EVALUATION OF MICROBIAL AND PHYSIOCHEMICAL CHANGES IN BIGEYE SCAD (*Selar crumenophthalmus*) DURING STORAGE AND TRANSPORTATION

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Abstract

Long-term storage and transportation require efficient controls to maintain food security and the high quality of fish products. This study focuses to identify potential microbial contamination sites and physicochemical changes in the Bigeye scad fish (Selar crumenophthalmus) during storage and transportation. Total aerobic bacteria, Salmonella, and Escherichia coli were counted in randomly obtained fish and ice samples. Temperature, pH, texture, color and lipid oxidation checked for quality changes and freshness were evaluated by Quality Index Method. Total aerobic bacterial count was significantly increased in fish gill and skin swab samples during the cold storage (18.59 ± 0.01). After 18-hours, all fish gill, muscle, skin swab samples collected from the market were positive for Escherichia coli and Salmonella. The temperature of fish varied significantly with storage time and initial pH value was gradually increased over time (5.61 for initial vs. 5.73, 5.82 and 6.1 for following periods). Fish muscle lightness decreased, and hardness, adhesiveness and gumminess of fish were significantly changed. The results of the analyses indicated a spoilage and reduction of the quality of fish during the cold storage. There is a need to initiate and maintain storage facilities and sanitation practices in both ports and market processes. Changing fresh indicators strongly suggests the urgent need to improve quality control and certification systems at ports, marketplaces and transportation.

Keywords: *Fish products, Quality control, Contamination, Handling, Storage*

INTRODUCTION

Fish is a highly nutritious food that is rich in proteins, fats, vitamins, minerals and water, which are an important parts of the diet of human in almost all countries in the world (Solanki et al., 2016). More importantly, fish is a major source of animal protein, overshadowing most other sources and represented a source twice as important as poultry, and three times larger than cattle (Béné et al., 2015). According to the Food and Agriculture Organization (FAO, 2020), the proportion of fish produced for human use is predicted to rise to 89 percent by 2030. The quality of fish post-harvest activities in the fisheries sector is crucial for significant improvements in fish commerce for both local and worldwide markets (Maulu et al., 2020). For the period 2010–2014, 84.6 million tons of an annual global fish catch 9.1 million tons (10.8%) was discarded (Gilman et al., 2020). Majority of discards are marketable taxa, implying that a combination of bad fishing tactics and poor management procedures is mostly to blame for the waste discarding represents (Zeller et al., 2018). In poor management procedures most of these situations where substantial quality and quantities are lost due to post-harvest mishandling during storage, transport, processing, on the way to markets and waiting to be sold.

Freshness is one of the most important attributes to measure the quality of aquatic products (Grigorakis, 2007; Zhang et al., 2011; Majumdar et al., 2018). Since, fish is a highly nutritious food commodity, spoilage begins as soon as the fish dies (Oparaku & Mgbenka, 2012). When a fish dies, several postmortem changes occur because of microbiological, chemical, and physical processes (Gutérrez et al., 2015; Pedrosa-Menabrito & Regenstein, 1990). Post-mortem changes in the process of muscle conversion play a crucial role in the development of qualitative characteristics and the overall acceptance of fresh produce (Matarneh et al., 2017). Within this postmortem changes that directly and strongly affect its quality and shelf-life there are the protein degradation, ATP degradation, drop of pH, lipid oxidation, undesirable compounds production as trimethylamine (TMA-N) and the molecular low weight volatiles (TVB-N), which are produced by bacterial action. Likewise, the muscle experiences change in texture, water-holding capacity and color (Ocaño-Higuera et al., 2009).

Fish muscles are completely relaxed when they die; the flesh is soft and supple, with a firm and elastic feel. The muscular tissue contracts and becomes rigid after a short period of time, resulting in an inflexible product known as rigor mortis. In the process, glycolysis produces several organic acids to lower the pH in fish muscle. The muscles are denatured, losing their ability to retain water, resulting in alterations in the texture of the fish and a loss of quality (Osorio et al., 2015). Upon completion of rigor motility, muscle tissue loses stiffness, and then self-dissociates to form amino acids and other low molecular weight compounds. Then, using these compounds that exist before and after self-decomposition, the microorganisms grow and then attack the higher molecular weight compounds.

Microbial growth is the most important decomposing factor for the quality of fresh or lightly preserved fish, which is the first mechanism by which fish decompose (Boziaris, 2013). Muscle tissues are usually sterile in healthy fish, whereas large populations of bacteria are present on the external surfaces, intestines and gills (Novoslavskij et al., 2016). After the death of fish, spoilage bacteria enter the muscle from the skin and gills, disintegrate the muscle cells and take necessary energy to grow (Dutta et al., 2018). Microbial growth is the main reason for the development of off flavors and odors which leads fish products unacceptable or spoiled (Béné & Friend, 2011). Another important aspect is that the rate of loss of quality depends directly on the species itself, as well as and the storage management and conditions (García-Soto et al., 2013). Consumption of these contaminated fish may cause intoxications or infections to the consumers (Sheng & Wang, 2021). Consuming these low-quality fish will end up with most of the foodborne diseases or gastroenteritis characterized such as diarrhea, vomiting, nausea, abdominal cramp, and fever.

Quality assurance in the fish sector is a timely requirement. It involves in monitoring and documenting defined quality criteria as required by regulations, product specifications and consumer demands (Gutérrez et al., 2015). Postmortem biochemical changes in fish muscle are strongly influenced by post-catch handling practices (Castillo-Yánez et al., 2014). To preserve the freshness of fish products, during prolonged storage and transportation while extending the shelf life, various holding temperature techniques including cooling, refrigeration, and freezing are used. Identification of contamination points during transportation and storage of fish from harbor to fish market will be helpful to reduce the fish quality deterioration.

The evaluation of postmortem sensory, physicochemical, and microbiological changes in marine species is used to determine freshness and quality (Li et al.,

2013). To determine the freshness of a particular species, all three methods have been applied (Hernández et al., 2009). The small pelagic big eye scad (*Selar crumenophthalmus*) is a commercially valuable species in small-scale local fishery (Echem & Miñoza, 2017). It is a key food source for predators at higher trophic levels. However, it is also well-liked in Asian communities as a daily meal (Espino-Barr et al., 2016). A limited study has been conducted on the physicochemical changes that occur in large eyes during storage and transportation. Therefore, the present study was carried out to investigate the changes of physiochemical and microbiological quality of the bigeye scad fish (*Selar crumenophthalmus*) during transportation from fisheries harbor to the local markets in the country sorted under refrigerating conditions.

MATERIALS AND METHODS

Sample collection

Fresh Bigeye scad fish gill samples taken by lift the operculum and cut this off at its base to expose the gills. A part of the gill filament of fish was exposed with the aid of a pair of forceps was swabbed with a sterile cotton swab. Fish muscle samples collected above the lateral line, between the dorsal fin and the caudal fin. Samples of the skin were taken by rubbing the sterilized cotton swab over the skin. Once the muscle has been removed from the fish, rinsed it in deionized water. Swab samples (from the fish skin near to gills), and ice samples were obtained from the Kudawella fish harbor and the Badulla fish market in Sri Lanka. Skin mucus samples were collected by gently stroking with the tip of a sterile rayon-tipped swab. The following samples were taken at Kudawella beach: ice samples from an ice plant, ice samples from a boat, ice samples and fish samples from a fish transporting truck. Before unloading fish from the truck at Badula fish market, ice samples and fish samples were collected from ice boxes. Furthermore, fish samples were taken after the fish were unloaded from the truck (on 6^{th} hour and 12^{th} hour).

Three replicates from each of the samples were collected from the same fish lot on the same day. Samples were placed in labeled sterilized zipper bags and stored at 4ºC. Then samples were transported immediately to the laboratory of Uva Wellassa University for further analysis.

Methods of analysis

Microbiological analysis

Total Viable Plate Count, *E. coli* and *Salmonella* tests were done for each collected samples for the identification of microbial contamination at each point. All microbial tests were conducted according to the official methods of analysis of AOAC 2016 International with modifications. Samples of each dilution (0.1 ml) were placed on each sterile of petri dish, spread evenly over a solid nutrient medium and incubated at 37˚C for 24 h. After the incubation period, the plates were examined for the presence of isolated colonies, and the true number of bacteria as described was estimated as the colon formation unit (CFU)/ g.

Physiochemical analysis

pH : pH of the fish samples and ice samples were measured in situ by using a pH meter at each point. Sample was dispersed in 100 ml of distilled water and stirred for 30 min, and then the mixture was filtered, pH value of filtrate was measured using a digital pH meter (HANNA HI 98190). Measurements of pH carried out according to the method described in AOAC (2016).

Temperature: Temperature of the fish samples and ice samples were measured in situ and recorded at each point by using a portable thermometer (TECPEL Thermometer 305B)

Texture: Texture profile analysis (TPA) and compression test was performed on big eye scad fish muscle samples using a Texture Analyzer. For the TPA analysis, samples were obtained by cutting parallelepiped pieces from the dorsal muscle of the fillet. Force-distance curves were processed to obtain seven texture parameters such as hardness, adhesiveness, springiness, cohesiveness, gumminess, chewiness and resilience (Skrede et al., 1990).

Color: Color of the fish muscle samples were analyzed using a colorimeter. Data were expressed using the CIE L*a*b* system to represent lightness (L*), redness (a*), and yellowness (b*) (Skrede et al., 1990).

Lipid oxidation: Lipid oxidation of fish muscle samples was measured with 2-thiobarbituric acid reactive substances (TBARS) values following the modified method described by Stalikas & Konidari (2001). Sample (3 g) was added to 9 mL of 1 N NaOH with 100 µL of 7.2% butylated hydroxyl toluene and kept for hydrolysis in a shaking water bath at 60 ℃ for 1 hour. The hydrolysate was filtered (filter paper, Whatman No 1) after stirred with 6 mL of 40% trichloroacetic acid (TCA) by vortex for 30 s. The filtrate (1 mL) was mixed with 20 mM 2-thiobarbituric acid (1 mL), and the mixture was kept in a boiling water bath at 90 ℃ for 40 minutes, cooled, and then centrifuged at 2090 x g for 15 minutes. Absorbance of the supernatant was measured at 532 nm with a 4120020 UV spectrophotometer. The amount of malondialdehyde was calculated using a standard curve prepared from 1,1,3,3-tetra-ethoxypropane and TBARS value was reported as mg malondialdehyde per kg of fish.

Freshness: The freshness of fish at each point were evaluated by Quality Index Method as described by Larsen et al. (1992). General appearance (skin, bloodspots on gill cover, stiffness, belly and smell), eyes (clarity and shape) and gills (color and smell) of fish evaluated.

Statistical analysis

All the numerical data were analyzed through mean value comparison using Microsoft EXCEL. According to the collecting points, mean values samples will be compared using one way ANOVA.

RESULTS AND DISCUSSION

Microbial quality of fish samples

Total viable aerobic bacterial count

Finfish and shellfish are highly perishable: high water content, non-protein nitrogen concentration and relatively high pH of fresh seafood make them more susceptible to microbial attack (Gram & Dalgaard, 2002). The growth of total aerobic bacterial counts are shown in Table 1.

The total aerobic bacterial counts gradually increased throughout the storage. Before transportation, the highest total aerobic bacterial count (18.03 ± 0.03 log CFU g^{-1}) was observed in fish gill samples and the lowest total aerobic bacterial count was observed in fish muscle samples (17.94 ± 0.03 log CFU g^{-1}). After 18 hours total aerobic bacterial count of fish gill samples was 18.56 ± 0.01 log CFU g^{-1} and in fish muscle samples it was 18.49 ± 0.01 log CFU g^{-1}. Total aerobic bacterial count was significantly increased in fish gill samples and skin swab samples during the cold storage ($p<0.05$).

This study exposed that the total aerobic bacterial counts gradually increased in fish gill, muscle and skin swab samples during the cold storage (under 0-4 C^0) in transportation process. Moreover, the total aerobic bacterial count was increased during the first 6 hours after unloading at fish market.

Table 1: Total aerobic bacterial count of Bigeye scad fish during cold storage (Mean ± Sd, n = 6)

	0 hours (Before transportation from the harbor) CFU/g	6 hours (Before unloading in fish market) CFU/g	12 hours (After unloading in fish market) CFU/g	18 hours (After unloading in fish market) CFU/g
Gill samples	18.04 ± 0.03^{a}	18.12 ± 0.01^{b}	18.46 ± 0.01^{c}	
Muscle samples	17.94 ± 0.03^{a}	17.99 ± 0.04^{a}	18.37 ± 0.01^{b}	18.50 ± 0.01^{c}
Skin swab samples	18.00 ± 0.01^{a}	18.13 ± 0.02^{b}	18.38 ± 0.01^{c}	18.59 ± 0.01^{d}

$^{a, b, c, d}$ Means in the same rows with different superscript letters differ significantly($p<0.05$)

Fish, crustaceans and mollusks can get microbes from a variety of sources: surface or tissue contamination can occur directly in the marine environment or during product handling, and processing. Storage and transportation at inappropriate temperatures, contamination by an infected food handler or cross-contamination by contact with contaminated seafood or seawater are major contributors to contamination (Iwamoto et al., 2010). The reasons of above high values could be the cross contaminations during handling and storage on board and shore. During transport, they were unable to control proper storage conditions, especially the temperature of the ice. Also, melting of ice in the ice boxes and cross contaminations during handling in fish market.

Fish skin usually has a small number of microorganisms and the highest number of bacteria is found in the gills and digestive tract of fish (Novoslavskij et al., 2016). Compared to the microbial load in gills the muscle also has the similar values in this study. In this study, bacterial colonization on fish skin and gills could be observed due to frequent exposure to contaminated water, ice, and cross-contamination during the capture and handling process.

Because it is linked to ice storage, washing, evisceration, and handling of seafood, the total aerobic bacterial count is used as a fish quality index indicator. According to the International Commission for Foods, the limit for total aerobic plate counts in fresh and frozen fish is set at 107 CFU/g (Broekaert et al. 2011). Therefore, these fish products are generally considered satisfactory to eat, as the total viable aerobic bacterial count does not exceed 10^{7} CFU per gram.

Fish and ice samples analysis for *E. coli* and *Salmonella*

Most foodborne illnesses are caused by *Salmonella* spp., *Staphylococcus* spp. and *Escherichia coli*, usually associated with the consumption of fish infected with those bacterial species, especially *Salmonella* and *E. coli* (Yagoub, 2009). Therefore, contamination of *Salmonella* and *E. coli* in fish and fish products is very unsafe to human health (Ava et al., 2020). All fish gill, muscle, and skin spout samples with ice samples collected from the fish market tested positive for *E. coli* and *Salmonella* after the 18-hour time intervals. In addition, as shown in Table 2, ice samples as well as fish gill and skin swab samples obtained from fish harbor and fish market were positive for *E. coli.*

Salmonella is a genus of Gram-negative bacteria in the Enterobacteriaceae family that includes the species *Salmonella enterica* and *Salmonella bongori* (Gal-Mor

et al., 2014). *S. enterica* subsp. *enterica* is responsible for 99 percent of salmonellosis in human, which causes symptoms such as diarrhea, fever, and stomach cramps (Jajere, 2019).

Contact with contaminated water, poor hygiene when handling, and other improper fish breeding, processing, or storage procedures can all introduce *Salmonella* spp. into fish and fish products (Fernandes et al., 2018). *Salmonella* infection in fish and fish products varies by county, as well as by fish species, geographic locations, sampling stages (fish farm vs. retail outlets), sampling portions (skin vs. gut), sources (imported vs. domestic), and fish product kinds (raw vs. RTE) (Sheng and Wang, 2021).

Coliforms are referred to as "Sanitary Index" organisms because their presence in in food suggests the possibility of unsanitary culturing or the use of dirty water during processing. Coliform bacteria detection is employed as a water sanitation indicator or as a general indicator of the hygienic state of the culture area and food-processing environment. As a result, fecal coliforms are thought to be a better predictor of food contamination by animal or human feces than total coliforms (Feng et al., 2002).

In this research, fecal coliform bacteria were found in ice samples, gill samples and skin swab samples collected from the fish harbor and fish market. This is in agreement with earlier report by Adebayo-Tayo et al. (2012), on frozen fish sold in the market has high contamination may be as a result of certain factors like temperature, poor personal hygiene, use of contaminated water *ae* as well as pathogenic microorganisms which may produce toxic material, when fish is consumed. Arannilewa et al. (2006), also found that the total coliform count range in fish was between $3.0x10^3$ - $7.5x10^6$ with increasing values, as the duration of storage increases. After unloading in fish market (18 hours), also found coliform bacteria in muscle samples. All samples were positive for *Salmonella* species after unloading in fish market (18 hours). After 18 hours, presence of higher number of fecal coliforms and *Salmonella* in the samples indicates the sewage contamination of culture environment, and handling, storage, transport and post processing is improper and is somehow contaminated by human or other warm blooded animal's excreta. Also, *Salmonella* contamination makes fish unfit for human consumption. These organisms generally do not grow below 0°C. *Salmonella* is heat sensitive and it is destroyed at temperature above 60°C. The high quantity of *E. coli* and *Salmonella* colonies made the experimental fish species unacceptable, and humans may suffer from various diseases after consuming those fish. *E. coli* and *Salmonella* can cause diarrhea, fever, and stomach cramps and kidney damage as well as uncomplicated community acquired urinary tract infections in human (Adelaja et al., 2013).

Change of temperature, pH and lipid oxidation of Bigeye scad fish during cold storage

Fish quality is strongly influenced by storage temperature as temperature affects bacterial growth and autolysis (Macagnano et al. 2005). The temperature of fish was shown to alter greatly with storage time in this study, and the temperature of fish received at the fish market was found to increase significantly with storage time. Before transportation the initial temperature of fish was 6.37 ± 0.17 ℃ and in first 6 hours the temperature was significantly reduced to 2.44 ± 0.36 ℃ ($p<0.05$). After fish received to the fish market the temperature was significantly increased (After 18 hours the final temperature was 11.49 ± 0.31℃) with the storage time ($p<0.05$) (figure 1A). The melting of ice in the ice boxes might cause temperature variations. Temperature

changes caused by inadequate ice coverage are prevalent and have a direct impact on the rate of deterioration (Olafsdottir et al. 2006).

The pH of the fish in this test was low during the initial study period. The good nutritional health of the fish was reflected in the low muscle pH during the initial period. Live fish muscle pH is typically around 7.0 (Guzman et al., 2015). The initial value of pH was 5.61 and it was increased progressively during the storage time (5.61 for initial vs. 5.73, 5.82 and 6.1 for following period of time) (Figure 1B). During the initial storage period in harbor, the pH was consistently low (5.61) and this may have contributed to the increased shelf-life of the fish. However, pH began to rise during the transit and storage phase, reaching 6.1 at the end of the timeframe.

After the initial period, the increase in pH values was due to the generation of alkaline bacterial metabolites in rotting fish, which coincided with an increase in Total Volatile Basic Nitrogen (TVBN) (Kyrana et al., 1997). In this study, pH concentrations of meat from fish after unloading at fish market (18 hours) may be advantageous for eating quality. However, this pH level is detrimental to the product's shelf life. Meat's salability suffers as a result of its reduced shelf life. The meat quality traits

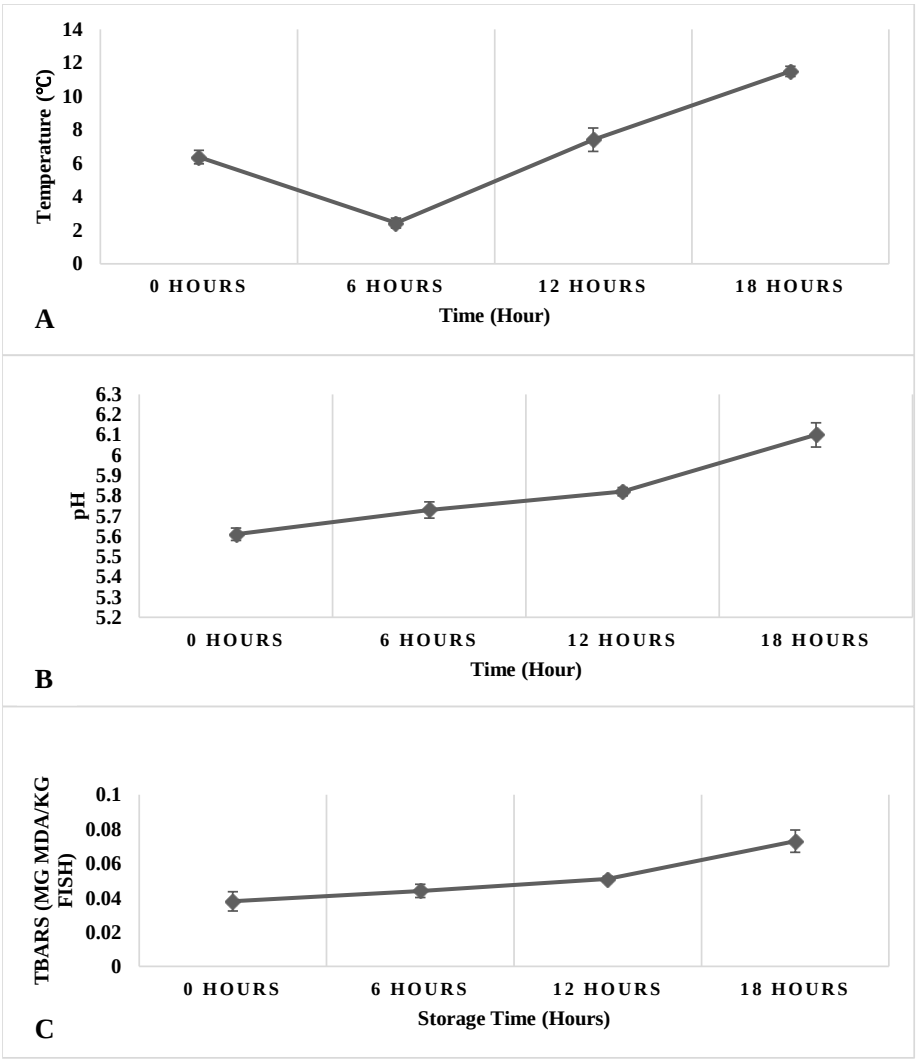

Figure 1: Change of temperature (A), pH (B) and lipid oxidation (C) values of bigeye scad fish during cold storage

must include suitable pH that indicates eating quality and shelf life. Lower pH values are associated with higher losses during further meat processing, while higher pH values are associated with shorter shelf life but better eating quality (Abbas et al., 2006).

The TBARS index remained low throughout the study, ranging between (0.038 and 0.073) mg MDA/ kg of fish (figure 1C). Therefore, it can be concluded that the lipid oxidation of samples in the present study was minimum resulting it has less impact on the keeping quality of fish during transportation. Different limits of acceptability values have been reported for this TBARS index. As described by Connell (1995), the limit of 1-2 mg MDA/ kg of fish is acceptable. Beyond that limit fish normally develops an offensive odor. Ruiz-Capillas & Moral (2001) established that the minimum TBARS index value detectable by panelists was 1.44 mg MDA/ kg. The oxidation is initiated and accelerated by heat, light and presence of several organic or inorganic compounds in

fish muscle, moisture content, large surface area and presence of air. Further antioxidants such as alpha-tocopherol, ascorbic acid, citric acid or carotenoids can inhibit oxidation (Lakshmanan, 2000).

Change of color values of Bigeye scad fish during cold storage

Chemical, microbiological and enzymatic reactions that develop after rigor motility cause significant changes in color during storage (Cheng et al. 2013). Lightness of Bigeye scad fish muscle significantly decreased with the storage time, while redness and yellowness parameters progressively increased as shown in Table 3 ($p<0.05$).

Table 3: Change of color values of Bigeye scad fish during cold storage

Time (Hours)	0 h	06 h	12 h	18 h
L* (Lightness)	46.65 ± 0.28^{a}	41.20 ± 1.07^{b}	44.25 ± 0.75^{c}	35.20 ± 0.87^{d}
a* (Redness)	6.94 ± 0.34^{a}	9.50 ± 0.09^{b}	7.67 ± 1.05^{ab}	12.55 ± 1.07^{c}
b* (Yellowness)	4.25 ± 0.53^{a}	6.76 ± 0.44^{b}	7.39 ± 0.88^{b}	7.65 ± 0.26^{b}

a, b, c, d Means in the same rows with different superscript letters differ significantly ($p<0.05$)

Fish species are mostly consumed fresh, and fresh fish is usually transported in iced polypropylene containers or foam boxes. During shipment, the ice in these containers may melt, ice may shrink, or the condition of the fish may change due to poor transport conditions or retail. In such cases, the upper part of the fish may be in contact with the air, and the lower part may remain in the melted ice. This common problem significantly changes the appearance of fish even within the same batch (Erdağ & Ayvaz, 2021). Previous studies have reported color changes in fisheyes due to contact with water (Balaban et al. 2014; Ünal Şengör et al. 2019). In addition, the surface of the fish in contact with air becomes dark and pale (Balaban & Alçiçek

2015). These color variations mislead the consumer in making decisions about the freshness of the fish.

Change of Texture in Bigeye scad fish during cold storage

The texture, also known as the firmness or elasticity of the fish meat, is an important sensory factor that determines the quality or acceptability of the product for use in high value products. Changes in texture parameters can cause to the development of toughness under certain conditions due to softening, changes in elasticity, or enzymatic and chemical reactions (Coppes et al., 2002). Hardness, adhesiveness and gumminess of Bigeye scad fish were significantly changed during the cold storage as shown in Table 4 ($p<0.05$).

determining the quality of fish during storage and in optimizing the acceptability and marketability of underutilized fish species through the development of new types of products (Coppes et al., 2002).

Evaluation of freshness of Bigeye scad fish by Quality Index Method (QIM)

Quality Index Method (QIM) uses a practical rating system in which the fish is inspected, and demerit points are recorded (Sen, 2005). This approach was derived from the realization that easily identifiable

Table 4: Change of texture in Bigeye scad fish during cold storage

Storage time (Hours)	0 h	06 h	12 h	18 h
Hardness (N)	9.86 ± 0.58^{a}	8.62 ± 0.15^{b}	7.62 ± 0.44^{c}	6.12 ± 0.12^{d}
Adhesiveness (mJ)	0.66 ± 0.06^{a}	0.20 ± 0.01^{b}	0.20 ± 0.01^{b}	0.10 ± 0.00^{c}
Springiness (ratio)	0.69 ± 0.012^{ab}	0.64 ± 0.05^{b}	0.74 ± 0.05^{a}	0.69 ± 0.011^{ab}
Cohesiveness (ratio)	0.57 ± 0.07^{a}	0.55 ± 0.04^{a}	0.63 ± 0.04^{a}	0.67 ± 0.04^{a}
Gumminess (N)	5.26 ± 0.40^{a}	5.12 ± 0.10^{a}	5.17 ± 0.05^{a}	4.27 ± 0.08^{b}
Chewiness (N)	3.59 ± 0.04^{b}	3.46 ± 0.05^{b}	3.79 ± 0.06^{a}	2.93 ± 0.06^{c}

[a, b, c, d] Means in the same rows with different superscript letters differ significantly ($p<0.05$)

It is important to note that the decrease of adhesiveness and hardness throughout the studied period indicates changes in the structure of fish. Fish death triggers autolytic and microbiological processes in the muscles of the fish, causing the muscles to become softer and less elastic (Guzman et al., 2015). Hernandez et al., (2009) found that hardness values highly correlated with storage time and microbial counts. In this study, significant changes in hardness and adhesiveness were observed during the storage period, which was consistent with other studies on fish muscle (Oliveira et al., 2014). The decrease in the hardness and firmness could be due to the temperature fluctuation, moisture change, storage time and enzymatic degradations (Hsieh & Regenstein, 1989). Therefore, it is important to consider the texture in

and often measurable changes occur during fish storage. The vast majority of chemical, biochemical, and microbiological experiments on fish products start with zero or less, and this is consistent with the fact that they increase in both temperature and storage time (Hyldig et al., 2010). The QIM is based on significant sensory quality parameters using the well-defined characteristics, changes of outer appearance attributes for raw fish and a score system from 0 to 3 demerit points (Hyldig & Petersen, 2004; Martinsdottir, 2002). The technique is based on selecting a number of quality attributes characteristic for a particular species and allocating the scores to each attribute depending on the state of freshness (Sveinsdottir et al., 2003).

Each parameter was assigned scores (0 to 1 and 0 to 2) according to the method. The

total sum of score was 10 points for before transportation, 10; 11; and 14 points for after received them into the fish market followed by 6, 12 and 18 hours. It is observed that sensory scores of fish samples scores increase from 10 to 12 which clearly indicates that the fish has spoiled in crushed ice storage condition. In this study, the deteriorative changes occurred in Bigeye scad fish were observed during the sample collection. Cloudy eyes and faded gill color were observed in all the fish samples and dull skin was observed in fish samples that were collected from the Badulla fish market. It indicated that the freshness of the fish was lower.

Consumers are usually looking for quality of fish before they consume. Finally, they must trust fishermen, processors, and traders to handle and process the fish with extreme caution. Many countries that import a lot of fish have rules in place to safeguard consumers from becoming sick from eating fisheries products. If these conditions are not met, fish may be prohibited from accessing that market, resulting in a loss of business and suffering for many individuals.

Natural features of each type of food include appearance, texture, smell, taste, and flavor. As a result, any change in one or more of these food properties signals food deterioration, which can result in illness due to pathogenic bacteria and their toxins (Shori, 2017). While fisheries products are vital to human nutrition around the world, they can also be a source of food-borne diseases (Dutta et al., 2018). Several postmortem changes take place when fish dies (Gutérrez et al., 2015). Previous research has discovered that the spoilage process and profiles of fish are related to the composition of their microbiota (Zhuang et al., 2020; Kuuliala et al., 2018). The microbiota of fish changes substantially depending on storage duration as well as a variety of other parameters such as species and environment, processing method, and so on (Hauptmann et al., 2020; Jääskeläinen et al., 2019). Preservation conditions and some quality control techniques such as the storage temperature, packaging atmosphere, and preservatives also have impacts on microbiota, and thus influence the quality and spoilage process of fishery products. (Sørensen et al., 2020; Liu et al., 2018). Identifying potential microbiological contamination points and physiochemical alterations in fish is therefore critical for the quality control procedure.

The physiochemical and microbiological investigations revealed that the quality of the “Big eye scad” fish had reduced during transportation and cold storage. Quality assurance in the fish sector is a timely requirement. It involves in monitoring and documenting defined quality criteria as required by regulations, product specifications and consumer demands (Gutérrez et al., 2015). To preserve the freshness of fish products, especially during prolonged storage and transportation, and to extend their shelf life, various holding temperature techniques including cooling, refrigeration, freezing are used (Magnussen et al., 2008). Moreover, vacuum and modified atmosphere packages are used as novel packaging techniques (Fletcher, 2012). Simultaneously, prolonged storage and transportation requires efficient control measures to ensure food safety and high quality of fish products including whole fish and pieces. Microbial load has to be controlled carefully and maintained below acceptable threshold levels. These requirements may be of different importance to the various parts of the supply and distribution chains for fish. Identification of contamination points during transportation and storage of fish from harbor to fish market will be helpful to reduce the fish quality deterioration. Therefore, findings of this study useful for further exportation, transportation and storage of food fish species in the international and local markets.

CONCLUSIONS

The findings of this present study may be considered as additional knowledge to enhance proper controlling of the storage life of fish, and fish product quality during transportation and storage of fish from harbors to market places. Gradually increased of total aerobic bacterial counts; present of *E. coli* and *Salmonella*; change of temperature, pH, color values and texture properties and increase of QIM parameters clearly indicate that Bigeye scad fish contaminated and physiochemical changes in progress. Thus, constitute potential public health hazard due to the unhygienic nature of fish handlers which predisposes frozen fishes to contamination by pathogenic microorganisms, physical and chemical changes. The total viable counts strongly suggest the urgent need to improve the quality control and assurance systems. Further use of hygienic practices is more important during handling and transportation process to minimize cross contaminations in fish before reaching to consumer.

Conflicts of Interest Statement

Authors state that there is no conflicts of interest exist.

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