Proc. Natl. Acad. Sci., India, Sect. B Biol. Sci. (Oct–Dec 2014) 84(4):1035–1042
DOI 10.1007/s40011-014-0325-8

RESEARCH ARTICLE

Evaluation of Quality and Shelf Life of Two Commercially Important Fish Species Viz., Tiger Tooth Croaker (*Otolithes ruber* Bloch and Schneider) and Flathead Grey Mullet (*Mugil cephalus* Linnaeus) in Iced Conditions

George Ninan · A. A. Zynudheen

Received: 22 June 2013 / Revised: 6 January 2014 / Accepted: 3 February 2014 / Published online: 7 March 2014

Abstract A study on the quality parameters to assess the shelf life of two commercially important species viz. Tiger tooth croaker and Flathead Grey mullet from different aquatic environments was carried out under iced conditions. Croaker, a marine species and grey mullet from brackish water sources was used for the study. Biochemical quality indices like non-protein nitrogen, total volatile basic nitrogen, peroxide value and free fatty acids were assessed. Changes in moisture, pH and K-value were also determined. For croaker, FFA values increased from the initial 2.2–20.1 % on 15 days of storage in ice, whereas in case of mullet it reached 17.9 % during the same period. During the same period the pH values showed an increase from 6.81 to 7.88 and from 6.68 to 7.53 in case of croaker and mullet respectively. TVBN and PV increased throughout the period of storage and the former crossed the limit of acceptability of 30 mg/100 g by 15 days in ice. The sensory evaluation based on demerit score system was carried out which showed that the species retained the high quality shelf life characteristics for 5 days in case of croaker and 7 days in case of mullet. However both the species remained in acceptable condition for a period of 13 days. Freshness index K-value for both species complemented the sensory evaluation scores.

Keywords Croaker · Mullet · Ice storage · Quality · K-value · Sensory evaluation · Shelf life

G. Ninan (✉) · A. A. Zynudheen
Fish Processing Division, Central Institute of Fisheries Technology (ICAR), Matsyapuri (P.O), Cochin 682 029, Kerala, India
e-mail: george66jiji@gmail.com

A. A. Zynudheen
e-mail: zynu@rediffmail.com

Introduction

Croakers are important marine fish species having good domestic and export market demand. Croakers contribute significantly to the marine fish landings in India. During 2011 the total landings of this species was estimated to be 220,120 t [1]. It is exported from India in different forms viz., block frozen, IQF, in shatter packs and as a chilled item. In 2010, 17,809 kg of frozen tiger tooth croaker worth Rs. 1, 73, 62188 was exported from India [2]. Croaker is an important raw material for good quality surimi. Mullet is also an important commercial species abundant in the coastal waters and brackish water lagoons of Kerala. It is considered as a highly valued local delicacy, particularly in the coastal areas of Kollam, Alleppey, Eranakulam and Thrissur districts of Kerala.

Mullets are exported in chilled condition as well as in the form of frozen fillets from India. In 2010, 31,999 kg of frozen mullet fillets and 3,440 kg of chilled mullet was exported from India [2]. The production figure of mullet during the year 2011 was 10,699 t [1]. Croakers and mullets are mainly sold in fresh condition in the domestic market. Ice is the medium used for the short term preservation of these species. The advantage of icing fish is to extend shelf life in a relative simple way as compared to storage of un-iced fish at ambient temperatures above 0 °C. Shelf life can be defined as the maximal period of time during which the predetermined attributes of the food are retained [3]. In fish, the total shelf life is defined as the period up to which it is rejected for any food use by sensory evaluation [4]. The chilled storage life of fish is primarily determined by sensory evaluation. Chilled storage life of fish depends on several factors such as composition, microbial contamination and the type of microflora present in the fish [5]. Croakers are considered to be lean fish and

the estimated shelf life for different species in this group is 8–22 days in ice [6]. In the case of grey mullets a shelf life of 22–29 days in ice has been reported [7]. Estimation of shelf life and quality evaluation is significant in developing package of practices for iced storage, transportation and marketing of these species as they form an important group in domestic fish trade. The objective of the present study is to relate the biochemical and sensory quality indices with shelf life of Tiger tooth croaker (*Otolithes ruber*) and Flathead grey mullet (*Mugil cephalus*) in iced conditions.

Material and Methods

Fresh Croaker (length 18 ± 3.2 cm, weight 115 ± 4.2 g) and Grey mullet (length 22.3 ± 2.5 cm, weight 160.3 ± 3.6 g) in initial post rigor condition were collected from Fort Kochi landing centre in Cochin. Both species were procured as wild caught catch from the local fishers operating country craft in coastal waters and backwaters off Cochin. The time elapsed between harvest and procurement of samples is about 3 h. The samples were immediately iced and brought to the laboratory in iced condition in insulated boxes. It was then washed and re-iced immediately with flake ice in 1:1 (W/W) ratio in separate insulated boxes. Re-icing was done daily to compensate the ice loss due to melting. Six samples from each group were drawn for analyses at an interval of 48 h for 15 days.

Preparation of Sample and Biochemical Analyses

The skinless, boneless edible anterior-dorsal muscle portion from the six samples was separated and homogenized in a Waring blender for 60 s. Composite muscle samples ($n = 3$) for each species was used for the biochemical analyses. Moisture, ash, fat and total nitrogen were determined by AOAC methods as 950.46, 938.08, 991.36 and 940.25 respectively [8]. For the determination of moisture content, the pre-weighed samples were dried in moisture dish in an oven (Labline, India) at 105 °C until constant weights were obtained. Pre-dried samples obtained from moisture content analysis were ashed in muffle furnace (Nabertherm, GmBH, Germany) at 550 °C overnight to determine the ash content. The total nitrogen in the sample was determined by Kjeldahl method. The procedure followed was digesting a known quantity of sample using H_2SO_4 followed by distillation and titration of the liberated ammonia with standard H_2SO_4. Crude protein in the sample is then determined using conversion factor for nitrogen to protein, which in the case of fish muscle is 6.25. Fat content of the moisture free sample was determined by extracting the fat with petroleum ether. Extraction was done using a Soxhlet apparatus. The pH of the homogenized samples was measured using a pH meter (Cyberscan 510, Eutech Instruments, Singapore) at 28 °C after being calibrated using buffer capsules. About 5.0 g of the homogenized sample was macerated with 45 ml of distilled water and the pH was measured. Non Protein Nitrogen (NPN) content of the samples was measured as per AOAC method 955.04 [9] by estimating nitrogen in the 10 % TCA extract by Kjeldahl distillation method. Total Volatile Base Nitrogen (TVBN) was determined by the micro diffusion method of Conway [10] from the trichloroacetic acid extract of the muscle and expressed in mg/100 g of the sample. Peroxide value (PV) and free fatty acid (FFA) was determined from the chloroform extract according to AOCS and AOAC methods respectively [8, 11] and expressed as milliequivalents/kg of lipid and percentage oleic acid, respectively.

Determination of K-value

K-value and the amount of different nucleotide degradation products were determined in HPLC by the method described by Ryder [12]. Muscle (5 g) taken from the anterior dorsal portion of the fish was homogenized in a homogenizer (IKA Labortechnik, USA) at a temperature below 5 °C for 1 min with 25 ml of chilled 0.6 M Perchloric acid. The homogenate was centrifuged at 3,911×*g* for 10 min at 4 °C using Fiber lite rotor (F 20–6 × 100) in a Thermo Scientific Multifuge X1R (Thermo Fisher Scientific Co. Germany). 10 ml of the supernatant was taken and pH adjusted to 6.8 with chilled 1 M KOH immediately and kept at 5 °C for 30 min. The solution was filtered through syringe filter of pore size 0.45 µm and the filtrate was stored at −30 °C for subsequent HPLC analysis. A Jasco Borwin Liquid Chromatograph (Jasco Ltd. Japan) with model PU 2089 plus quaternary gradient pump and Jasco 2015 MD plus wavelength detector was used. A Lichrospher 100C-18 encapped reverse phase column (5 µm) was used for the separation of nucleotides. The nucleotide separation was achieved by isocratic elution with phosphate buffer solution prepared by mixing equal volumes of 0.04 M M KH_2PO_4 and 0.06 M K_2HPO_4 in deionized water at a flow rate of 2.4 ml min^{-1} and an injection pressure ranging from 350 to 355 MPa. All solutions were passed through 0.45 µm filter prior to the injection on to column. 20 µl of the sample was injected into the column and the elute was monitored at 254 nm. The peaks were identified by comparing with the peak of chromatogram of standard solutions. K-value was calculated as a ratio of the sum of hypoxanthine and inosine to total amount of ATP related compounds as defined by Saito et al. [13].

The standards of ATP, ADP, AMP, IMP, Inosine and Hypoxanthine were supplied by Sigma Chemical Co., St. Louis, USA. KH_2PO_4 and K_2HPO_4 used for preparation of phosphate buffer were supplied by BDH Laboratory, England. De-ionized water used was collected from

Millipore Filter System (QTUM 0001X) supplied by Millipore, Bangalore, India.

Sensory Evaluation

The freshness of whole fish samples were determined by the quality index method (QIM) originally developed by Tasmanian Food Research Unit [14]. The panel consisted of 10 regular assessors consisting scientists and technical staff from the Fish Processing Division, each trained in fish quality assessment. Each assessor was given up to four simple descriptors, scoring demerit points from 0 to a maximum of 3, where 0 represented best quality and any higher score indicated poorer quality. The scores for the separate characteristics were summed to give an overall sensory score. In the case of croaker and mullet 18 parameters were considered for evaluation. Each of these parameters were given attributes with 0–3 scores. Maximum demerit score was fixed at 39 and the demerit score of 10 was set as the limit for high quality shelf life. The sample demerit score system is given in Table 1.

Sensory evaluation was conducted by five trained panelists who assigned the sensory scores based on a modified ten point hedonic scale originally described by Amerine et al. [15]. Sensory attributes viz., appearance, colour, odor, texture, and flavour were evaluated by the panelists. Fish samples were boiled in 1.5 % brine for 10 min, cooled and served to the panelists. Samples were labeled in such a way that the panelist would not be able to identify them and were placed in separate booths. The panelists were provided with clean water to rinse their mouth after tasting each sample. The samples were evaluated using a ten point hedonic scale basis (10 = like extremely, 9 = like very much, 8 = like moderately, 7 = like slightly, 6 = neither like nor dislike, 5 = dislike slightly, 4 = dislike moderately, 3 = dislike very much, 2 = dislike extremely and 1 = reject). An overall sensory score of 4 was taken as the borderline for acceptability.

Statistical Analysis

Statistical analysis was done using SPSS (Version 16.0) software. All analyses were carried out in triplicates and the results were expressed as mean value ± standard deviation (SD) for $n = 9$. Analysis of variance (ANOVA) was carried out at 5 % level of significance.

Results and Discussion

Proximate Composition and pH

The proximate composition of the two species is given in Table 2. Both species are medium fatty fishes having fat content in the range of 2.2–2.3 % by weight. Generally fishes are classified based on the fat content as lean fishes (less than 0.5 %), semi fatty fishes (0.5–2 %) and fatty fishes (more than 2 %). The pH of fish muscle was near neutral in both species for 5–7 days and progressively changed to alkaline by the end of storage period (Table 3). The pH value of live fish muscle is close to 7.0, however post mortem pH can vary from 6.0 to 7.0 depending on season, species and other factors [16]. The decrease in pH indicates the stress which the fish encountered during harvesting [17]. The more the fish struggled during harvesting, the more the lactic acid production by anaerobic pathway post mortem and the less the pH. Increase in pH during storage is owing to the production of amines and other volatile bases by the autolytic and microbial action on protein and other compounds. In the present study, both samples showed significantly higher values ($p < 0.05$) of pH from the third day of ice storage which corresponds to the production of alkaline bacterial metabolites in spoiling fish which coincides with the increase in TVBN. The post-mortem pH limit of acceptability is usually 6.8–7.0 [18].

There was a gradual increase in the moisture content up to 7 % in both species during ice storage (Table 4). The same trend was observed in the ice storage studies of many commercially important freshwater fish species [19] and cultured major carps [20]. An increase of 7.1 % of moisture content was observed in silver jewfish (*Johnius argentatus*) after 13 days storage in ice [21]. For croaker, significant increase in moisture content was observed from third day of ice storage ($p < 0.05$) whereas for mullet it was from the fourth day in ice storage. The increase in moisture content of samples could be due to the uptake of melted ice water by the fish muscle due to loss of texture. Another reason could be the relative increase associated with the loss of proteins and other solubles from the fish body due to leaching by melted ice water.

Non Protein Nitrogen (NPN) and Total Volatile Base Nitrogen (TVBN)

Table 5 illustrates the changes in NPN and TVBN during ice storage. NPN values showed a steady increase up to fifth day and thereafter a gradual decrease occurred in croaker as the ice storage progressed. In the case of mullet NPN was almost steady for the first three days and afterwards followed the same pattern observed for croaker. By the fifteenth day in ice storage, significant reduction in NPN value was observed, indicating the loss of flavour as well as commencement of spoilage of the samples. Hydrolysis of proteins brings about an increase in NPN which is composed of low molecular weight amines, free amino acids, peptides and nucleotides during the initial days of ice storage [22, 23]. The reduction in NPN content

Table 1 Demerit score system

	Parameters	Attributes	Demerit points
1	Appearance of surface	Very bright	0
		Bright	1
		Slightly dull	2
		Dull	3
2	Skin	Firm	0
		Soft	1
3	Scales	Firm	0
		Slightly loose	1
		Loose	2
4	Slime	Absent	0
		Slightly slimy	1
		Slimy	2
		Very slimy	3
5	Stiffness	Pre rigor	0
		Rigor	1
		Post rigor	2
6	Eyes clarity	Clear	0
		Slightly cloudy	1
		Cloudy	2
7	Eye shape	Normal	0
		Slightly sunken	1
		Sunken	2
8	Iris	Visible	0
		Not visible	1
9	Blood in the eye	No blood	0
		Slightly bloody	1
		Very bloody	2
10	Gills colour	Characteristic	0
		Slightly dark/slightly faded	1
		Very dark/very faded	2
11	Mucus in gill	Absent	0
		Moderate	1
		Excessive	2
12	Smell of gill	Fresh oily/fresh seaweedy	0
		Fishy	1
		Stale	2
		Spoiled	3
13	Belly discolouration	Absent	0
		Detectable	1
		Moderate	2
		Excessive	3
14	Firmness of belly	Firm	0
		Soft	1
		Burst	2
15	Vent condition	Normal	0
		Slight break/exudes	1
		Excessive/Opening	2
16	Smell of vent	Fresh	0
		Neutral	1
		Fishy	2
		Spoiled	3
17	Belly cavity stains	Opalescent	0
		Grayish	1
		Yellow-brown	2
18	Blood	Red	0
		Dark red	1
		Brown	2

Total demerit points (Minimum 0–Maximum 39)

Table 2 Proximate composition of fresh fish

	Croaker	Mullet
Moisture (%)	78.5 ± 0.62	77.2 ± 0.52
Fat (%)	2.3 ± 0.41	2.2 ± 0.35
Ash (%)	1.4 ± 0.17	1.5 ± 0.28
Protein (%)	19.8 ± 0.84	19.2 ± 0.66
Carbohydrate (as glycogen) (%)	<0.50	<0.50

Values are reported as mean ± standard deviation for $n = 9$

Table 3 Changes in pH during storage in ice

Days	Croaker	Mullet
0	6.81 ± 0.11^{a}	6.68 ± 0.08^{a}
1	6.86 ± 0.10^{a}	6.56 ± 0.07^{a}
3	6.90 ± 0.20^{b}	6.93 ± 0.13^{b}
5	6.98 ± 0.32^{b}	7.02 ± 0.37^{b}
7	7.15 ± 0.24^{b}	7.05 ± 0.22^{b}
9	7.27 ± 0.19^{b}	7.21 ± 0.24^{b}
11	7.68 ± 0.15^{c}	7.28 ± 0.12^{b}
13	7.87 ± 0.26^{c}	7.49 ± 0.13^{c}
15	7.88 ± 0.11^{c}	7.53 ± 0.16^{c}

Values are reported as mean ± standard deviation for $n = 9$. Treatment mean values with same letters within the column are not significantly different from each other ($p < 0.05$)

during later stages of ice storage is associated with the utilisation of the same by microorganisms. Similar pattern of change in NPN was observed in ice storage studies of major carps [20] and common murrel (*C. striatus*) [22]. The concentration of TVBN in freshly caught fish is typically between 5 and 20 mg N/100 g, whereas levels of 30–35 mg N/100 g fish are generally regarded as the limit of acceptability for ice-stored cold water fish [24]. However, various authors have reported different acceptability

Table 4 Changes in moisture content (%) during storage in ice

Days of storage	Croaker	Mullet
0	78.5 ± 0.62[a]	77.2 ± 0.52[a]
1	79.3 ± 0.55[a]	77.8 ± 0.40[a]
3	80.5 ± 0.39[b]	78.8 ± 0.71[a]
5	81.0 ± 0.78[b]	79.5 ± 0.55[b]
7	81.5 ± 1.01[b]	79.8 ± 0.90[b]
9	82.2 ± 1.08[c]	80.4 ± 0.89[b]
11	82.8 ± 0.56[c]	81.7 ± 0.51[c]
13	83.7 ± 0.50[d]	82.5 ± 0.57[c]
15	84.1 ± 0.58[d]	83.2 ± 0.49[c]

Values are reported as mean ± standard deviation for $n = 9$. Treatment mean values with same letters within the column are not significantly different from each other ($p < 0.05$)

Table 5 Changes in non-protein nitrogen (NPN) and total volatile base nitrogen (TVBN) during storage in ice

Days	NPN (mg 100 g^{-1})		TVBN (mg 100 g^{-1})	
	Croaker	Mullet	Croaker	Mullet
0	413 ± 2.0[a]	318 ± 2.28[a]	12.10 ± 0.67[a]	9.26 ± 0.93[a]
1	415 ± 3.10[a]	312 ± 3.58[b]	14.50 ± 0.55[b]	9.67 ± 0.36[a]
3	420 ± 1.88[b]	318 ± 1.93[c]	14.80 ± 0.85[b]	12.76 ± 0.70[b]
5	433 ± 2.93[c]	268 ± 2.26[d]	19.50 ± 0.83[c]	12.85 ± 0.81[b]
7	428 ± 3.92[d]	231 ± 3.35[e]	20.13 ± 0.40[c]	14.55 ± 0.46[c]
9	425 ± 2.60[d]	235 ± 2.78[e]	20.90 ± 0.59[c]	19.24 ± 0.51[d]
11	410 ± 3.64[a]	235 ± 3.77[e]	22.80 ± 0.60[d]	23.15 ± 0.77[e]
13	389 ± 2.73[e]	245 ± 3.19[f]	29.46 ± 0.53[d]	28.62 ± 0.59[f]
15	350 ± 2.31[f]	241 ± 2.29[f]	42.25 ± 0.72[e]	38.2 ± 0.91[g]

Values are reported as mean ± standard deviation for $n = 9$. Treatment mean values with same letters within the column for the same parameter are not significantly different from each other ($p < 0.05$)

levels for different fish species, specific treatments, and processing conditions for TVBN value as 35–40 mg/100 g [25]; 25–30 mg/100 g [26]; 25–35 mg/100 g [27]. The increase in TVBN is caused by a combination of microbiological and autolytic deamination of amino acids [28]. Increase in TVBN was significant ($p < 0.05$) in croaker sample from the first day of ice storage onwards whereas in mullet sample, significant increase of TVBN started from third day of ice storage. In both species, TVBN content crossed the limit of acceptability (30 mg 100 g^{-1}) by 15 days in ice.

Peroxide Value (PV) and Free Fatty Acid value (FFA)

The changes in PV and FFA values are given in Table 6. PV measures peroxides and hydroperoxides and a value of above 10–20 meq O_2/Kg is an indication of rancidity [24].

Table 6 Changes in peroxide value (pv) and free fatty acid (ffa) during storage in ice

Days	PV (meq O_2/Kg)		FFA (% oleic acid)	
	Croaker	Mullet	Croaker	Mullet
0	06.33 ± 0.22[a]	07.27 ± 0.18[a]	02.22 ± 0.16[a]	02.60 ± 0.11[a]
1	07.81 ± 0.30[b]	07.90 ± 0.28[b]	03.21 ± 0.31[b]	04.22 ± 0.33[b]
3	12.60 ± 0.66[c]	15.32 ± 0.48[c]	04.62 ± 0.52[c]	04.93 ± 0.55[b]
5	14.32 ± 0.64[d]	15.10 ± 0.62[c]	07.84 ± 0.67[d]	05.72 ± 0.39[c]
7	14.50 ± 0.64[d]	16.33 ± 0.49[d]	10.20 ± 0.51[e]	08.91 ± 0.46[d]
9	15.20 ± 0.50[d]	17.14 ± 0.55[e]	12.70 ± 0.30[f]	10.23 ± 0.38[e]
11	17.30 ± 0.21[e]	18.20 ± 0.39[f]	16.80 ± 0.60[g]	12.10 ± 0.69[f]
13	18.18 ± 0.99[e]	19.14 ± 1.01[f]	19.20 ± 0.89[h]	15.60 ± 0.97[g]
15	22.20 ± 1.12[f]	25.20 ± 1.20[g]	20.10 ± 0.50[h]	17.90 ± 0.59[h]

Values are reported as mean ± standard deviation for $n = 9$. Treatment mean values with same letters within the column for the same parameter are not significantly different from each other ($p < 0.05$)

In this study PV showed a significant increase ($p < 0.05$) in both species during ice storage reaching the threshold level by 15 days. Peroxide value, however cannot be considered as reliable quality index for the following reasons. First, the hydroperoxides are odour- and flavour-less, thus the PV is not related to the actual sensory quality of the product analyzed. However, the peroxide value may indicate a potential for a later formation of sensorial-objectionable compounds. Second, lipid hydroperoxides break down with time, and a low PV at a certain point during the storage of a product can indicate both an early phase of autoxidation and a late stage of a severely oxidized product, where most hydroperoxides have been broken down [24]. It has been reported that during the initial days of chilling process, FFA is produced mainly by endogenous enzyme and later on, microbial enzymes becomes predominant in FFA formation [29]. FFA exerts a pro oxidative effect due to complex formation between hydroperoxides and carbonyl groups through a hydrogen bond which results in an accelerated decomposition of hydroperoxides into free radicals. FFA progressively increased during the period of iced storage in mullet and croaker and the accumulation was significant in case of croaker than in mullet.

K–value

K–value has been proposed as freshness index of seafood by Saito et al. [13]. Figure 1 shows the K-value for the species in ice storage. K–value for croaker reached 82.6 % from 8.5 % by 15 days in ice. For mullet the corresponding values were 73.6 and 6.8 %. Croaker retained the high quality shelf life up to 5 days in ice for which the corresponding K–value was 39.2 %. As for mullet, the high quality shelf life was for 7 days and the K–value was

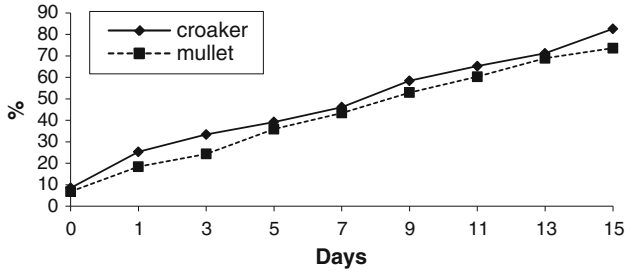

Fig. 1 Changes in K-value (%) during iced storage. Values are presented as mean values for $n = 9$

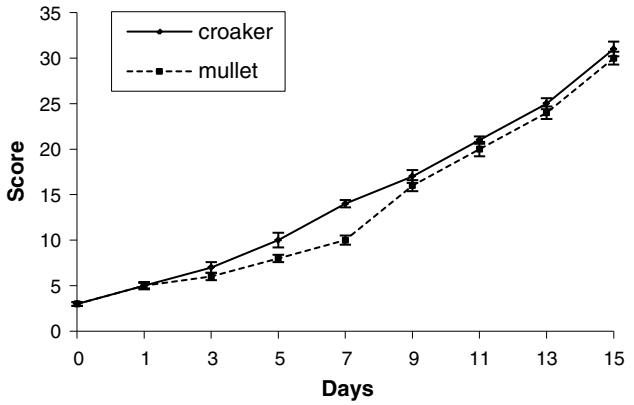

Fig. 2 Sensory changes during iced storage of whole fish based on demerit score system (Total demerit points 0–39). Values are presented as mean values for $n = 6$

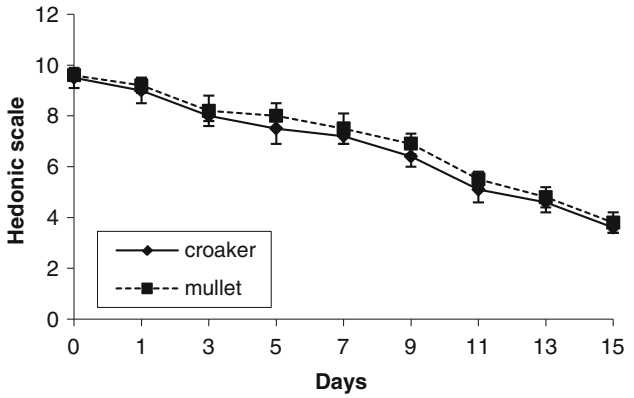

Fig. 3 Sensory evaluation of cooked meat of ice stored fish. Values are presented as mean values for $n = 6$

43.4 %. K-value of fish varies with the species, with threadfin bream having a K-value of 35 % as the limit of acceptability [30] while for wild turbot (*Scophothalmus maximus*) a K-value of 75–85 % was considered as the limit of acceptability [31]. There is a report on *Liza corsula,* which is a mullet species retaining the prime quality up to 4 days in ice with a K-value of 29.8 % [32]. The rejection level of K–value for both species is above 60 % which is the limit set by previous workers [33, 34].

Sensory Characteristics

Figure 2 illustrates the sensory changes of whole fish during ice storage assessed by QIM. The maximum QIM score reaches at the point in storage when the sensory panel rejects the cooked product. A demerit score of 10 was set as the limit of high quality shelf life for croaker and mullet in ice. For croaker this score was attained after 5 days in ice and for mullet it took 7 days in ice. After this period, both species showed marked changes in organoleptic qualities as evidenced by faded appearance, cloudy and sunken eyes faded gill colour, soft belly and excessively opened vent. However both species remained in acceptable condition for thirteen days in ice. The corresponding demerit scores were 25 and 24 for croaker and mullet respectively, which was set as the limit for acceptable quality. These maximum QIM scores were complemented by sensory panel score for cooked meat which reached the limit of acceptability of 4 by the thirteenth day in ice storage. QIM has been developed for a number of species, taking into account the intactness of the fish (whole, gutted, fillets) and the technological treatment used (chilling, freezing, freeze-thawing or cooking). The quality index method has been developed for round fish [35], herring [36], red fish [37], anchovy [38], sardine, iced horse mackerel and Atlantic mackerel [39], raw gilthead seabream [40] and whole shrimp [41].

Figure 3 shows the changes in the sensory qualities of cooked meat which complemented with the demerit score evaluation of whole fish. The limit for high quality shelf life was set at 7.5 in the hedonic scale. For croaker and mullet, the cooked meat retained the flavour and texture up to 5 and 7 days respectively. The cooked meat of both species showed signs of texture deterioration and flavour reduction as the ice storage progressed but was in acceptable condition up to 13 days with hedonic score above 4 which was set as the limit of acceptability. The reduction in flavour could be primarily due to nucleotide decomposition as suggested by other workers [42, 43].

Conclusion

The present study shows that croaker and mullet has a high quality shelf life of 5 and 7 days respectively in ideal ice stored conditions. Both the species have an acceptable shelf life of 13 days in ice. Total volatile base nitrogen and peroxide value showed an increase in both species during the ice storage, reaching the limit of acceptability which corresponded with that of sensory and K-value results. However, in the present study, these two biochemical indices can be considered as supporting the more reliable spoilage parameters viz., K-value and sensory evaluation. The sensory

evaluation together with K value estimation can be considered as effective tools for freshness quality evaluation in these species as compared to other spoilage indices.

Acknowledgments The authors are thankful to the Director, Central Institute of Fisheries Technology (ICAR), for according permission to present the paper. The technical assistance provided by the staff of Fish Processing Division of the Central Institute of Fisheries Technology is acknowledged.

References

1. Anonymous (2013) Estimated marine fish landings in India, CMFRI Annual Data, Central Marine Fisheries Research Institute, Cochin. www.cmfri.org.in. Accessed 04 May 2013
2. Anonymous (2012) Statistics of Marine Products, Marine Products Export Development Authority (MPEDA). Ministry of Commerce Government of India, Cochin, pp 33–68
3. Daun H (1993) Introduction. In: Charalambous (ed) Shelf life studies of foods and beverages—chemical, biological, physical and nutritional aspects. Elsevier, Amsterdam, pp 9–10
4. Gelman A, Pasteur R, Rrave M (1990) Quality changes and storage life of common carp (*Cyprinus carpio*) at various storage temperatures. J Sci Food Agri 52:231–247
5. Venugopal V (2006) Chapter 3 bulk handling and chilling. In: Low S (ed) Seafood processing: adding value through quick freezing, retortable packaging and cook chilling. CRC Press, Boca Raton, pp 61–95
6. Huss HH (1995) Quality and quality changes in fresh fish. In: Boerresen T, Dalgaard P, Gram L, Jensen B (eds) FAO fisheries technical paper No 348. FAO, Rome, p 203
7. Gopakumar K (2002) Text book of fish processing technology. DIPA, ICAR, New Delhi, p 43
8. AOAC (2000) Official methods of analysis, 17th edn. Association of Official Analytical Chemists, Washington, DC, p 1298
9. AOAC (1990) Official methods of analysis, 15th edn. Association of Official Analytical Chemists, Arlington
10. Conway EJ (1962) Determination of volatile amines, microdiffusion analysis and volumetric error, 5th edn. Parch Croskey and Sockwood & Son Limited, London
11. AOCS (1989) Official methods of recommended practices of American oil chemists society (AOCS). Champaign, Urbana
12. Ryder JM (1985) Determination of adenosine triphosphate and its breakdown products in fish muscle by high—performance liquid chromatography. J Agric Food Chem 33:678–680
13. Saito T, Arai K, Matsuyoshi M (1959) A new method for estimating the freshness of fish. Bull Jap Soc Sci Fish 24(9):749–750
14. Bremner HA, Olley J, Vail AMA (1987) Estimating time temperature effects by a rapid systematic sensory method. In: Kramer DE, Liston J (eds) Seafood quality determination. Elsevier, New York, pp 413–435
15. Amerine MA, Pangborn RM, Roessler EB (1965) Principles of sensory evaluation of food. In: Anson ML (ed) Food science and technology monographs. Academic Press, New York, pp 338–339
16. Simeonidou S, Govaris A, Vareltzis K (1998) Quality assessment of seven Mediterranean fish species during storage on ice. Food Res Int 30:479–484
17. Mohan CO, Ravishankar CN, Sreenivasa Gopal TK (2008) Effect of oxygen scavenger on the shelf life of catfish (*Pangasius sutchi*) steaks during chilled storage. J. Sci. Food Agri 88:442–448
18. Zang B, Deng S (2012) Quality assessment of *Scomber japonicus* during different temperature storage: Biochemical, textural and volatile flavor properties. International conference on artificial intelligence and soft computing. Lecture notes in information technology, Vol. 12: pp 301–307
19. Bandopadhyay JK, Chattopadhyay AK, Bhattacharya SK (1985) Studies on iced storage characteristics of commercially important freshwater fishes. In: Aditya SB (ed) Harvest and post-harvest technology of fish. Society of Fisheries Technologists, Cochin, pp 381–384
20. Joseph J, Perigreen PA, Surendran PK, Gopakumar K (1990) Iced storage characteristics of cultured major carps of India. I.I.F—I.I.R—Commission C2, Aberdeen, pp 117–121
21. Reza MS, Bapary MA, J Ahasan CT, Islam MN, Kamal M (2009) Shelf life of several marine fish species of Bangladesh during ice storage. Int J Food Sc Technol 44:1485–1494
22. Perigreen PA, Joseph J, Surendran PK, Gopakumar K (1987) Studies on iced storage of common murrel (*Channa striatus*). Fish Technol 24:99–102
23. Murata M, Sakaguchi M (1986) Storage of yellowtail (*Seriola quinquerqdiata*) white and dark muscles in ice: changes in content of adenine nucleotides and related compounds. J Food Sci 51:321–326
24. Connell JJ (1995) Control of fish quality, IV edn. Fishing News Books Ltd, Farnham, pp 159–160
25. Lakshmanan PT (2000) Fish spoilage and quality assessment. In: Mathew PT, Iyer TSG, Kandoran MK, Mary Thomas, Mathew PT (eds) Quality assurance in seafood processing. Society of Fisheries Technologists, Cochin, pp 26–40
26. Lopez-Caballero ME, Perez-Mateos M, Montero P, Borderias AJ (2000) Oyster preservation by high-pressure treatment. J Food Prot 63:196–201
27. Ababouch LH, Souibri L, Rhaliby K, Ouahdi O, Battal M, Busta FF (1996) Quality changes in sardines (*Sardina pilchardus*) stored in ice and at ambient temperature. Food Microb 13:123–132
28. Truelstrup L, Gill T, Huss H (1995) Effect of salt and storage temperature on chemical, microbiological activity on quality of cold-smoked salmon. Food Res Int 28(2):123–130
29. Aubourg SP, Victoria A, Javier P (2010) Lipid hydrolysis and oxidation in farmed gilthead seabream (*Sparus aurata*) slaughtered and chilled under different icing conditions. Int J Fat Oil 61(2):183–190
30. Yongsawatdigul J, Worratao A, Park JW (2002) Effect of endogenous transglutaminase on threadfin beam surimi gelation. J Food Sci 67:3258–3326
31. Ozogul Y, Ozogul F, Kuley E, Ozkutuk AS, Gokbulut C, Kose S (2006) Biochemical, sensory and microbiological attributes of wild turbot (*Scophthalmus maximus*), from the Black Sea, during chilled storage. Food Chem 99:752–758
32. Lakshmanan PT, Antony PD, Gopakumar K (1996) Nucleotide degradation and quality changes in mullet (*Liza corsula*) and Pearlspot (*Etroplus suratensis*) in ice and at ambient temperatures. Food Control 7(6):283–2777
33. Ehira S (1976) A biochemical study on the freshness of fish. Bull Tokai Reg Fish Res Lab 88:1–132
34. Ehira S, Uchiyama H (1986) Determination of fish freshness using K-value and comments on some other biochemical changes in relation to freshness. In: Kramer DE, Liston J (eds) Seafood quality determination. Elsevier, Amsterdam, pp 185–207
35. Branch AC, Vail AMA (1985) Freshness quality assessment for round fish. Bring fish inspection into computer age. Food Technol Aust 37(8):352–355
36. Jonsdottir S (1992) Quality index method and TQM system. In: Olafsson R, Ingthorsson AH (eds) Quality issues in the fish industry. The Research Liaison Office. University of Iceland, Reykjavik, pp 81–94
37. Martinsdottir E, Arnason A (1992) Redfish. Quality standards for fish: final report phase II. Nordic Industrial Fund, Reykjavik, pp 21–35

38. Nielsen J, Hansen TK, Jonsdottir S, Larson EP (1992) Development of methods for quality index of fresh fish. FAR Meeting, Noordwijkkerhort
39. Andrade A, Nunes ML, Batista I (1997) Freshness quality grading of small pelagic species by sensory analysis. In: Methods to determine the freshness of fish in research and industry. Proceedings of the final meeting of the concerted action "evaluation of fish freshness," AIR3CT94 2283 (FAIR Programme of the EU) International Institute of Refrigeration, Nantes Conference, Paris 12–14 November 1997, pp 333–338
40. Huidobro A, Pastor A, Tejada M (2000) Quality index method developed for raw gilthead seabream (*Sparus aurata*). J Food Sci 65(7):1202–1205
41. Martinsdottir E Siguroardottir H, Magnússon O (1998) Development and implementation of a computerized sensory system in the quality management of a shrimp factory. Presented at 28th Western European Fish Technologists' Association Conference. Tromso, Norway
42. Huss HH (1988) Fresh fish quality and quality changes. FAO Fisheries Series, Rome, p 27
43. Regenstein JM (1996) Assuring the freshness and quality of aquacultured fish. In: Froid (ed) Aquaculture refrigeration and aquaculture. FAO Fisheries & Aquaculture, Bordeaux, pp 343–362