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Modification of Quality Index Method Scheme for Nile Tilapia Fillets and Application in Quality Assessment of the Product Stored at Low Temperatures

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ABSTRACT

This work describes the modification of quality index method (QIM) scheme for de-skinned Nile tilapia (*Oreochromis niloticus*) fillets, firstly developed for the farmed product in Iceland, and its application in sensory evaluation of the product originated from Vietnam during low temperature storage. Three batches of tilapia fillets were used during modification of the QIM scheme. During the storage study, five stable storage temperature regimes were set at 1, 4, 9, 15 and 19 ± 1°C, three batches of fish were assessed for every temperature. The modified QIM schemed consisted of 6 attributes, including Colour and Mucus of the skin side, Odour, Colour, Texture and Stickiness of the flesh (fillet side), with the total score or quality index (QI) of 13. Changes of some attributes and describing words from the previous scheme were made, due to the fish origin differences, to describe the sensory changes better. All the QI at different temperatures were in a well positive linear correlation with storage time. Furthermore, QI increased faster at higher storage temperatures. Parallel sensory evaluation by other methods like quantitative descriptive analysis (QDA) and Torry gave less clear sample differentiation throughout storage hours compared to QIM results. These supported the advantage of QIM over other methods and the application of QIM during cold chain management.

Keywords: Chilled product, tilapia, quality index method, sensory.

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INTRODUCTION

Sensory quality index method (QIM), originally developed by the Tasmanian Food Research Unit in Australia (Bremner, 1985) and further developed by European fisheries research institutions, was often used for freshness evaluation of raw fish materials. A QIM scheme consists of a number of attributes with demerit score range from 0 for very fresh fish to 1, 2, or 3 as the fish deteriorates (Martinsdóttir et al., 2001). The total score of all attributes called quality index (QI) is linearly correlated with time at a certain storage condition, thus useful for estimating the shelf life of the product. The method is considered unique and reliable as QIM scheme has been developed for each fish species and/or product.

Tilapia, one of the most popular aquaculture species (Cai, 2017), is widely promoted as a healthy protein source thanks to its high-quality protein and low-fat content. World production of tilapia was about 5.67 million tons from aquaculture and 0.7 tons from capture in 2015 (FAO, 2017); and reached over 6 million tons in 2016 with top producers including China, Indonesia, Egypt, Brazil, Bangladesh, the Philippines, Thailand, and Vietnam (VASEP, 2017). Nile tilapia production alone was more than 3.67 tons in 2014 (FAO FishStat, 2017), Tilapia fillets have gained popularity among consumers in the Europe, the United States, and elsewhere. The most popular form of this product is frozen, which may be thawed and purchased as chilled/fresh fish at retailers at later stage. Some significant part of tilapia fillets are also processed and purchased as fresh (Fitzsimmons, 2010).

Temperature and time of storage are main factors leading to the quality changes of seafood (Kreyenschmidt et al., 2010; Mai et al., 2011). A simple method for evaluating the freshness of seafood in general, and tilapia fillets stored at low temperatures in particular is therefore important. QIM scheme for fresh Nile tilapia fillets was first developed by Cyprian et al. (2013) based on fish farmed in "warmed water" recirculation aquaculture system in Iceland. However, our pre-observations on the sensory changes of similar product farmed in Vietnam showed some differences from the description of certain attributes, thus the scheme needs to be modified for the product originated from other climatic regions such as Vietnam.

The aim of this work was to modify the original QIM scheme of Cyprian et al. (2013), and apply the modified one to evaluate the sensory/freshness changes of the product during low temperature storage.

MATERIALS AND METHODS

Materials and Storage Design

De-skinned farmed Nile tilapia (*Oreochromis niloticus*) fillets of size 120-170 g/fillet were bought in individual quick frozen form from a processing company in An Giang province, Vietnam. Frozen fish fillets on the day of processing was packed in 30-kg expanded polystyrene (EPS) boxes with gel mats on top and cover with tight lids. Boxes were then transported by car to the laboratories in Nha Trang city within 16 h. On arrival at the laboratories, fillets were repacked into polyamide (PA) packs (2 fillets/pack) and stored at -18 ± 2°C for further experiments.

Before each trial, fish in PA packs were thawed overnight (for about 8 hours) in a refrigerator at 6-8°C. Fillets were then put on EPS trays (2 fillets/tray), covered with thin polyethylene (PE) film, and stored in a refrigerator with controlled temperature for the study.

Three batches of tilapia fillets were used during modification of the QIM scheme. During the storage study, five stable storage temperature regimes were set at 1, 4, 9, 15 and 19 ± 1°C, three batches of fish were assessed for every temperature. Day 0 was the first day of storage at certain temperature regime. The temperatures selected for this study were based on the temperatures being practiced as seafood and meat storage temperatures at retails (1, 4 ± 1°C) and at household refrigerators (4, 9 ± 1°C), or abused during cabinet opening for loading/unloading, during purchasing and transportation from supermarkets to home (9, 15, 19 ± 1°C); Also, these temperatures have been used for product shelf life modelling (Bruckner et al., 2013).

Loggers of EC850A type (MicroLogPRO II, Israel) were used to monitor the temperatures of the refrigerator. Loggers DS1922L-F5 iButton® (Maxim Integrated Products, Inc., CA) were put on tray surfaces (top and bottom), and inside the trays in direct contact with the fish recording temperature at 10-min intervals.

Sensory Evaluation by QIM

Sensory evaluation was carried out by 3 panellists familiar with QIM, selected from the staffs of the Faculty of Food Technology.

The original QIM scheme (Cyprian et al., 2013) included 6 attributes, namely Skin side Colour (lateral stripes at the middle of the loin), Flesh Colour-loin, Flesh Colour-flap, Flesh Mucus, Flesh Texture, and Flesh Odour. The quality index was within the range of 0-13.

During the modification step, panellists were asked to use the original QIM scheme to score the freshness of the fish fillets from 3 batches of different storage days at 1 ± 1°C. The evaluation was conducted in 3 sessions, with fish of 0-15 days of storage, give comments on the scheme, and note down other/undescribed sensory attributes/changes of the fillets. QIM scheme was then modified by removing those attributes and describing words, which were destructive and difficult to evaluate and recorded minor changes over storage time (Odoli, 2008; Sveinsdottir et al., 2003). More suitable parameters and describing words were added to the new scheme to better illustrate the quality changes of fish fillets with time.

During the storage study at five stable temperatures regimes (1, 4, 9, 15 and 19 ± 1°C), the modified QIM scheme was applied.

Two fillets of each batch were used at each evaluation. Fillets were coded with 3-digit random numbers.

Sensory Evaluation by QDA and Torry

Quantitative descriptive analysis (QDA) and Torry methods were used in parallel to assess the freshness of fish fillets stored at 1 and 4 ± 1°C for comparison.

Sensory vocabulary for cooked tilapia (QDA) developed by Cyprian et al. (2013) was modified. The new scheme consisted of 7 odour attributes (Boiled potatoes, Fishy upon cooling, Mud, Ammonia, Mouldy, Rancid, and Putrid), 2 appearance descriptors (Colour: Light-Dark, and Surface: Smooth-Rough), 6 texture attributes (Flake, Softness, Fibre, Mushy, Chewy, Juicy), and 5 flavour parameters (Sweet, Fatty, Sour, Rancid, and Rotten).

Torry scheme for medium fat fish, developed by Shewan et al. (1953) and modified by former Icelandic Fisheries Laboratories, was applied for testing cooked samples as well. Fish with Torry score under 5.5 was considered unfit for human consumption.

The panel included 7 assessors, selected and trained according to ISO 8586: 2012. During the storage study, at each session judges evaluated 4 samples of 2 different storage time. Samples were taken at 0, 72, 144, 192, 216, 240, and 264 h of storage at 1 ± 1°C; and at 0, 48, 96, 120, 144, 168, and 192 h of storage at 4 ± 1°C.

Fillets were trimmed from belly and tail parts, cut into pieces of about 2-2.5 cm long and 2-3 cm wide, placed in coded aluminium boxes (1 piece per box), covered with aluminium foil lids, and cooked by steam at 95-100 °C for 10 minutes, and finally served to the panel.

Statistical Analysis

Microsoft Excel 2010 was used to calculate means and standard deviations and to build charts. Analysis of variance (ANOVA) with Tukey's test were conducted in SPSS 17.0 software to compare means at a significance level of 0.05.

RESULTS AND DISCUSSION

Modification of QIM scheme

The modified QIM schemed consisted of 6 attributes, including Colour and Mucus of the skin side, Odour, Colour, Texture and Stickiness of the flesh (fillet side), with the total score or quality index (QI) of 13, as shown in Table 1.

During the QIM scheme modification, it was observed that the skin side colour of tilapia fillets were different from those described by Cyprian et al. (2013), e.g. fresh fillets had pink colour instead of dark red or red brown. Furthermore, in this study mucus on skin side changed remarkably with time, while the change of flesh mucus could not been clearly observed as indicated by Cyprian et al. (2013), which might be due to the fact that our fillets were packed skin side down in direct contact with the tray surface. The two attributes Flesh Colour-loin and Flesh Colour-flap from the original scheme were combined into the parameter Flesh Colour. Besides, the stickiness of the flesh when touching also changed with time, thus the attribute Stickiness was added to the new scheme. Differences in sensory pattern changes of tilapia fillets between this study and Cyprian et al. (2013) might be due to fish origin (Vietnam versus Iceland) and farming conditions (non-recirculation versus recirculation aquaculture systems). It is a common practice to remove unchangeable or difficultly recordable attributes from a QIM scheme (Cyprian et al., 2013; Sveinsdottir et al., 2003) to improve its applicability.

Freshness Evaluation of Tilapia Fillets using the Modified QIM Scheme

Quality index progress of deskinned of tilapia fillets stored at 1, 4, 9, 15, and 19 ± 1°C was illustrated in Figure 1. All the QI at the five temperature regimes were in a well positive linear correlation with storage time (R^2 = 0.83, 0.95, 0.98, 0.96, and 0.98 for the storage at 1, 4, 9, 15, and 19 ± 1°C, respectively). Furthermore, QI increased faster at

Table 1
Modified QIM scheme for chilled stored deskinned tilapia fillets

Quality parameter		Description	*Score*
Skin side	Colour	Pink, bright, lateral stripes reddish	0
		Pinkish, somewhat bright, sparse visible black thread, lateral stripes pale red with blue spots	1
		Bluish, greyish, or brownish, more visible black thread, lateral stripes brownish surrounded by yellow colour or covered by a thin opaque white film	2
	Mucus	Little or almost no mucus	0
		Thin opaque mucus	1
		Thick dry mucus	2
		Thick, dry, and clotted mucus	3
Fillet side/ Flesh	Odour	Fresh, light seaweed and/or grass smell	0
		Light marine, light alcohol	1
		Sour	2
		Acetic, putrid	3
	Colour	Pink, homogenous, bright/shiny	0
		Pinkish, not so homogenous, bluish around the longitudinal stripes at the middle of the loin	1
		Greyish, and/or yellowish, inhomogeneous, pale, sparse visible black thread, longitudinal stripes pale red to brownish, belly and tail parts turn yellow, blue-yellow, dark	2

Table 1 (*Continued*)

Quality Parameter	Description	Score
Texture	Firm	0
	Rather soft	1
	Soft	2
Stickiness	No flesh scraps attached to hands (after touching the fillet)	0
	Some or a lot of flesh scraps attached to hands (after touching the fillet)	1
	Quality index (QI) (0-13)	

higher temperatures. This is in accordance with the QIM development procedure, which is to make the QI linearly correlated with storage time (Cyprian et al., 2008; Sykes et al., 2009; Sveinsdottir et al., 2003).

Significant growth ($p < 0.05$) of QI was observed after 192 h at 1 ± 1°C, 144 h at 4 ± 1°C, 48 h at 9 ± 1°C, 63 h at 15 ± 1°C, and 44 h at 19 ± 1 °C (Figure 1). At the end of the shelf life, QI is normally around 75% of the maximal total QI (Sykes et al., 2009; Mai, 2014; Mai & Huynh, 2017). In this study, based on the time of fish rejection determined by the total viable count (TVC) level of 10^6 colony forming unit (CFU) per g (Decision 46-2007/QD-BYT, 2007), shelf life of tilapia fillets stored at 1, 4, 9, 15, and 19 ± 1°C were below 144, 48, 24, 24, and 20 h, respectively, when the TVC were 1.10 x 10^7, 2.43 x 10^6, 1.17 x 10^6, 1.83 x 10^7, and 1.28 x 10^8 CFU/g, accordingly. The QI after 144 h at 1 ± 1°C was as high as 4, accounting for only 30.8% of the maximal QI. The highest QI at 4 ± 1°C after 48 h, 9 ± 1°C after 24 h, 15 ± 1°C after 24 h, and 19 ± 1°C after 20 h were 5.9 (45.4%), 1.5 (11.5%), 1.8 (13.8%), and 5.2 (40.0%), respectively. The lower percentage of QI at the end of the product shelf life in this study compared to others, e.g. the case of *Pangasius* fillets at similar storage temperatures in a study of Mai and Huynh (2017), might be contributed by high initial TVC of tilapia fillets in this research (5.29 ± 3.87.10^5 CFU/g (data not shown), closed to the acceptable limit of 10^6 CFU/g). This revealed the importance of good hygiene practices to keep microbial counts as low as possible, in order to maintain the quality and prolong the shelf life of aquatic products.

Freshness Evaluation of Tilapia Using QDA and Torry Scheme

Results of assessment of cooked samples prepared from tilapia fillets stored at 1 and 4 ± 1°C by QDA are shown in Table 2. At 1 ± 1°C, only 3 out of 20 QDA attributes were detected with significant differences ($p < 0.05$) between storage hours, however, no correlation change with time was observed. At 4 ± 1°C, only 1 descriptor (Flavour Sweet) decreased significantly ($p < 0.05$) after 194 h. In addition, there was no high

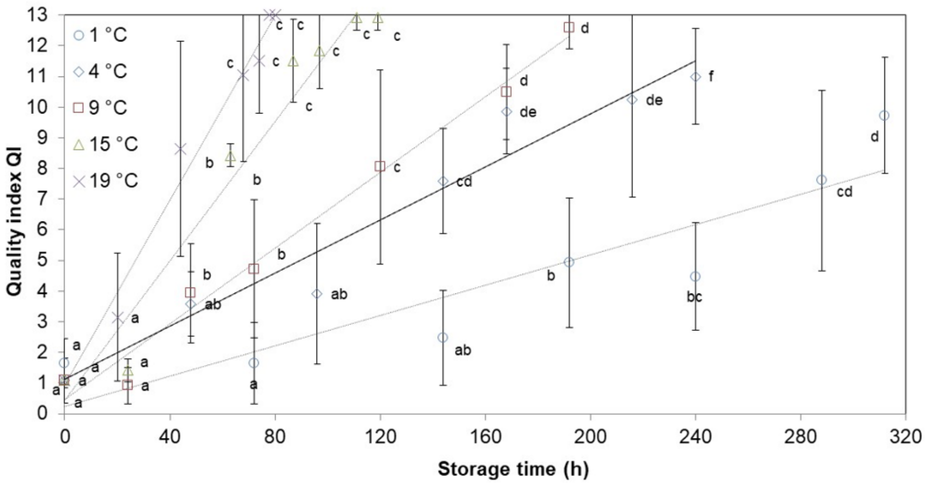

Figure 1. Changes of quality index (QI) of tilapia fillets stored at 1, 4, 9, 15, and 19 ± 1 °C over storage time**.** Different letters within the same storage temperature indicate significant differences ($p < 0.05$) in Torry scores between storage hours

enough score (≥ 20 on the scale 0-100) of bad attributes (e.g. Odour Mouldy, Rancid, or Putrid; Flavour Sour, Rancid or Rotten) to signal the rejection point of the product at both studied temperature regimes during the storage time. Rancid, putrid/rotten/spoilage and mouldy/musty odour and flavour are considered spoilage attributes of chilled-stored fish (Cyprian et al., 2008; Mai, 2013; Mai, 2014; Sveinsdóttir et al., 2002). The average score of above 20 for these negative parameters has been applied to determine the end of chilled seafood shelf life (Bonilla et al., 2007; Cyprian et al., 2008; Cyprian et al., 2013; Mai, 2013; Mai, 2014; Magnusson et al., 2006; Sveinsdóttir et al., 2002).

Linear correlation between Torry score and storage time was observed for both temperature regime 1 and 4 ± 1°C (Figure 2), which is in accordance with the characteristics of Torry score of other fresh fish products (Martinsdóttir et al., 2001). At storage temperature 1 ± 1°C, there was no difference ($p > 0.05$) in Torry scores during storage hours from 0 to 264 (Figure 2). The score after 264 h was 7 ± 1.2, i.e. higher than the acceptable limit of 5.5 (Mai et al., 2011), while the TVC exceeded the allowable limit of 6 log CFU/g (Decision 46-2007/QD-BYT, 2007) after 144 h at 1 ± 1°C. At storage temperature 4 ± 1°C, significant drop ($p < 0.05$) of Torry score was observed after 144 h (Figure 2), when the score reached 6.6 ± 0.9 (> 5.5). Meanwhile TVC was higher than the allowable limit just after 48 h at 4 ± 1°C.

These above show that QIM was more sensitive than QDA and Torry methods in detecting the sensory changes of tilapia fillets stored at low temperatures. Similar findings were reported for cobia portion sensory evaluation (Mai, 2014), where QIM showed more advantageous compared to Torry method.

Results from this study also support those of Mai and Huynh (2017) that freshness and remaining shelf life of seafood should be judged based on the worst quality indicator, the one that exceed its acceptable limit the soonest/earliest during storage.

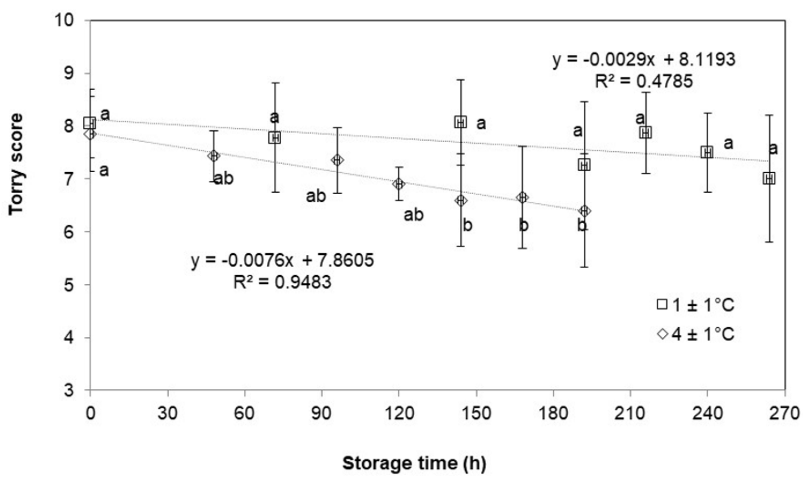

Figure 2. Changes of Torry scores of tilapia fillets stored at 1 and 4 ± 1°C over storage time. Different letters within the same storage temperature indicate significant differences ($p < 0.05$) in Torry scores between storage hours

Table 2

QDA attributes' scores of tilapia fillets stored at 1 and 4 ± 1ºC

	Storage time (h) at 1°C						
QDA attribute	*0*	*72*	*144*	*192*	*216*	*240*	*264*
O_Boiled potatoes	45.73^{a}	44.60^{a}	51.07^{a}	56.40^{a}	54.07^{a}	45.07^{a}	59.67^{a}
O_Fishy	20.40^{a}	24.53^{a}	25.33^{a}	17.33^{a}	24.53^{a}	23.40^{a}	17.47^{a}
O_Mud	15.87^{a}	14.20^{a}	10.20^{a}	11.67^{a}	11.67^{a}	11.33^{a}	12.33^{a}
O_Ammonia	7.73^{a}	5.27^{a}	4.87^{a}	9.94^{a}	7.93^{a}	10.73^{a}	14.33^{a}
O_Mouldy	1.73^{a}	3.60^{a}	3.07^{a}	2.53^{a}	4.07^{a}	3.53^{a}	3.60^{a}
O_Rancid	0.60^{a}	1.27^{a}	0.73^{a}	1.20^{a}	1.73^{a}	1.33^{a}	2.07^{a}
O_Putrid	0.93^{a}	1.33^{a}	1.40^{a}	3.93^{a}	3.20^{a}	2.80^{a}	6.13^{a}

Table 2 *(Continued)*

QDA attribute	Storage time (h) at 1°C						
	0	72	144	192	216	240	264
A_Light-Dark	*52.67^{a}*	47.34^{ab}	*25.60^{b}*	50.47^{ab}	44.80^{ab}	39.47^{ab}	51.73^{ab}
A_Smooth-Rough	37.67^{ab}	*47.93^{a}*	*20.93^{b}*	43.27^{ab}	26.13^{ab}	33.47^{ab}	33.27^{ab}
T_Flake	35.40^{a}	38.33^{a}	30.20^{a}	37.20^{a}	37.40^{a}	33.67^{a}	37.33^{a}
T_Softness	48.00^{a}	51.60^{a}	38.00^{a}	52.13^{a}	44.47^{a}	48.27^{a}	50.13^{a}
T_Fibre	41.20^{ab}	45.33^{ab}	*28.60^{a}*	*50.73^{b}*	44.27^{ab}	42.13^{ab}	*50.67^{b}*
T_Mushy	29.07^{a}	32.47^{a}	27.53^{a}	35.27^{a}	38.20^{a}	33.00^{a}	33.93^{a}
T_Chewy	40.60^{a}	54.80^{a}	55.53^{a}	45.33^{a}	54.47^{a}	46.60^{a}	43.80^{a}
T_Juicy	31.13^{a}	33.00^{a}	44.67^{a}	36.60^{a}	38.07^{a}	42.20^{a}	34.67^{a}
F_Sweet	48.67^{a}	43.87^{a}	39.00^{a}	29.07^{a}	32.20^{a}	38.53^{a}	26.00^{a}
F_Fatty	9.27^{a}	10.27^{a}	13.27^{a}	4.60^{a}	12.87^{a}	9.07^{a}	4.73^{a}
F_Sour	3.07^{a}	1.20^{a}	2.53^{a}	7.93^{a}	4.47^{a}	3.80^{a}	4.34^{a}
F_Rancid	0.53^{a}	1.47^{a}	0.00^{a}	0.47^{a}	0.07^{a}	0.67^{a}	0.53^{a}
F_Rotten	0.07^{a}	0.07^{a}	0.00^{a}	5.47^{a}	0.00^{a}	0.33^{a}	0.40^{a}
	Storage time (h) at 4°C						
	0	48	96	120	144	168	192
O_Boiled potatoes	46.67^{a}	51.54^{a}	49.93^{a}	47.40^{a}	44.53^{a}	49.00^{a}	43.73^{a}
O_Fishy	19.53^{a}	18.27^{a}	19.53^{a}	15.87^{a}	15.93^{a}	22.40^{a}	14.53^{a}
O_Mud	7.73^{a}	11.20^{a}	9.67^{a}	8.27^{a}	10.20^{a}	6.13^{a}	12.33^{a}
O_Ammonia	11.67^{a}	14.60^{a}	13.93^{a}	11.40^{a}	15.07^{a}	8.93^{a}	11.73^{a}
O_Mouldy	3.53^{a}	3.40^{a}	8.00^{a}	5.20^{a}	5.80^{a}	2.93^{a}	4.87^{a}
O_Rancid	3.27^{a}	2.93^{a}	7.87^{a}	5.73^{a}	4.47^{a}	2.33^{a}	7.33^{a}
O_Putrid	6.00^{a}	4.73^{a}	5.27^{a}	5.93^{a}	5.27^{a}	6.87^{a}	4.73^{a}
A_Light-Dark	53.27^{a}	47.87^{a}	54.40^{a}	39.53^{a}	43.27^{a}	44.53^{a}	47.40^{a}
A_Smooth-Rough	32.07^{a}	39.73^{a}	42.00^{a}	36.93^{a}	42.40^{a}	35.87^{a}	36.93^{a}
T_Flake	41.20^{a}	44.20^{a}	45.27^{a}	38.54^{a}	50.33^{a}	50.53^{a}	56.13^{a}
T_Softness	32.93^{a}	41.13^{a}	40.80^{a}	41.27^{a}	47.80^{a}	51.67^{a}	46.20^{a}
T_Fibre	37.40^{a}	44.13^{a}	43.67^{a}	48.73^{a}	50.40^{a}	52.07^{a}	43.93^{a}
T_Mushy	35.53^{a}	38.07^{a}	33.40^{a}	37.60^{a}	44.00^{a}	45.13^{a}	41.33^{a}
T_Chewy	53.33^{a}	43.40^{a}	43.33^{a}	46.73^{a}	39.73^{a}	47.60^{a}	38.07^{a}
T_Juicy	47.20^{a}	39.20^{a}	40.07^{a}	29.67	35.53^{a}	30.33^{a}	30.47^{a}
F_Sweet	*44.20^{a}*	39.60^{ab}	37.94^{ab}	25.67^{ab}	35.87^{ab}	27.47^{ab}	*15.33^{b}*
F_Fatty	8.67^{a}	5.80^{a}	10.34^{a}	5.47^{a}	4.53^{a}	10.53^{a}	2.13^{a}
F_Sour	1.13^{a}	3.67^{a}	3.20^{a}	1.87^{a}	4.20^{a}	4.27^{a}	1.53^{a}
F_Rancid	0.00^{a}	0.33^{a}	3.27^{a}	0.60^{a}	0.53^{a}	2.40^{a}	1.73^{a}
F_Rotten	0.00^{a}	0.13^{a}	2.67^{a}	0.33^{a}	0.27^{a}	0.80^{a}	0.60^{a}

*Values followed by the different letters (a, b) within the same row are significantly different from each other ($p < 0.05$). Capitalized letter O denotes for Odour, A for Appearance, T for Texture, and F for Flavour.

CONCLUSIONS

All the QI at different stable temperatures were linearly correlated with storage time, and QI increased faster at higher temperatures. Quality index method showed to be more sensitive than QDA and Torry in detecting the quality changes of fish over time, which supported the advantage of QIM compared to other methods and the application of QIM during cold chain management.

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