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S Sabu
School of Industrial Fisheries, Cochin University of Science and Technology, Fine Arts Avenue, Cochin, Kerala, India

A Sasidharan
Department of Fish Processing Technology, Kerala University of Fisheries and Ocean Studies, Panangad, Kerala, India

Corresponding Author:
S Sabu
School of Industrial Fisheries, Cochin University of Science and Technology, Fine Arts Avenue, Cochin, Kerala, India

Impact of fishing on freshness and quality of seafood: A review

S Sabu and A Sasidharan

Abstract
"Quality" implies different things to different people and is a term that must be defined in association with an individual product type. As far as fish is concerned quality refers to the visual appearance, freshness and the changes in body due to spoilage. The fish catching process, composition, and keeping time are factors that influence the quality of fish. Different views exist regarding the effects of catching and the methods employed on the quality of fish. Basically, the catching method should be as gentle as possible and fish should not die during the catching process. Studies pointed out that fish suffer stress when they are crowded in a trawl net. There are many methods for evaluation of fish quality, but only a few of them have been used for testing the differences caused by catching methods. The soaking time for the fishing gears is different. Significant differences in fish quality due to soaking time using trawl and gillnet have been reported. The longer the soaking time the lower the quality of fish. The struggle and exhausting of the energy of fish due to fishing duration or method of capture varies with catching methods. The quality changes in fish are directly related to the high energy phosphate bonds in the body. The release of catecholamine in response to the stress, the increase in blood or serum constituents and finally death in water affect the final quality of the fish. The ensuing anaerobic condition alters the pH with subsequent increase in the quality indices such as k-value due to nucleotide breakdown and alteration in the texture of the fish flesh. Though reports in these lines are inadequate, it is a new line of approach which could pave way for identifying catch to suit the utilization pattern. Improving food security requires making better use of fish produced by reducing post-harvest losses and increasing the percentage of fish used for direct human consumption.

Keywords: Impact of fishing, harvest methods, freshness, seafood quality, quality assessment

1. Introduction
Fish is considered as the prime nutritionally balanced diet for the growing populations around the world. Seafood includes finfish, shellfish and other edible aquatic organisms from the wild and cultured fisheries. Per capita, fish consumption in the world has increased from 9.9 kg in 1960 to 19.7 kg in 2013. Total world fish production has touched 167.2 mt in 2014 and 92.3 mt of fish catch contributed by the capture fisheries sector and the remaining by the culture fisheries. Direct human consumption accounts for 85% of total fish produced; among this 46% are consumed in live, fresh or in chilled forms. Fish remains among the most traded commodities in the world [1]. A portion of 150 g of fish can provide about 50 to 60% of the daily protein requirement of an average adult [2]. India is one of the major producers of fish in the world with 9.58 mt of fish production during 2013-14. The marine fish contribution was 3.44 mt and inland fish contribution was 4.14 mt to the total [3]. About 75% of India's total fish production was consumed or marketed domestically in different forms [4-5].

2. Freshness and quality of seafood
The 'freshness' of fish is a concept that sums up many factors. It describes a particular fish that will still possess its set of characteristics at the time it is processed, cooked, presented, and eaten or all of these. The extent to which a fish retains these properties is related to the time and temperature history since capture or harvest [6]. The term quality broadly refers to the degree of excellence of any product. Quality is defined as those characters in a product which have significance in consumer acceptability [7]. The quality of a product is influenced and controlled by several factors. The quality of fishery products is the result of the physical, chemical, biochemical, organoleptic and bacteriological characteristics of the product.

Thus, the quality depends on factors such as intrinsic composition, nutritive value, degree of spoilage, damage, deterioration during processing, storage and distribution, hazards to health, consumer satisfaction, aesthetic consideration, product yield and profitability to producer and seller. In general, the quality of fish means all those attributes which consciously or unconsciously the consumer/ buyer considers should be present. However, the decision on quality ultimately rests with fish consumers [4, 8].

The freshness of fish and dietary quality during the first step of the value chain is at its best, any change in quality at this stage cannot be improved at a later stage. Safety and quality of fish products is of great importance for many countries in the light of increased demand, consumers' safety requirements and the globalization of fish trade. Fish contains 70-80% of water, makes the item more susceptible to spoilage than any other foodstuffs. Handling the fish from each fishing method with the utmost care and preserving the fish immediately after catching is essential to extend the storage life of fresh fish and for minimizing spoilage or food loss [9]. Every delay in 1-hour icing or chilling reduces the storage life of fish into half the original [2]. Immediate cooling of fish after capture, proper hygienic practices onboard, ensuring the ideal temperature during transportation and marketing are important measures to prevent the fish borne diseases [10]. Fish, one of the highly nutritious food items especially to the poorer sections living in the coastal areas. Post-harvest losses caused by spoilage of fish amount to about 10 to 12 million tonnes per year [1]. In 2050, there is a need to increase the food supplies by 60% in order to meet the increasing demand. Approaches for increase in food production, distribution and reduction in losses are essential for ensuring food availability and accessibility. Reduction of post-harvest food losses is a vital part for ensuring global food security [11].

3. Fish capture process and its impact on fish freshness

The art of catching fish (Fishing) has a great influence on the quality of the fish caught. The onset of rigor, duration of rigor and the storage life of fish in different preservation steps depend on the catching methods [9]. Purse seining and trawling are considered as the most successful fishing methods in the world contributing the bulk of the marine catch [12]. Both gears are actively operating to catch fish in the water. The fish caught by using trawl nets are more exhausted and with little or nil reserve energy than fish caught from purse seining. Gillnet one of the most popular environmentally safe fishing gear gives the poor quality catch due to its principle of catching process and the prolonged struggling of fish under the water. Handline, Jigging, Trap fishing are comparatively better catching methods in terms of the quality of fish harvested are considered. Considering the struggling of fish during capture, duration of the fishing operation, method of capture adopted, fishermen have to handle the fish to preserve the available quality of fish onboard the fishing vessels. Generally, fish caught from offshore waters are free from pathogenic bacteria compared to near shore or inland water bodies.

Fishing gears have multiple impacts on the fish quality and may result in the downgrading of the quality of fish products [13-17]. Long lined fish is affected by gaffing injuries [16] and trawl caught fish with bruises during hauling [17]. Gillnet and trap caught cod was considerably downgraded compared to hand line and long line caught cod according to sensory judgment [18], while gillnet and trawl caught cod had increased pH compared to long lined cod [15,19]. In addition, different fishing gears affect the length and condition factors of the catch [14].

Literature related to the fishing and quality loss from various harvesting systems both from freshwater and marine waters is sparse. Studies have reported regarding the quality of fish from gillnet with varying soaking time [20] and also compared the fish quality of two fishing gears namely gillnet and long line [18]. The effect of gillnetting, pound netting, and trawling on the quality of herring has also been evaluated [21]. Handling affects the quality of the fish was also reported in a study [15]. The effects of pH and bleeding of Cod caught by long line methods were reported by some scholars [19, 22]. Condition factor, muscle pH and glycogen content of fish caught from trawling and long line methods have also been reported [14, 23]. Pre-harvest stress and handling of Barramundi from cage culture on rigor onset, change in pH and drip loss were reported [24]. Atlantic cod caught by long lining and trawling and its quality assessment at the same time and location was studied [25]. Physiological response and mortality due to scale loss of Atlantic salmon was reported [26-27] reported the quality changes of *Rutilus kuntum* under iced storage caught from Iranian waters due to the effects of fishing method. The pumping effect of mackerel catches and their quality from purse seiners to onboard fishing vessels was observed [28]. Some researchers have investigated the effect of soaking time of gill netting fishing on the quality of fish and recommended change in soaking time and method of fishing for the better quality of fillets [29]. It is understood from the literature review that the works conducted already in this area were preliminary and are primarily to assess the quality of fish during storage mainly from selected marine fish harvesting systems. The fish freshness and quality assessment during storage at various periods were reported by many authors in the world [7, 30-32].

There are many studies reported from India on the sensory, chemical and microbiological assessment of fresh fish landed in markets or at harbors of various parts of India [33-35]. Effect of delay in icing on fish quality also was observed by many [36-37]. Preliminary studies on quantitative loss assessment of fish from the harvest and post-harvest sector based on physical damage and spoilage from landing center and from pre-processing and processing centers were reported based on field level observation [38-39]. However, there is a wide gap in scientific knowledge on the subject *i.e.*, the real reasons behind the freshness loss of fish and quality change during storage and transportation from various commercial fishing, methods to minimize the loss after harvesting of food items from aquatic environments.

4. Freshness loss evaluation of harvested fish

The freshness loss of fish from various aquatic environments can be assessed based on physical observation, instrumental methods, biochemical, microbiological and by using statistical methods. New structural changes in fishing gear design; changes in protocols of handling, modifications; development of innovative facilities onboard the fishing vessels, landing centers; species-specific catch handling and preservation strategies throughout the supply chain are the other benefits. The evaluation of freshness loss during harvesting, storage, and transportation of seafood can be assessed by (i) evaluation of onboard quality parameters, (ii) evaluation of quality parameters during the storage and transportation of seafood.

During the harvest process, fish species suffer increased activity and stress prior to death, and the subsequent endocrine response has been found to result in a fast drop in muscle pH due to increased lactic acid through anaerobic metabolism of fish muscle [40-45]. Reduced muscle pH results in a quick onset of rigor mortis. Reduced shelf-life, increased muscle gaping and blood spots, flesh texture alterations and reduced water holding capacity of the muscle are the other consequences [46-47].

Bloodstains and gaping have a profound negative effect on the quality of fish fillet [48-49]. Gaping of flesh, texture alteration and a lower fillet yield are the issues due to lapses in handling and processing of fish while in rigor [50-52]. Blood residue in fish muscle has also been shown to cause lipid oxidation in i.e. sea bass, smoked Atlantic salmon, trout and mackerel [53-55]. Maintaining a physiologically normal flesh pH is necessary to achieve higher flesh quality post-harvest by employing a harvesting technique that minimizes pre-harvest activity and stress. Harvest methods practiced in aquaculture farms are designed with the aim of ease of operation and to minimize cost [47].

The freshness of fish harvested and landed after the completion of various catching process can be subjected to freshness and quality evaluation by following the methods *viz.*, (i) Physical catch damage assessment, (ii) Sensory evaluation (iii) Instrumental analysis for freshness (iv) Biochemical evaluation (vi) Microbiological evaluation and (vii) Statistical analysis.

5. Physical catch damage assessment

Fishing gears have multiple impacts on the fish quality and damages caused by the fishing gear may downgrade the end products [15]. Quality Damage Index (QDI) [17] is assessed based on the bruises (observed as blood extravasations and red discoloration of the skin, loss of scales, injuries due to piercing of net in body, dead fish, etc) Catch Damage Index (CDI) [56] is a sensory method where five specified quality defects (death in gear, gear-related damages, bruises, gaffing damages, poorly bled) with significant impact on product quality or yield are evaluated by a trained person, inspecting the skin of the whole fish and the blood vessels and color of the muscle in the belly flaps. Quality defects caused by the fishing gear or by improper bleeding were evaluated on the thawed, gutted and beheaded fish and assigned scores (0 for flawless, 1 for moderate and 2 for severe damage) [25]. Gaffing is a necessity for holding and securing the catch during de-hooking or rescuing drop offs during long line fishing. During gaffing, it is essential for the fishermen to target the fish in the head to avoid damages to the muscle. Otherwise, hemorrhages will be formed in fillets due to gaffing outside head region and may cause downgrading and reduced economic value of the raw material [16].

The well-being of the fish during capture can be assessed by Fultons K-factor (Condition factor) [23]. Length-weight relationships are used for comparing the "condition", "fatness" or "well-being" of fish [57-58]. The condition factor is influenced by both intrinsic (gonadal development, organic reserves, presence or absence of food in the gut) and extrinsic (food availability, environmental variability) factors, reflect the physiological state of a fish [59].

6. Sensory evaluation of fish

Sensory analysis are considered as the most acceptable way of assessing fish freshness and quality loss compared to many methods available for fish quality assessment [19]. Color, odor, and texture assessment of food through sight, smell, and taste are assessed recorded in sensory evaluation. Sensory evaluation involves fish freshness evaluation and interpretation of experienced and trained personnel. Many schemes have been proposed for assessing raw fish quality based on the Torry system [60]. Other common methods of sensory evaluation include the European Union (EU) scheme and Quality Index Method (QIM) methods [34, 61].

QIM got much popularity than EU scheme which based on freshness category (E, A, B/unfit). QIM is an accurate and an objective method for the determination of fish freshness that gives scores of 0 for very fresh fish and higher number (9) when the fish deteriorates [61].

7. Instrumental analysis for freshness

Instrumental techniques like Fish Freshness Meter (Torry Research Station of UK); onboard pH meter Texture analyzer gives comparative results of the freshness of fish immediately after catching process from various methods/species/seasons [62]. The Torry meter instrument measures dielectric properties and the readings start at a peak and then decline with post mortem storage. It is handheld and portable as well as being rapid and non-destructive. 'Artificial nose' with gas sensors responds to the headspace gases above a sample in a chamber which also responds to a variety of organic volatiles [63].

It is commonly regarded that rigor is a useful indicator of whether a fish is 'fresh' or not. If it is in rigor it cannot have long been caught and hence *ipso facto* it must be 'fresh.' The breakdown of the pericellular tissue occurs before rigor resolves and that this can be demonstrated by a puncture test, a physical test where a cylindrical tooth-shaped probe is pressed into the flesh [64]. Textural changes of fish muscle normally measured by texture analyzer with texture profile analysis. The hardness, toughness, and stiffness of fish during post-mortem changes can be investigated by texture analyzer [22, 62].

The development of new rapid test instruments such as near-infrared transmission (NIT), near-infrared reflectance (NIR), nuclear magnetic resonance (NMR), and fluorescence have prompted exploration of their use on fish. NMR can be used to measure the distribution of high-energy phosphates (ATP and phosphocreatine) and their metabolites [63, 65].

8. Biochemical evaluation

Moisture, volatile compounds, changes in protein, ATP decomposition, lipid oxidation products and K value are normally estimated under biochemical evaluation of fish samples. Measuring biochemical indices of fish-like Total Volatile Base Nitrogen, Trimethylamine, Thio Barbituric acid value, Free Fatty acid value, Peroxide value, and water holding capacity, etc gives the status of quality of fish at various stages of the supply chain and can be used to compare the quality of fishes from different catching processes [66-68]. A comparison of pH, glycogen content, ATP content also gives the status of freshness. Moisture by oven drying method or through electronic moisture analyzer and also by NIR spectroscopy [69]. Microbial activity and endogenous enzyme affects some decomposition in fish muscle and create volatile compounds. Odor of fresh fish relates to the C6–C9 alcohols and carbonyl compounds of volatile substances; odor due to microbial spoilage mainly due to ammonia, trimethylamine (TMA), hydrogen sulfide, and methyl mercaptan and plays a fundamental role in fish freshness evaluation; and the reason

for odor due to lipid is hexaldehyde, and 2, 4, 7-decatrienal [19].

The initial quality loss in fish is mainly due to autolytic changes, including degradation of nucleotides by autolytic enzymes. Changes in nucleotide and inosine monophosphate (IMP), accountable for the loss of fresh fish flavor. Enzymatic changes make catabolites accessible for bacterial growth [9]. pH and glycogen content estimation in fish muscle [13] and K-value [70] measurement has been proposed by many researchers. K value, popular method for the assessment of fish freshness. Higher rate of ATP decomposition results in higher K value and rejection. ATP degradation and K-index by NMR spectroscopy was proposed by many researchers [71-72]. Break down of fatty acids due to light and temperature lead to the production of aldehydes, ketones, and carboxylic acid groups and results in the changes of texture, smell, color and nutritional composition of fish. The thiobarbituric acid (TBA) employed to assess the degree of lipid oxidation [34].

9. Microbiological analysis

One of the main reasons for fish spoilage is bacteria. The enumeration of the specific spoilage organisms that cause deteriorative changes is a far more useful indicator than Total bacterial plate counts as the later gives misleading indicators since they may be no relationship to the period of storage, often being very high when the fish are first caught [63]. The initial value of native bacterial flora is usually approximately 10^2–10^4 CFU/g. Assessing the total count of native bacterial flora of fish at the time of capture and measuring the H_2S producing bacteria gives clear status of microbiological quality of fish during various stages or hours of storage [73-74].

10. Statistical analysis

Partial Least Square Regression, PLSR1, [75] with Martens Uncertainty Test can be applied to identify the effect of catching method, weight, length and storage time on the different quality attributes. A significant difference between the results can be analyzed statistically using ANOVA.

11. Conclusion

Marketing of safe seafood meant for export and for domestic consumption should be of high quality. Quality of fish harvested needs to be preserved by adopting the best available science and procedures. Proper awareness among fishermen is required to improve the quality of catch they brought to the shore. Spoilage of fish during production, handling, processing, and marketing of fish needs to be minimized to achieve the objective of providing safe food to the global fish eaters. Food borne illness due to the consumption of spoiled fish, unhygienic fish and contaminated fish with hazardous chemical preservatives needs to be discouraged. Proper icing, chilling or freezing right from the capture should be made mandatory not only for the export market but also for the domestic market in order to safeguard the safety of fish eaters especially the poorer sections of society and those consume fish on a daily basis. Adopting codes and practices for the safe production of fish in the primary level will results in (i) minimizing the wastages of fish during harvesting, handling, and marketing, (ii) export earnings can be increased to many folds through the processing of more quantity of quality fish and (iii) quality protein food can be supplied to the growing Indian population for maintaining healthy life.

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