properly labelled for identification and grouped according to catch days. This practice facilitates off-loading at the factory and subsequent grouping in the reception area where the order of processing follows old-recent catch.

In assessing the quality of the raw materials, appropriate samples of fish tubs from each post-mortem day are randomly picked and taken for organoleptic assessment. Prior to this, the tub together with fish and ice is placed on a computerised pallet where the weight is displayed on a small screen and manually entered into a computer. Then the fish is removed from the tub and the following quality attributes checked: ice on top, middle and bottom of the tub; outer cleanliness of the fish (washing); degree of bleeding; gutting and cleanliness of viscera; weight of ice; weight of fish and so on. Each attribute is given a quality grade and the assessed fish is then put in the same tub and re-weighed to calculate the amount of ice that remains on arrival at the factory:

$$amount\ of\ ice\ remaining = (weight\ of\ tub + fish + ice) - (weight\ of\ tub + fish).$$

The amount of ice that remains is recommended to be at least 18% of the weight of the fish. It is worth noting that during evaluation of raw materials; emphasis is not only put on how much ice remains but also how well it is distributed amongst the fish. Loading more than 305 kg of fish in the tubs is discouraged so as to avoid mechanical load (pressure) on the bottom fish. Thus, the attribute of the amount of fish in the tub is given a grade one if the amount is not more than 305 kg. Results from assessment are availed to the concerned trawler captain emphasising areas to be improved. As a way of motivation, normally the trawler crew get a bonus based on the quality of their fish.

4.1.8   Auction market

To speed up and shorten the time between catch and processing, most fishermen especially those with trawlers, sell fish through computerised fish auctions and in some cases fish is sold before it is landed, though buying fish that is not seen can be difficult, as this requires information on the quality of fish (temperature and time from catch) from a reliable supplier.

Fishing vessels that don't land fish directly to fish processing plants land fish at a harbour (with an auction market) where sales are done on the Internet. Fish on the auction market is inspected together with the amount of ice that remains on landing. Gutting is done on fish that is landed un-gutted and then reweighed. Fish is then graded according to quality and catch days, iced in tubs and stored awaiting orders from buyers. Information on the name of the harbour, fishing method, name of ship, name of seller, landing date of catch and date re-weighed and general information on the quality of the fish is availed on the auction market website. This information is also vital for traceability. Each buyer has to be registered with the fish market and with enough security on his/her account before an order can be placed. Once an order

is made, a card order (with the buyers address) is put on the respective tubs and then transported by a transport company to the respective buyer. Payments are done on the Internet within one week from reception of the ordered fish. The owner of the fish market (middleman) receives a commission for the transactions made between the seller (owner of fish) and the buyer.

SELLER ⟶ AUCTION MARKET ⟶ BUYER.

At fish markets, every fisherman (seller) strives to have good quality fish in the auction market so as to maintain his image in the market.

4.1.9   *Effects of post-catch storage time on fish quality*

The sensory assessment results of whole cod and subsequently of fillets of different post-catch days (PDs) are shown in Figure 4. The fish quality is reduced with increased number of days from catch. The quality deterioration was greater between PD 7 and 11 compared to the loss between PD 1 and 7 from both whole fish and fillet organoleptic assessments. This is shown by the relatively small difference in sensory scores from PD 1 to 7 after which the difference in quality between PD 7 and 11 was greater.
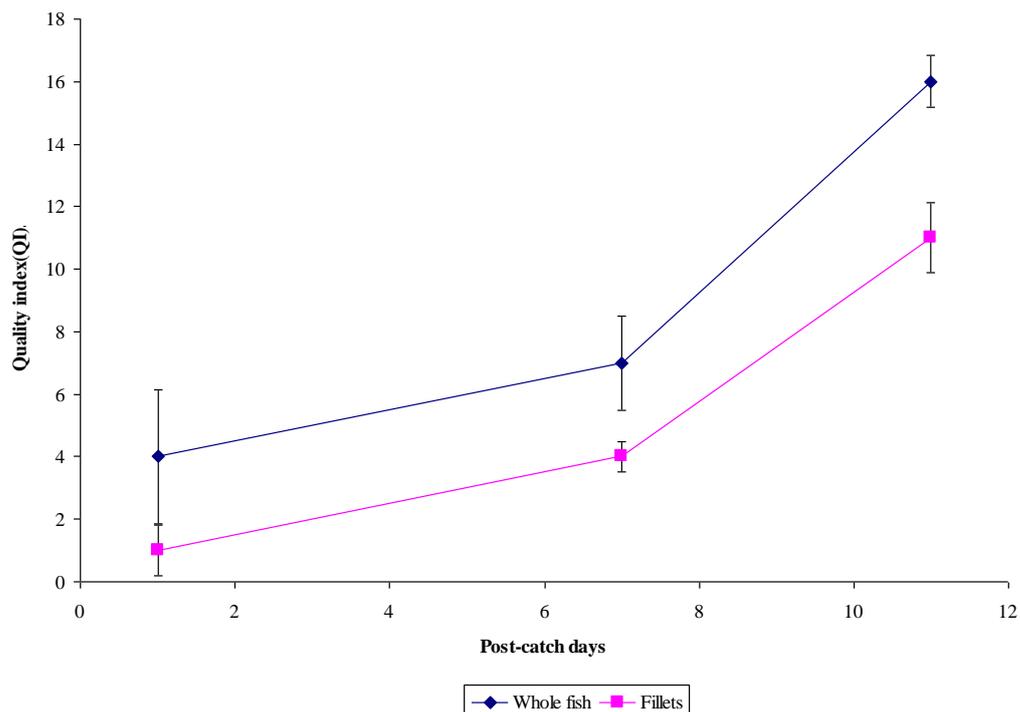
Figure 4**:** Sensory quality of gutted cod of different post-catch days.

As was expected, results from the microbiological evaluation showed the skin of the fish to have more bacterial load than the flesh (Figure 5). Specific spoilage organisms (SSO) were less than 10 colony forming units in fish on PD 1. There was a wider range in microbial counts between fish of PD 1 and PD 7 than between PD 7 and PD 11.
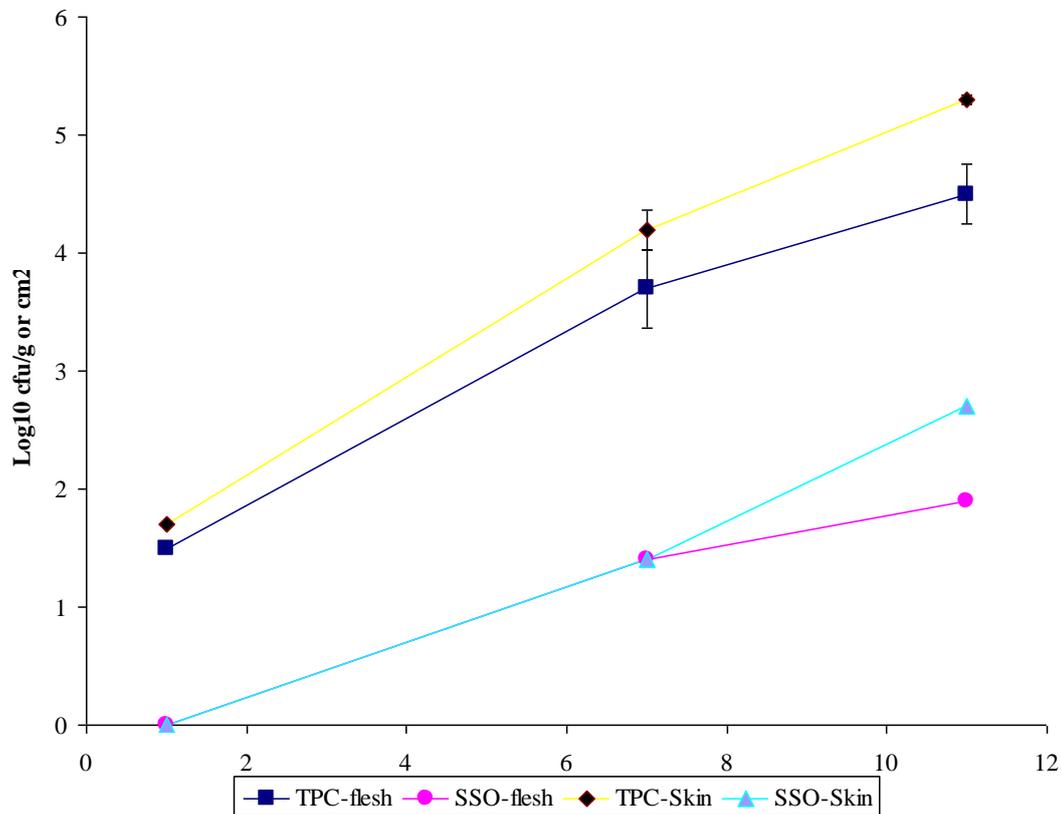
Figure 5: Microbial counts from gutted cod of different post-catch days (TPC, total plate count and SSO, specific spoilage organisms).

Measurements of TVB-N indicated an increase in TVB-N with increasing days from catch. The difference in TVB-N levels in cod of PD 11 and PD 7 is three times the difference in levels between PD 7 and 1(Figure 6). In addition, TVB-N of PDs 1 and 7 overlap while there is no overlap with PD 11.
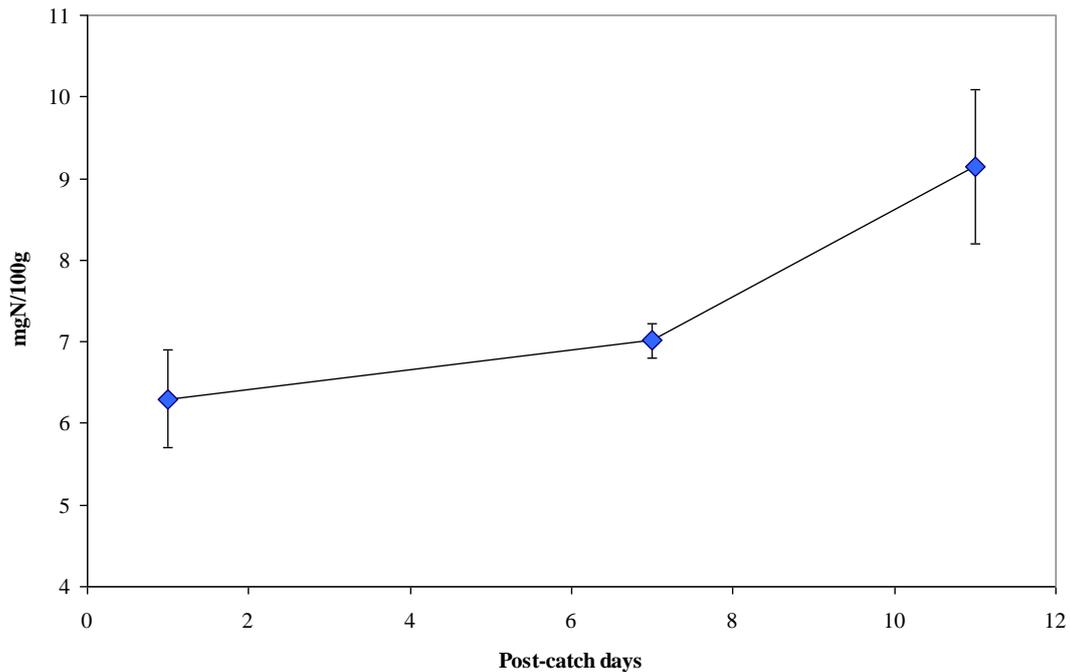
Figure 6**:** TVB-N levels in gutted cod of different post-catch days.

4.3   Effects of mechanical load on fish quality

The sensory assessment of cod iced under the two treatments (with load, WL and without load, WOL) is presented in Figure 7. The fish samples before the treatments had a firm, elastic and bright skin colour; convex eyes; translucent, bluish flesh; clear mucus and blood clearly red with a mean quality score of one.

On further sensory assessment of whole fish on day seven, fish WL had undergone greater quality reduction changes than WOL fish. The skin of the former had become soft with milky mucus and the form of cornea slightly sunken. From assessment of fillets, the fillets colour had started to develop a little pinkish colour and the texture was generally rather soft.
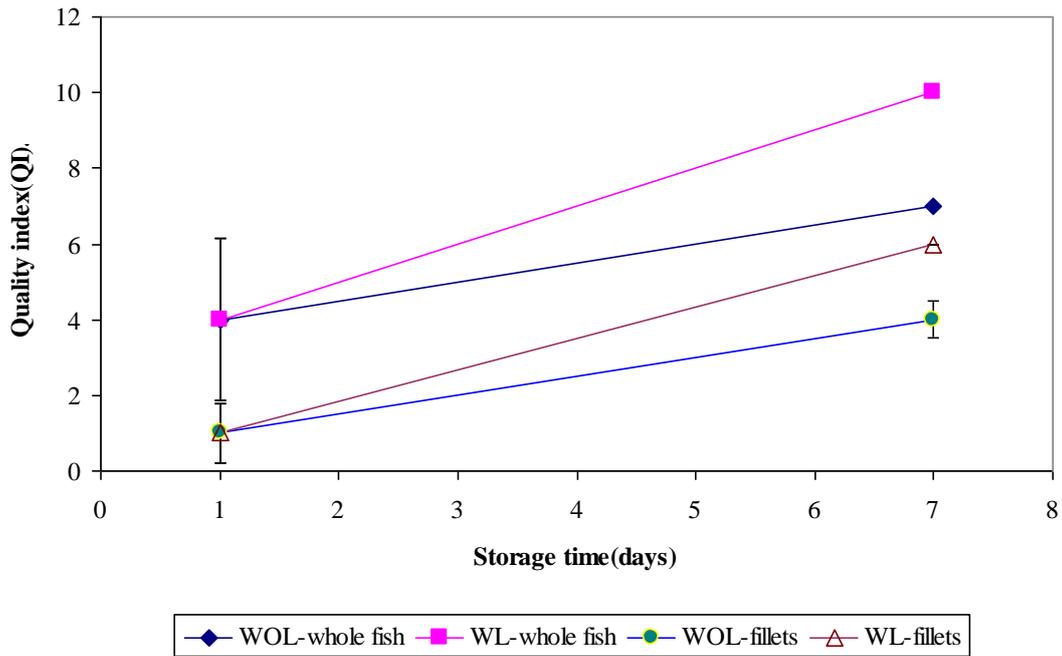
Figure 7: Sensory quality changes in gutted cod iced with mechanical load (WL) and without mechanical load (WOL) conditions.

A higher increase in surface total viable bacteria counts and of hydrogen sulphide (H_2S) forming bacteria in fish without load was observed compared to fish with load (Figure 8).
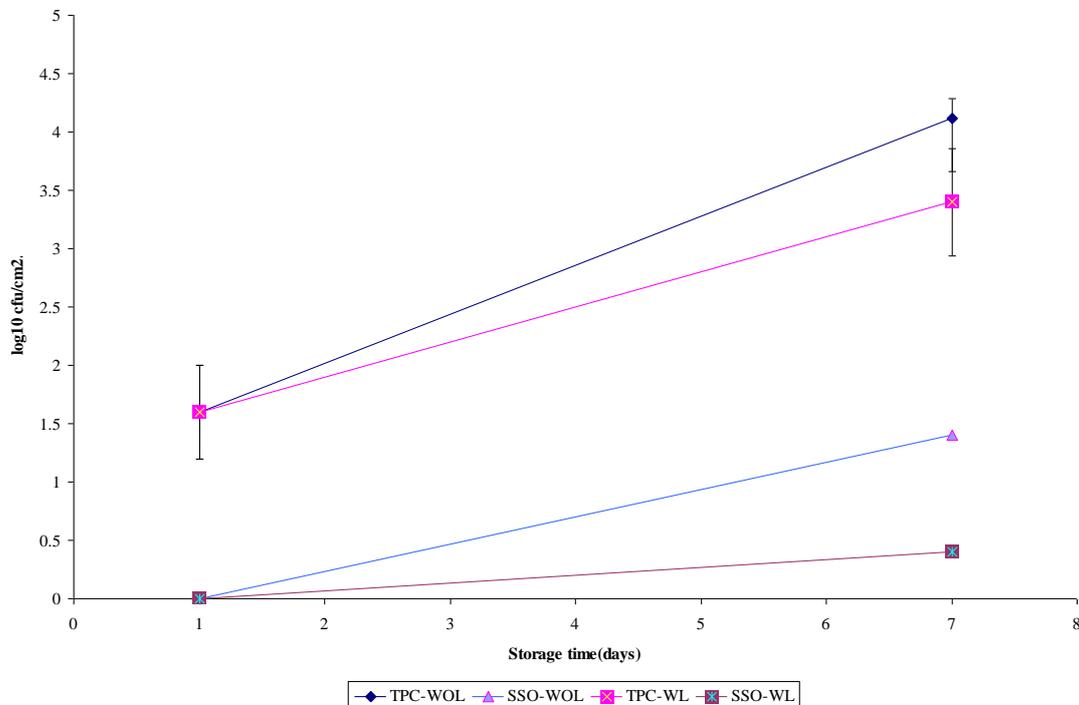
Figure 8: Changes in surface bacterial counts of gutted cod iced under the different mechanical load conditions.

TPC, total plate count; WOL, fish without load; SSO, specific spoilage organisms and WL, fish with load.

On the other hand, there was an increase in total viable bacterial counts in the flesh of fish with load than in fish without load, whereas SSO counts in both treatments were similar (Figure 9).
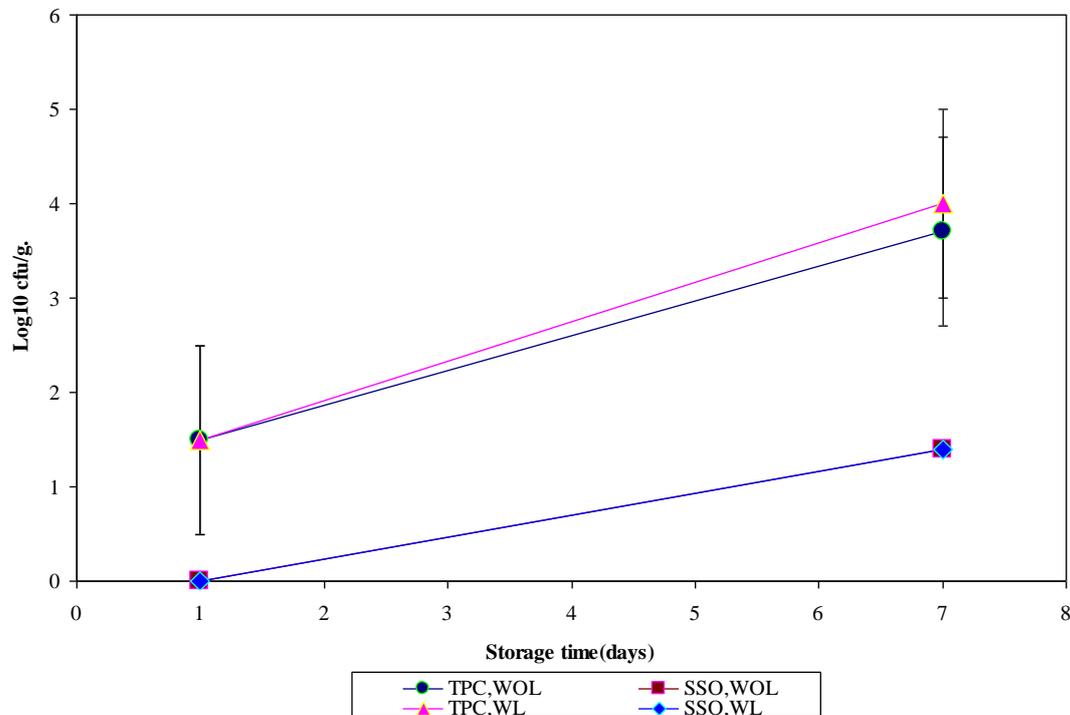
Figure 9: Changes in bacterial counts in the flesh of gutted cod iced under the different mechanical load conditions.

TPC, total plate count; WOL, fish without load; SSO, specific spoilage organisms and WL, fish with load.

TVB measurements indicate the extent of the breakdown of proteins due to bacterial and enzymatic action, leading to amines and thus a low nutritional value of the product. From the results, levels of TVB-N in both treatments WOL and WL, increased from the initial, TVB-N 6.7 mgN/100 g to 6.9 mgN/100 g and 7.14 mgN/100 g respectively, with a slightly higher increase in fish with mechanical load (Figure10).
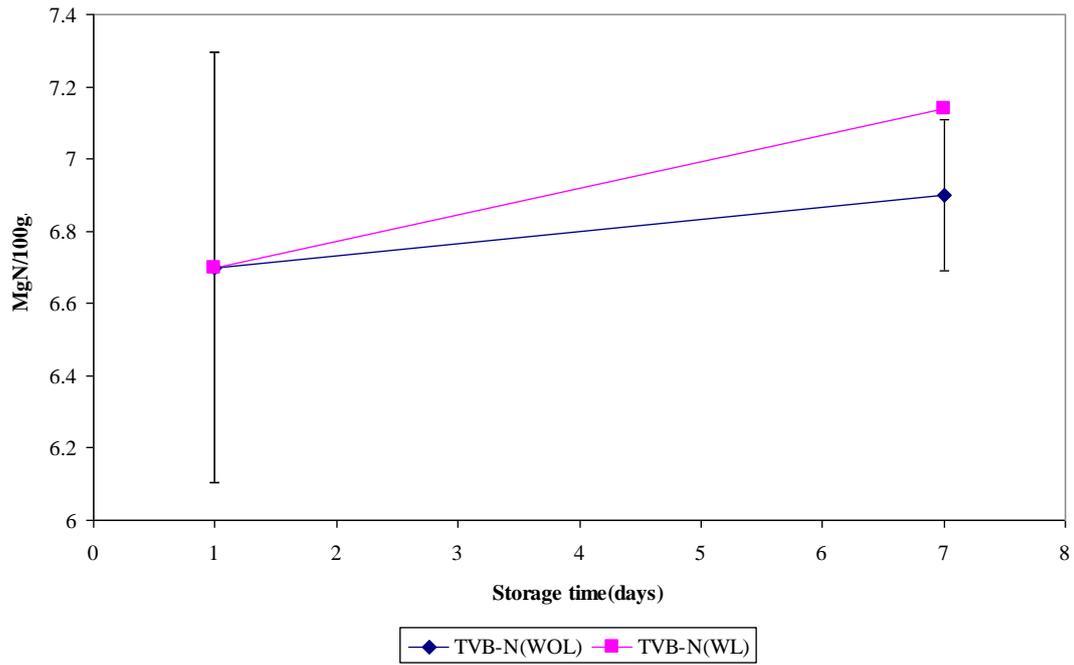
Figure 10: Changes in TVB-N of gutted cod stored on ice under the different mechanical load conditions. (WOL, with load and WL, without load)

5   DISCUSSION

Fish catch prior to processing in Uganda is generally characterised by fishing vessels landing un-chilled fish at landing sites, delayed icing, un-efficient transfer of fish on and from the loading container (ice boat), unhygienic icing in the fish holds and constant handling of fish prior to processing. All these practices affect and reduce the quality of fish, thereby accelerating spoilage and in the end resulting in short shelf life of the fish products. Previous studies on Nile perch showed an increase in mesophilic bacteria plate counts from $4 \log_{10}$ cfu (colony forming units) when iced immediately to $4.7 \log_{10}$ cfu when icing was delayed for 3 or 6 hours, which was about 0.5 log cycle increase (Muyonga 2004). In addition, the shelf life of Nile perch had an estimated shelf life of 13 hours and 28 days when stored at ambient temperature (25°C) and on ice respectively (Gram *et al*. 1989). In comparison to Iceland, the handling practices employed right from the fishing vessels to the factory have been shown to minimise fish quality deterioration, which is attributed to the immediate icing of fish, gutting and bleeding, use of tubs of appropriate size, reduction in number of times the fish is handled and general hygiene involved. Analyses of fish of different post-catch days showed that storage time influences the quality of fish. From the microbiological point of view, all the fish from the post-catch days had colony forming units less than 5×10^5 and therefore were of good quality (ICMSF 1986). Results from sensory evaluation showed that the PD 11 fish had an estimated shelf life of 2 and 6 days from whole fish and fillets respectively compared to the remaining storage time of 4 days from previous studies (QIM-Euro fish 2001).

Results further indicated that properly iced cod loses its quality slowly in the first week, after which the rate of spoilage increases as seen from sensory evaluation and TVB-N results. The cause of quality loss in post-catch days (PDs) 1 and 7 was most likely due to autolysis which was found to precede microbiological spoilage and contributed very little to overall spoilage (Huss 1994). During these enzymatic changes, ATP-related compounds are degraded resulting in intermediate compounds such as inosine monophosphate (IMP) which is broadly accepted to be responsible for loss of fresh fish flavour. The broken down compounds avail metabolites necessary for bacterial growth (Huss 1995). This explains the higher increase in bacterial counts between PDs 1 and 7. The wider difference in bacterial counts between PD 1 and 7 and PD 7and 11 can probably be explained in respect to bacterial growth in response to changes in the environment, where on PD 1 (counts were less than 10 and therefore estimated), the bacteria were in the lag phase and therefore not growing faster whereas on PD 7 they had acclimatised to the environment and were therefore in the exponential phase. Between PDs 7 and 11, the bacteria were probably approaching the stationary phase. From the mechanical load experiment, mechanical load seems to accelerate entry of microorganisms from the surface of the fish into the flesh, leading to a reduction in microbial counts on the skin surface and an increase in microbial counts in the flesh as shown by the higher bacterial counts on the skin of WOL-fish compared to WL-fish and vice versa in the flesh. It is likely that the high pressure bruises the fish thereby allowing bacteria from the skin surface into the flesh. However, the higher surface bacterial counts on the skin of WOL fish might suggest that the spoilage bacteria were aerobic and therefore flourished since the tubs were not closed during the experiment. The same compactness probably explains the higher sensory quality loss in WL fish.

6   CONCLUSIONS

It can be concluded that the results of post-catch analysis revealed that good handling practices employed from sea to the factory are important. If the best quality fish products are to be realised in cod, fish should be processed within a week from the catch-day.

Based on my own experience and results from the study, it can be concluded that the major cause of fish spoilage in Uganda is bacterial growth which is accelerated by delayed icing and un-hygienic handling. Therefore, in order to maintain the shelf life of Nile perch up to the market demands, the fish should be iced within the first 6 hours from catch.

From the results of mechanical load, it can be said that its effects on fish quality are less significant provided that fish is properly and sufficiently iced. However, more work is required to investigate this in more detail, by comparing the quality of fish from the bottom, middle and top layers of un-gutted fish in a fully filled fish hold (Uganda's situation). It is important to draw recommendations and guidelines for fish handling in Uganda based on the study results as outlined in the next section.

7 RECOMMENDATIONS/GUIDELINES FOR IMPROVING FISH HANDLING IN UGANDA

Production of high quality fishery products requires that each stakeholder in the production chain participate responsibly including the fishermen, factory suppliers, processors, distributors and resource managers. These recommendations (guidelines) are drawn from the study results and are intended to encourage fishermen, suppliers and processors in producing high quality fish products that can sustain Uganda's foreign fish markets.

Fishing boat on lake

- After nets are hauled, fish should be immediately removed from the nets. Prolonged time in nets leaves marks on the skin and hence affects its physical quality attributes.
- Fish should not be thrown around as this practice can damage the fish.
- Efforts should be made to avail ice to fishing communities where the potential to access ice prevails, especially landing sites on the mainland where electricity is available. In such cases, fish should be chilled rapidly after they are caught to preserve their fresh flavour by slowing down the rate of chemical and bacterial spoilage.

Landing site, container and truck

- Fish should not be put on the ground or floors of factories. This practice is unhygienic and can lead to fish spoilage through contamination. This is critical since most landing sites lack sanitary and handling facilities.
- Fish display tables must be smooth and kept clean.
- Since the fish is landed by fishing boats un-iced, once landed they should be immediately weighed and chilled as quickly as possible so as to reduce the temperature (0°C-4°C), thereby slowing down the rate of bacterial spoilage.
- Violent throwing and dropping from a considerable height should be avoided. Care should be taken to prevent damage to the fish. Any bruises, abrasions or cuts spoil the appearance, reduce yield of edible flesh and accelerate spoilage. As a rule, the more bruises or cuts on fish, the more spoilage spreads.
- Fish holds of insulated containers should not be left unprotected from direct radiation from the sun and wind as the ice melts quickly. Therefore fish containers should not be left uncovered for long during icing.
- Fish should be properly iced. Ice should not be used as "cosmetic (or additive) to make fish happy and fool buyers". Rather, ice should be used to chill fish as soon as possible after landing and keep it chilled afterwards until it is processed. "It is better to throw out ice than fish at the landing site or factory". An ice to fish ratio of 1:1 and 1:2 is recommended for tropical and temperate areas respectively, though the amount eventually would depend on experience. Begin with a layer of ice at the bottom, followed by a layer of fish that alternates with a layer of ice until the hold is appropriately filled, ending with a layer of ice on top. Make sure to fill all spaces between fish with ice.

- To reduce rough fish handling and crushing due to large sizes of fish holds in the insulated containers, the fisheries department, in collaboration with processing plants, needs to develop an appropriate design and regulation for insulated containers if the rough handling and unhygienic practices involved in container operations are to be improved. The design should at least allow fish to be loaded, iced and the container unloaded without the fish being trampled in the fish hold.
- Temperature recorders should be fitted at appropriate points in the truck so that temperature can be monitored throughout the trip. This provides the factory with the previous storage conditions of fish in the truck.
- Cleanliness is an important part of good handling. Much of the care exercised in chilling can be wasted if the container or box is un-clean, or if dirty ice is used. Fish chilled in dirty ice spoil faster than fish chilled in clean ice. After off-loading fish at the next landing site or factory, the container should be cleaned with suitable detergent and disinfectant to avoid contaminating ice and fish during the next route.
- Container and truck surfaces should be robust, impervious and easily cleanable. Wood is discouraged as contact surface with fish (food in general) because it is very difficult to clean and can cause the occurrence of "stinkers". Smooth metal alloy or plastic are the recommended materials of choice.
- Water used in washing fish, equipment, fish hold and any other fish contact surface should be clean or portable water. For landing sites in islands where portable water is not available, fish once caught should be properly handled and never in contact with landing site water whose quality is doubted. Alternatively, deep offshore water can be used to clean equipment and the fish hold.
- Processors need to encourage fish suppliers to start a plan of separating fish of different catch days and quality levels so that the government can also enact appropriate laws and guidelines. This would be advantageous to the factories in assisting them in fish inspection and grading.

Processing plant

- The factory should ensure that it keeps a list of reliable suppliers who can be judged from their constant supplies and the level of fish quality from well conducted sensory evaluation. Suppliers who always have many rejects should be discouraged or abandoned. This encourages the others to improve their fish handling practices. In addition, good quality fish should be given attractive prices to keep fishermen and suppliers motivated and strive to handle fish with care.
- Fish in the factory reception should not be allowed to heat up. The fish should be kept close to 0ºC in ice at an ambient temperature of 0-4ºC, which should be continuously recorded by temperature loggers fitted in strategic positions and monitored through observation by the quality manager. In addition, the doors of the reception area and all other cold rooms should not be left open for long periods of time as this allows hot air from the outside to come in. In case the temperature runs out of control, the raw materials should be re-inspected, sorted and low quality ones rejected for other uses such as fishmeal production.

ACKNOWLEDGEMENTS

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APPENDICES

Appendix 1: Sensory assessment sheet for whole Cod (QIM).

Sensory evaluation score sheet for whole Cod fish.				Sample code				
Quality parameter		Description	Score	1	2	3	4	5
	Skin	Bright, iridescent pigmentation	0					
		Rather dull, becoming discoloured	1					
		Dull	2					
	Stiffness	In rigor	0					
		Firm, elastic	1					
		Soft	2					
		Very soft	3					
Eyes	Cornea	Clear	0					
		Opalescent	1					
		Milky	2					
	Form	Convex	0					
		Slightly sunken	1					
		Sunken, concave	2					
	Pupil	Black	0					
		Opaque	1					
		Grey	2					
Gills	Colour	Bright	0					
		Less coloured, becoming discoloured	1					
		Discoloured, brown spots	2					
		Brown, discoloured	3					
	Odour	Fresh, sea weedy, metallic	0					
		Neutral, grassy, musty(mouldy)	1					
		Yeast, bread, beer, sour, milk	2					
		Acetic acid, sulphuric acid, very sour	3					
	Mucus	Clear	0					
		Milky	1					
		Milky, dark, opaque	2					
Flesh, fillets	Colour	Translucent, bluish	0					
		Waxy, milky	1					
		Opaque, yellow, brown spots	2					
Blood	colour	Red	0					
		Dark red	1					
		Brown	2					
Quality index(0-23) sum:								

Appendix 2: Sensory assessment guide for Cod fillets (QIM).

Sensory evaluation of Cod Fillets				Samples				
Quality parameter		Description	Score	1	2	3	4	5
Skin	Brightness	Iridescent pigmentation	0					
		Rather dull	1					
		Dull	2					
	Slime	Uniform, thin transparent	0					
		Little thicker, opaque	1					
		Clotted, thick, yellowish	2					
Flesh	Texture	Firm	0					
		Rather soft	1					
		Very soft	2					
	Blood	Bright red, not present	0					
		Dull red	1					
		Shadowy, brown	2					
	Odour	fresh, neutral	0					
		Sea weedy, marine, grass	1					
		Sour milk	2					
		Acetic, ammonia	3					
	Colour	White, greyish	0					
		Some yellowish, a little pinkish	1					
		Yellow, overall pink	2					
	Bright	Translucent, bluish	0					
		Opaque	1					
		Milky	2					
	Gaping	No gaping, one longitudinal along neck part	0					
		Slight gaping<25% of the fillet	1					
		Slight gaping 50-75% of the fillet	2					
		Deep gaping over 75% of the fillet	3					
Quality index(0-18) sum:								