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Development of Quality Index Method (QIM) Scheme for Farmed Tilapia Fillets and Its Application in Shelf Life Study

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The aim was to develop a Quality Index Method (QIM) scheme for fresh tilapia fillets and evaluate the scheme in a shelf life study. Farmed tilapia fillets were stored at 1 and −1°C for up to 20 days, and changes during storage were observed with sensory evaluation using the QIM scheme and General Descriptive Analysis (GDA), total viable counts (TVC), and hydrogen sulphide (H_2S) producing bacteria. The maximum shelf life of fillets stored at1 and −1°C was determined with GDA and microbial counts as 16 and 19 days, respectively. A high correlation of $R^2 = 0.943$ between Quality Index (QI) and storage time at 1C° was found to be 0.843 at −1°C. At the end of shelf life, the QI was 5.3 and 6.5 out of a maximum score of 15 for fillets stored at 1 and −1°C, respectively. Total viable counts and H_2S-producing bacteria showed an increasing trend during storage time for both groups. At the end of shelf life, TVC was log 7 cfu/g in the flesh of both groups, with H_2S producing bacteria constituting a higher proportion (log 6 cfu/g) of the total. The scheme was modified at the end of the study to better characterize deskinned farmed tilapia fillets.

Keywords: tilapia fillets, sensory evaluation, shelf life, Quality Index Method

INTRODUCTION

Tilapia (*Oreochromis niloticus*), also known as Nile tilapia, is a lean fish species of potential commercial value found in warm waters (Bolivar et al., 2004). It is a freshwater fish of the family Cichlidae, which is native to Africa and the Middle East. The increased production of this species as an aquaculture product has made it more available to consumers. An important component of the growing tilapia industry is the proliferation of product forms. Tilapia exports initially consisted of frozen fillets and whole fish, but lately fresh fillets have become more available in different sizes and packages (FAO, 2002). This is because higher prices can be obtained for fresh fillets compared to frozen (Watanabe et al., 2002).

Advances in methods of quality determination and possibilities of air transportation have further increased the availability of fresh fish, meeting the increased demand for high quality products.

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Loss of freshness and spoilage of fish are complicated processes, and various factors such as species and different storage conditions influence the spoilage pattern. It has been suggested that no single spoilage or freshness indicator for fish can be used, but rather a combination of selected indicators that represent the different changes occurring during spoilage (Huss, 1988; Olafsdóttir et al., 1997). Sensory assessment of the outer appearance, odor, and texture of raw fish and evaluation of cooked fish are the most convenient and successful methods for fish freshness determination (Olafsdóttir et al., 1997; Martinsdóttir et al., 2001).

Evaluation of fish freshness using the Quality Index Method (QIM) appears to be a very useful sensory method, as it fits well for use in quality control, is easy to use, gives valuable information about freshness, and is useful for training and monitoring of fish assessors (Martinsdóttir et al., 2001). The QIM is specific for each species; various QIM schemes have been developed for different fish, mainly whole—such as European cuttlefish (*Sepia officinalis*; Sykes et al., 2009), Arctic charr (*Salvelinus alpines*; Cyprian et al., 2008), Mediterranean hake (*Merluccius merluccius*; Baixas-Noguerras et al., 2003), farmed Atlantic salmon (*Salmo salar*; Sveinsdottir et al., 2003), and frozen hake (*M. capensis* and *M. paradoxus*; Herrero et al., 2003). QIM schemes have also been developed for other types of fish products, such as thawed cod fillets (Warm and Nielsen, 1998) and fresh cod (*Gadus morhua*) fillets (Bonilla et al., 2007), and similar schemes could be developed for fillets from other species. It is important to have information about the maximum shelf life of the product and thus the need to evaluate sensory attributes of cooked fillets, including spoilage attributes to estimate the maximum storage life—e.g., by using methods such as General Descriptive Analysis (GDA).

The aim of this study was to develop a QIM scheme for chilled tilapia fillets, define sensory vocabulary for cooked fillets, and correlate sensory methods to microbiological analysis (total viable counts [TVC] and hydrogen sulphide [H_2S] producing bacteria). In addition, the applicability of the developed QIM scheme to chilled and superchilled fillets was tested.

MATERIALS AND METHODS

Sample Preparation

The study was carried out at MATIS in Reykjavik, Iceland. Fish used was farmed tilapia (*Oreochromis niloticus*) transported by air from Canada, whole-gutted and iced in thermally insulated expanded polystyrene (EPS) boxes. Upon arrival at MATIS 2 days postharvest, fish measured 2°C contact temperature. Fish was filleted and divided into two sample groups after de-skinning: C (stored at ambient temperature of 1°C) and Sc (stored at −1°C) with temperature data loggers inside and outside the EPS boxes. Both groups were sampled simultaneously on days 0, 7, 14, and 20 for sensory evaluation and microbiological analysis. Every sampling day, fillets were taken randomly from each group (C and Sc): three fillets for QIM and six for GDA evaluations. Additionally, two fillets from each group were used for microbiological analysis.

Sensory Evaluation

Eight to 12 panelists, all employee of Matis ohf (Icelandic Food and Biotech), participated in the sensory evaluation of raw (QIM) and cooked (GDA) tilapia fillets. They had all been trained according to international standards (The International Organization for Standardization [ISO] 8586, 1993), including detection and recognition of tastes and odors, use of measurement scales, and in the development and use of descriptors. The members of the panel were familiar and experienced in using QIM and the GDA method for other fish species.

Sensory Evaluation of Raw Fillets with QIM Scheme

The panelists were trained in three sessions in evaluating changes in color, odor, appearance, and texture using a QIM scheme for fresh deskinned tilapia fillets developed during a preliminary study. During the training sessions, panelists were encouraged to register any additional sensory parameters (observations) not included in the QIM scheme which could be used to characterize changes in tilapia fillets with storage time. After the training sessions, the developed QIM scheme (Table 1) was used to evaluate the freshness of tilapia fillets in the shelf life study. On each evaluation day, three fillets per group were blind coded and placed randomly on a clean table. All observations of the fillets were conducted under standardized conditions following the general guidance for the design of test room and testing conditions described in ISO 8589 (1988).

Sensory Evaluation of Cooked Fillets with GDA

Before the shelf life studies, the panel was trained in three sessions during a preliminary study as reported with raw fish evaluation. The panel was trained in recognition of sensory characteristics of the samples and to describe the intensity of each attribute using an unstructured scale from 0 to 100% (Stone and Sidel, 1985). The sensory attributes described in Table 2 were used during the sensory evaluation of the cooked fillets. Fillet loins were cut into pieces of about 5–6 cm long and 2–3 cm wide. The pieces were placed in aluminum boxes coded randomly with three digit numbers and cooked in a preheated Convostar electric oven (Convotherm, Eglfing, Germany) with circulation air and steam at 95–100°C for 5 min. Each panelist evaluated duplicates of samples in a random order

TABLE 1
Quality Index Method scheme developed for de-skinned tilapia (*Oreochromis niloticus*) fillets

Quality parameter		*Description*	*Score*
Skin side	Color	Dark red, red brown	0
		Red brown	1
		Light brown	2
Flesh	Mucus	Transparent, thin, little	0
		Opaque, a little thicker	1
		Grayish, thick, clotted	2
	Color	Light, beige, bluish transparent	0
		A little darker, brownish or grayish	1
		Grayish and yellowish	2
	Texture	Firm, recovers quickly from pressure	0
		Rather soft recovers slowly from pressure	1
		Very soft doesn't recover from pressure	2
	Blood	Bright red or not present	0
		Dull red	1
		Shadowy brown	2
	Odor	Fresh, neutral, trace of grass odor	0
		Seaweed, marine, grass	1
		Sour milk, silage	2
	Gaping	Acetic, putrid	3
		No gaping	0
		Slight gaping, less than 25% of fillet	1
		Some gaping, 25–75 of fillet	2

Quality index (1–15).

TABLE 2
Sensory attributes developed for cooked tilapia (*Oreochromis niloticus*) fillets

Odor	*Flavor*	*Appearance*	*Texture*
Boiled potatoes	Arctic char	Color on top (light-dark)	Softness
Hot milk	Sweet	Underneath (brown-grey)	Juiciness
Moldy	Metallic	Black stripes in flesh	Fiber
Rancidity	Moldy		Flakes
	Sour		Sticky
	Pungent		
	Rancidity		
	Rotten		

in one session. A computerized system (FIZZ, Version 2.0, 1994-2000, Biosystemes, Couternon, France) was used for data recording.

Microbial Analysis

Two fillets of each group were analyzed separately on each day of sampling. The samples were minced, and 20 g was weighed into 180 g of Maximum Recovery Diluents (MRD, Oxoid, Hampshire, UK) and blended in a Stomacher® Lab Blender 400 (Seward, West Sussex, UK) for 1 min to obtain 1/10 dilution. Total viable psychrotrophic counts (TVC) and counts of H_2S-producing bacteria were evaluated on iron agar (IA) as described by Gram et al. (1987), with the exception that 1% NaCl was used instead of 0.5% with no overlay and spread plating was applied. Plates were incubated at 17°C for 4–5 days. Bacteria forming black colonies on IA produce H_2S from sodium thiosulphate and/or cysteine.

Data Analysis

The mean values of quality index (QI), GDA attributes scores, TVC, and counts of H_2S-producing bacteria were plotted separately against storage time using Microsoft Office Excel 2007 (Microsoft Corp., Redmond, WA, USA). GDA data were corrected for level effects (level effects caused by level differences between assessors and replicates were removed) by the method of Thybo and Martens (2000). Multivariate comparison of sensory attributes and samples were performed with Principal Component Analysis (PCA) on mean level corrected sensory attribute values using full cross validation. Multivariate Analysis was performed using the statistical program Unscrambler® (Version 8.0 CAMO, Trondheim, Norway). Analysis of variance (ANOVA) was carried out on the level corrected GDA data in the statistical program NCSS 2000 (NCSS, Kaysville, UT, USA). Duncan's multiple-comparison test was used for stepwise comparison at the 95% significance level.

RESULTS AND DISCUSSIONS

Temperature Changes

The average temperature in EPS boxes with whole gutted tilapia transported by air from Canada was 2°C upon arrival at the MATIS laboratory (2 days postharvest). Fish were kept in a cooling cabinet at 0°C for 13 h before filleting. During tilapia fillets storage, the average ambient temperatures of −1 and 1°C (outside the EPS boxes for sample) designed for superchilling and chilling storage resulted in fillet contact temperatures (inside EPS boxes) of 0.5 ± 0.5 and 2.0 ± 0.3°C for sample group Sc and C, respectively. The fillet contact temperature in the study redefined both storage conditions under conventional chilling, which according to Duun and Rustad (2007) may be defined as the process of cooling fish or fish products to a temperature approaching that of melting ice. On the other hand, superchilling may be defined as a process where the surrounding temperature is set below the initial freezing point of the product without freezing it (Ando et al., 2005). This was not the case with designated superchilling storage condition (Sc) reported in the current study. However, the difference of just 1.5°C between the groups led to a big difference in shelf life as discussed under evaluation methods.

Sensory Evaluation

Sensory Evaluation of Raw Fillets with QIM Scheme

The sensory parameters describing the different levels of freshness: color skin side; flesh mucus, color, texture, blood, odor, and gaping were well-utilized during the study, although in neither group was the maximum score reached at the end of storage time (Figure 1). This is in accordance with how the QIM scheme is constructed, where fish evaluated shortly after catch should be scored low and subsequently increase with storage time reaching close to maximum score at the end of shelf life (Martinsdóttir et al., 2001). However, flesh blood and gaping parameters were omitted from the scheme as they were difficult to evaluate and recorded minor changes with storage time (Figure 1). Their scores were removed or added to other parameters in the final QIM scheme developed toward the end of the study (Table 4). This is in agreement with Sveinsdottir et al. (2003) who reported removal from the scheme of parameters whose evaluation was destructive and difficult. The description of flesh color in the scheme was modified toward the end of study into two parameters: color loin and color belly flap to describe changes more precisely. In addition, changes in selection of words were made for color-related parameters to better describe the changes. Modifications were necessary toward the end of study to come up with an inclusive QIM scheme for farmed tilapia fillets. The maximum sum of points (QI) in the recommended scheme is 13 (Table 4).

The sum of individual parameter scores evaluated according to the QIM scheme was presented as QI based on average of three fillets per trial. The QI showed a linear relationship with the storage time (Figure 2) for both groups. A strong correlation of $R^2 = 0.943$ was found for fillets stored at 1°C ambient temperature (C). These results showed that attributes gradually deteriorated with time as it is assumed in the Quality Index Method that the scores for all quality parameters increase with storage time. The slope was steeper in the case of sample group C than Sc, indicating that fillets stored at 1°C deteriorated faster than storage at −1°C. Additionally, the linear relationship between the QI and storage time was not as strong ($R^2 = 0.849$), presumably due to higher fillet temperature at the beginning of storage compared to the ambient temperature. Due to individual variations present in samples of the same storage day (and conditions), three samples per group were used. According to the guidelines for freshness assessment of whole fish given by Martinsdóttir et al. (2001), a minimum of 3 (large fish) to 10 (small fish) random samples should be taken to cover the biological differences in spoilage rate of fish.

Sensory Evaluation of Cooked Fillets with GDA

Figure 3 shows how the two sample groups of tilapia fillets (ambient temperature 1 and −1°C, respectively) were described by the sensory attributes. A clear grouping was evidenced on each side of the PC1-axis, indicating that fresh samples were easily distinguished from samples of deteriorated quality. The odor and flavor sensory attributes of cooked tilapia (arctic charr, boiled potatoes, metallic, and sweet) detected at the beginning of storage on the left side of the loadings plot along the first principal component (PC1) were considered freshness attributes. Consequently, the sensory attributes detected closer to the end of storage (pungent, sour, and rancid) were considered spoilage

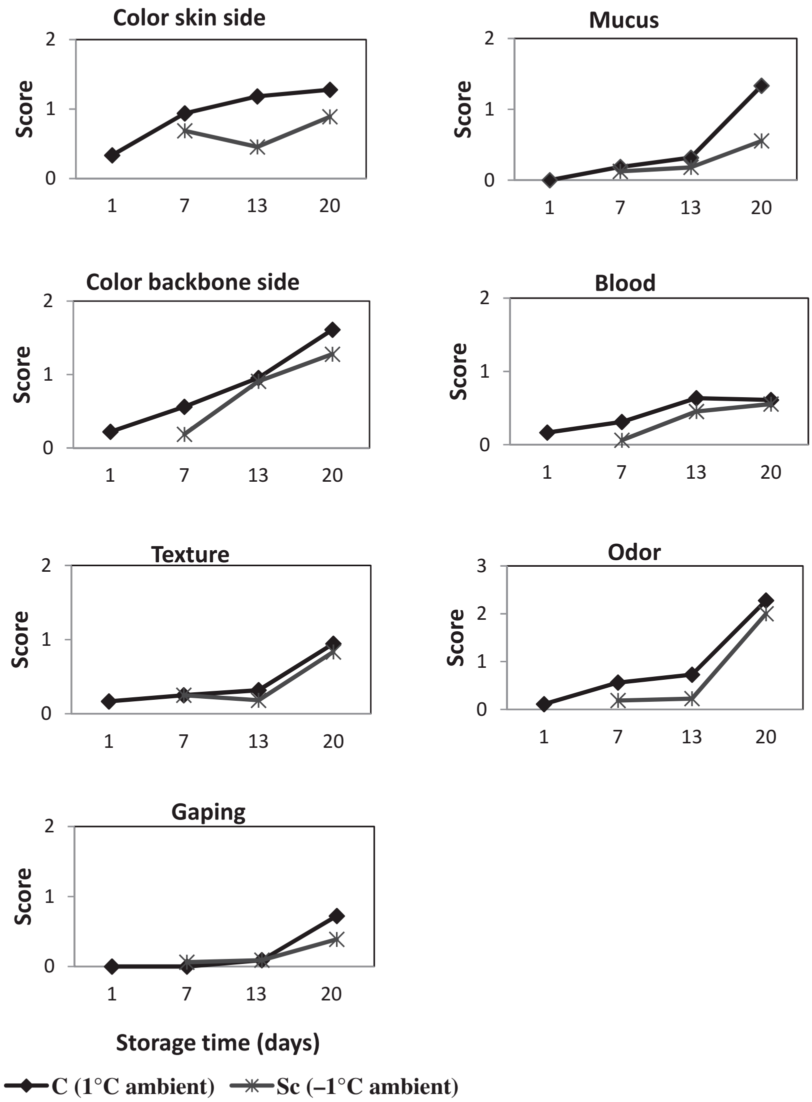

FIGURE 1 Average score for individual quality descriptors (attributes) evaluated with QIM scheme for de-skinned tilapia (*Oreochromis niloticus*) fillets ($N = 3$ per group) against storage days.

attributes. The samples varied mainly with regard to differences in odor and flavor attributes along the first principal component, explaining 79% of the variation between the samples. The main difference occurred with the storage time, as the sample groups are located to the left side at the beginning of storage but on the right side after longer storage. Samples also varied along the second principal component (PC2) especially with regard to differences in appearance and texture attributes, explaining 13% of the variation between the samples (Figure 3).

Additionally, the freshness odor attributes, such as arctic charr and boiled potatoes, were very characteristic at the beginning of storage time for both groups, recording scores of between 30 and 50 until 13 days (Figure 4 and Table 3). These attributes became less evident (score of 10 to

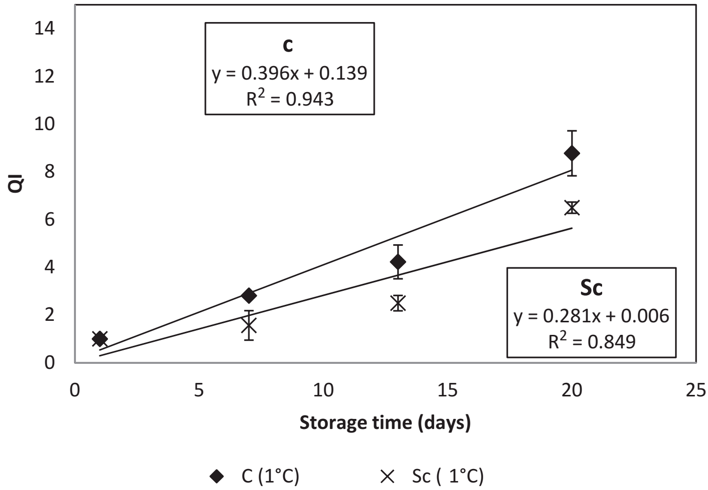

FIGURE 2 Quality index of de-skinned tilapia (*Oreochromis niloticus*) fillets. Averages (±*SD*) over each day analyzed ($N = 3$ per group) against storage days.

TABLE 3
Mean sensory scores of odor, flavor, and appearance/texture attributes of cooked tilapia (*Oreochromis niloticus*) fillets (average scores $N = 2$)

Group attributes	*Significance*	*D01C*	*D07C*	*D07Sc*	*D13C*	*D13Sc*	*D20C*	*D20Sc*
Odor								
Boiled potatoes		34	42	44	31	33	25	26
Hot milk		26	29	32	26	25	21	21
Arctic charr	***	31^{a}	33^{a}	34^{a}	28^{ab}	29^{ab}	14^{b}	13^{b}
Metallic		25	24	26	18	20	19	20
Sour		2^{b}	5^{b}	4^{b}	8^{bd}	5^{b}	28^{e}	15^{d}
Rancidity	***	2^{b}	5^{b}	4^{b}	7^{bd}	7^{bd}	32^{e}	16^{d}
Flavor								
Arctic charr		39	33	34	31	29	20	19
Sweet		37	29	30	28	31	22	20
Metallic		30	30	31	25	24	24	18
Sour	***	3^{a}	10^{a}	6^{a}	12^{ab}	11^{a}	41^{f}	26^{b}
Pungent	***	5	7	6	14	15	37^{a}	23^{b}
Rancidity	***	3	7	5	9	9	46^{a}	25^{b}
Appearance/Texture								
Color on top	***	32^{c}	41^{cb}	41^{cb}	57^{b}	50^{cb}	45^{cb}	44^{cb}
Color under		41	44	45	56	50	39	50
Black threads		21	18	20	24	23	22	19
Softness		69	68	65	64	64	71	65
Flakes	**	43^{b}	27^{a}	26^{a}	24^{a}	31^{ab}	26^{a}	26^{a}

C = stored at 1°C; Sc = stored at −1°C ambient temperature (1°C); D = storage days.
*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$ (significant difference in a sensory attribute between sample groups, different letters indicate significant different values between samples within a line).

30) toward the end of storage time, but similar in both groups. As with the odor attributes, flavor freshness attributes were prominent at the beginning of storage but decreased with storage time in both groups (Figure 5 and Table 3).

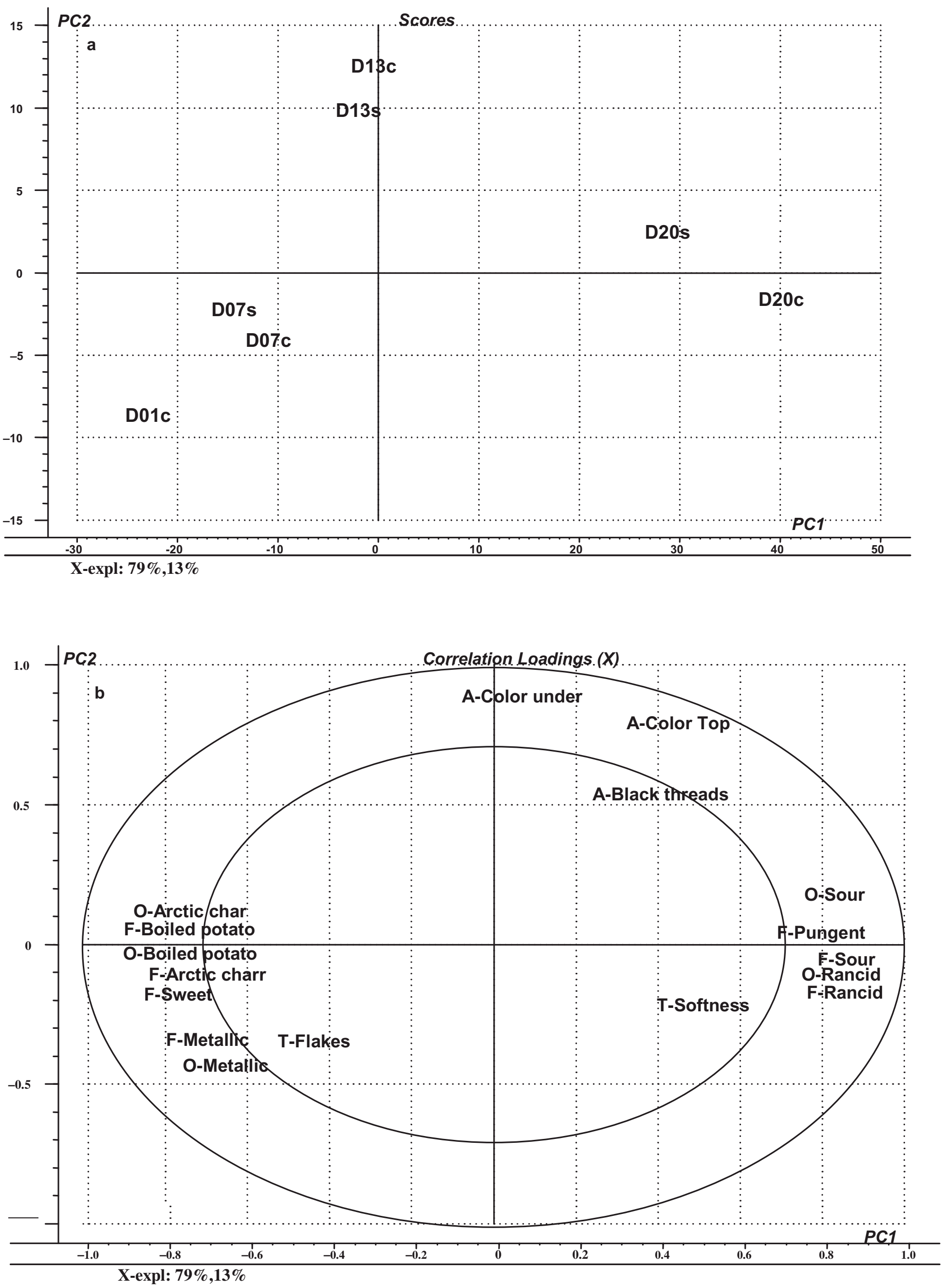

FIGURE 3 PCA describing sensory quality of cooked tilapia (*Oreochromis niloticus*) as evaluated by a trained sensory panel. Scores (a) and correlation loadings (b); PC1 (79%) versus PC2 (13%); D = days of storage; C = chilled (1°C); Sc = superchilled (−1°C); O = odor; F = flavor; T = texture; A = appearance.

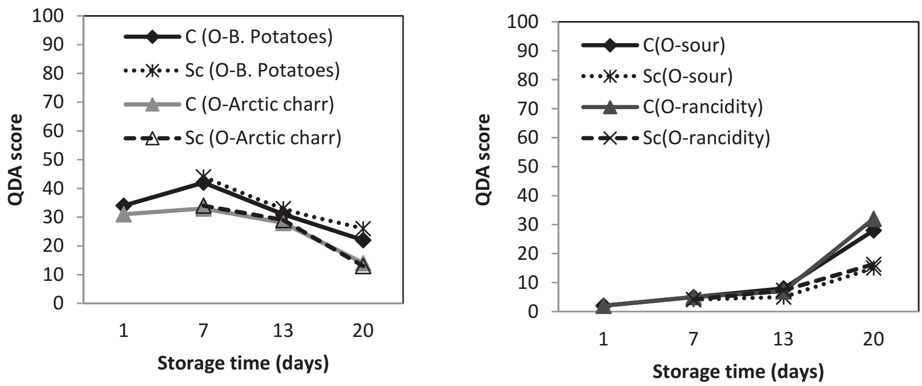

FIGURE 4 Changes in freshness (left) and spoilage (right) odor attributes of cooked tilapia (*Oreochromis niloticus*) fillets stored at 1°C (C) and −1°C (Sc) against storage days (average scores $N = 2$).

TABLE 4
A modified Quality Index Method scheme developed from preliminary scheme for de-skinned tilapia (*Oreochromis niloticus*) fillets

Quality parameter		*Description*	*Score*
Skin side	Color*	Dark red, red brown	0
		Red brown, lighter color	1
		Light brown	2
Flesh	Color, loin	Light, beige, trace of red or bluish	0
		A little darker color, a little brownish or grayish	1
		Grayish, brownish, yellowish	2
	Color, flap	Bluish, transparent	0
		Light, milky color	1
		Grayish or brownish	2
	Mucus	No mucus, mat texture	0
		A little shiny, trace of mucus	1
		Milky or greenish mucus	2
	Texture	Firm	0
		Rather soft	1
		Soft	2
	Odor	Fresh, neutral	0
		Seaweed, marine, grass	1
		Sour milk, silage	2
		Acetic, putrid	3

Quality index (0–13).
*Stripes at the middle of the loin.

The sensory attributes sour and rancid odor and flavor were considered spoilage attributes (Cyprian et al., 2008; Sveinsdottir et al., 2002). These attributes did not change significantly until after 13 days of storage for both groups, but progressed rapidly thereafter (Figure 5 and Table 3). End of shelf life is usually determined when spoilage-related sensory attributes become evident and most panelists detect them. The average GDA score of above 20 (on the scale 0 to 100) for these attributes (spoilage) indicates that the sample is approaching the end of shelf life. Based on this and using a GDA score of above 20 for spoilage attributes as the value which indicates the fish to be

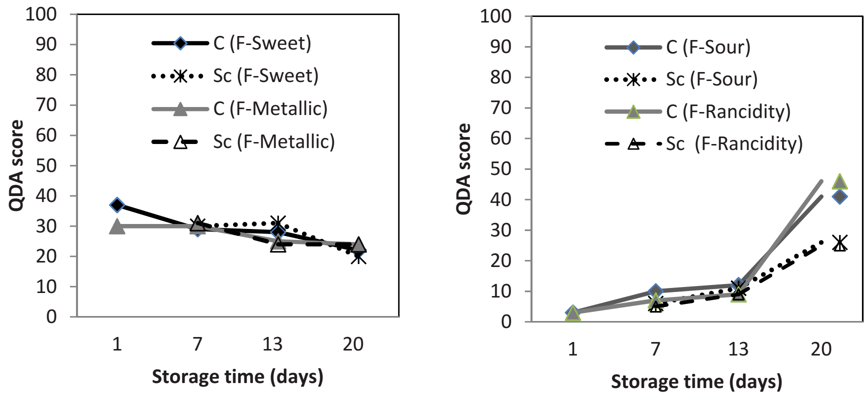

FIGURE 5 Changes in freshness (left) and spoilage (right) flavor attributes of cooked tilapia (*Oreochromis niloticus*) fillets stored at 1°C (C) and −1°C (Sc) against storage days (average scores $N = 2$).

unacceptable for human consumption, both groups were past shelf life on day 20. Sour and rancid flavor attributes were just within the unacceptable limits (20–30) for Sc. However, it was clear that sour and rancid flavor for C on day 20 was far above the limit and thus past shelf life. These limits have been used in determination of maximum shelf life of farmed arctic charr (Cyprian et al., 2008), cod fillets (Bonilla et al., 2007), desalted cod (Magnússon et al., 2006), and farmed Atlantic salmon (Sveinsdottir et al., 2002). Spoilage of chilled tilapia fillets during storage at 2.0 ± 0.3 and 0.5 ± 0.5°C (contact temperature) might have been due to combined effects of chemical and bacterial activity, as sour and rancid flavor were both evidenced during evaluation of cooked samples at the end of storage time. This observation is similar to earlier research (Cyprian et al., 2008) that reported both chemical and bacterial spoilage in temperature abuse prior to icing and iced arctic charr at the end of storage life.

Attributes describing appearance and texture, color underneath the fillets, black threads, and softness were not significantly different and showed no correlation with storage time (Table 3) and can be considered less important in characterizing cooked tilapia fillets. However, color on top and flakiness (flakes) attributes depicted particular trends with storage time. Scores for fillet color on top increased, whereas flakiness scores decreased with storage.

Microbial Counts

Changes in TVC and counts of H_2S-producing bacteria are shown in Figure 6. The results show low initial bacterial load at 1 day of storage and an increasing trend for the succeeding days in both groups. The low total counts reported at the beginning of storage time were due to the flesh of newly caught fish being sterile, since the immune system of the fish prevents the bacteria from growing (Cyprian et al., 2008). However, when the fish dies, the immune system collapses, and consequently during storage, bacteria invade the flesh (Sveinsdottir et al., 2002). Growth curves for TVC and counts of H_2S-producing bacteria had moderately similar shape, though the proportion of H_2S-producing bacteria to the TVC increased with storage time. At the end of shelf life estimated to be about 16 and 19 days for C (1°C ambient) and Sc (−1°C ambient), respectively, TVC could be averaged to log 7 cfu/g. The observed microbial counts are similar to counts reported in a previous study done by Reddy et al. (1995) of log 7 cfu/g at rejection time (13 days) for tilapia fillets packaged under 100% air and stored at a temperature of 4°C.

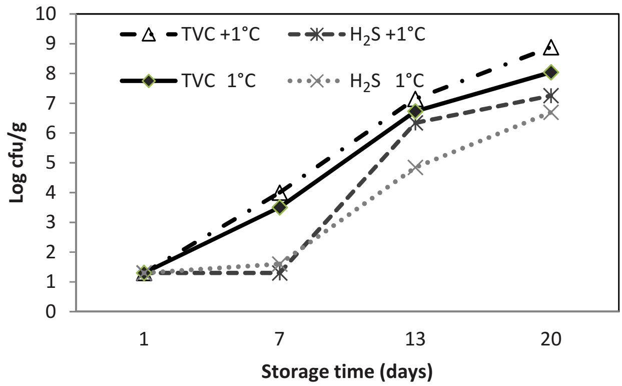

FIGURE 6 Total viable counts (TVC) and H_2S-producing bacteria on iron agar in tilapia (*Oreochromis niloticus*) fillets stored at 1°C (C) and −1°C (Sc) against storage days (average scores $N = 2$).

Shelf Life Estimation

The GDA method is useful in shelf life studies, as can be used to provide information about maximum shelf life. According to GDA, group Sc reached unacceptable sensory quality after around 18–20 days of storage, whereas C attained the limits at approximately 15–17 days of storage, but was beyond consumption limits at 18 days of storage. The findings are supported by results from microbiological analysis where H_2S-producing bacteria count of log 6 cfu/g was observed in both C and Sc groups on 19 and 16 days of storage, respectively. Similar counts of H_2S-producing bacteria were reported at rejection time of tilapia fillets stored at 4°C (Waliszewski and Avalos, 2001). The results from GDA and microbiological analysis indicated that the shelf life of sample groups Sc and C was 19 and 16 days, respectively. Using the linear relationship, the QI score was 5.3 and 6.5 for the fillets stored at 1 and −1°C, respectively, at the end of the estimated shelf life.

Tilapia fillets seem to have longer shelf life than fillets from most temperate species: cod fillets at 8 days in ice (Bonilla et al., 2007), vacuum-packed cod fillets at 9–10 days at 0°C (Gram et al., 1987), and salmon fillets at 6.5 days at 4°C (Rasmussen et al., 2002). Fish from warm waters kept under chilled conditions keep longer than fish from cold waters (Gram et al., 1990). This widely held view is apparently in relation to the relative proportions of psychrotrophic bacteria on fish from waters of different temperatures. Cold waters tend to favor proliferation of high numbers of psychrotrophs on fish, which in turn enhances spoilage at chilled condition and ultimately shortens the shelf life of fish (Karungi et al., 2004).

CONCLUSIONS

A QIM scheme for de-skinned tilapia fillets showing a linear increase with storage time was developed. Sensory evaluation of cooked tilapia fillets showed that minor changes occurred in sensory attributes at the beginning of storage time. Based on sensory evaluation and microbial counts, the maximum storage time of the tilapia fillets was 16 days for C group and 19 days for Sc group, filleted 2 days postharvest. Storage at 1 and −1°C ambient temperature resulted in a 2 and 0.5°C fillet contact temperature inside EPS boxes in both groups, respectively. The 1.5°C difference in storage temperature led to 3 days difference in shelf life between the groups, despite both falling under conventional chilling.

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