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Sensory Changes of Chill-stored Black Tiger Shrimp as Evaluated by Different Methods

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Abstract:
This study was to assess the sensory quality changes of refrigerated black tiger shrimp at 1 ± 1 ℃, using different methods, such as quality index method (QIM), quantitative descriptive analysis (QDA), and Torry scheme, in order to find out a convenient and reliable mean to quickly determine the product quality and remaining shelf-life. Quality index grew linearly with time, while Torry score linearly decreased. After 8-10 days of storage, black spots on shrimp were clearly observed by both QIM and QDA, while significantly odour changes ($p < 0.05$) were found only by QIM. QDA attributes grouped into positive and negative parts. Some negative attributes such as black spots and mushy texture exceeded the score of 20 after 9 days, which was determined as the shrimp maximum shelf-life. All the three methods detected the spoilage around 8-10 days. QIM showed to be the most simple and convenient method to quickly assess the quality and estimate the shelf-life of the product.

Keywords: *black tiger shrimp, sensory, shelf-life, quality index method, quantitative descriptive analysis, Torry scheme*

1. Introduction

Black tiger shrimp *(Penaeus monodon)* is one of the most valuable aquatic products, which are traded around the globe. The total world production of this product in 2014 was 634,521 tons and major producers are India and South East Asian countries, such as Thailand, Viet Nam, Indonesia, the Philippines, Malaysia and Myanmar (FAO, 2015). In Vietnam, the export value of black tiger shrimp was above 930 million USD in 2016, accounting for 13.2% of the total seafood export value (VASEP, 2017).

Shrimp is perishable and subjected to lose its quality over storage time even at chill condition. Therefore, it is important to monitor the quality changes of shrimp during storage with convenient methods to enable its freshness and shelf-life determination. Sensory assessment shows to be the most common and simple method to evaluate the quality of aquatic products. Among sensory methods, quality index method (QIM), firstly developed by the Tasmanian Food Research Unit in Australia (Bremner, 1985), then by European fisheries research institutions and other institutions around the world, has been considered as a fast and reliable tool to check the quality of raw seafood. Each QIM scheme is built for a specific species and product type; therefore, it is unique for the product. QIM scheme consists of a range of organoleptic attributes, characterizing the quality changes with increasing demerit score from 0 to 3, sum of which gives a total quality index (QI) (E. Martinsdóttir, Sveinsdóttir, Luten, Schelvis-Smit, & . 2001). QI, around 0 for newly harvested seafood and rising as the product become less fresh, is linearly correlation with storage time, which made QIM capable of predicting the product shelf-life (E. Martinsdóttir et al., 2001). QIM has been developed for various products, such as fresh cod (*Gadus morhua*) fillets (Bonilla, Sveinsdottir, & Martinsdottir, 2007), Acoupa weakfish (*Cynoscion acoupa*) (dos Santos, Kushida, Viegas, & Lapa-Guimarães, 2014), chill-stored farmed cobia (*Rachycentron canadum*) slices (T. T. N. Mai, 2013), farmed Atlantic salmon (*Salmo salar*) (K Sveinsdottir, Hyldig, Martinsdottir, Jorgensen, & Kristbergsson, 2003), etc. The QIM scheme developed for whole black tiger shrimp stored in ice includes 4 colour attributes (head colour, body colour, tail colour, and fresh colour of 0-2 demerit scores), appearance (0-3), fresh texture (0-1), and odour (0-2), giving a maximum QI of 14 (Lien, Hoa, & Loc, 2011). To characterise the sensory description and determine the maximum shelf-life of seafood, quantitative descriptive analysis (QDA), introduced by Stone & Sidel (1985), can be used for samples after being cooked. End of shelf life is determined as soon as negative/spoilage QDA attributes become evident, that is normally when the average attribute score is around 20 on the unstructured scale of 100 (Bonilla et al., 2007; Magnússon, Sveinsdóttir, Lauzon, Thorkelsdóttir, & Martinsdóttir, 2006; Nga T. T. Mai et al., 2011). Besides, Torry scheme, originally described by Shewan, Macintosh, Tucker, & Ehrenberg (1953) and further developed at Torry Research Station or modified by other institutions, has been widely used. When using a Torry scheme for cooked samples, higher score is given to fresher samples. When Torry score dropped to certain limit, normally when most of the panellists detect spoilage attributes, this limit is used as rejection time from human consumption (Nga T. T. Mai et al., 2011; E. Martinsdóttir et al., 2001). Torry score is well linearly correlated with storage time (Nga T. T. Mai et al., 2011; E. Martinsdóttir et al., 2001; Emilia Martinsdóttir, Sveinsdóttir, Luten, Schelvis-Smit, & Hyldig, 2001; Shewan et al., 1953).

This study is aimed to assess the sensory changes of black tiger shrimp *(Penaeus monodon)* during refrigerated storage at 1 ± 1 °C by QIM, QDA, and Torry methods in order to make the prediction of the shrimp (remaining) shelf-life simple and possible.

2. Materials and methods

2.1. Sample Preparation and Sampling

Three different batches of farmed black tiger shrimp *(Penaeus monodon*) of size 30-40 individuals per kg (25-33.3 g per shrimp) were used. Each batch consisted of 160-170 shrimps.

Shrimp harvested from local ponds of Khanh Hoa and Binh Dinh provinces, Vietnam, was quickly iced, put in 5-kg expanded polystyrene boxes with alternative ice layers on the bottom, in the middle, and on the top. Temperature loggers 3M TL30 (3M, Saint Paul, MN, USA) with a precision of ± 0.5 °C were placed inside the boxes the on top of the shrimp mass to record the temperature every 10 minutes. Insulate boxes of shrimp were transported to Nha Trang University laboratories within 2-5.5 hours. When arriving at the laboratories, shrimp was washed in 0-1 °C iced water, drained, packed into polystyrene trays with 5 individuals per tray, and covered with thin polyethylene film. Shrimp trays were stored in a refrigerator at 1 ± 1 °C. Repack day was considered Day 0.

To continuously monitor the temperatures, DS1922L-F5 iButton® loggers (Maxim Integrated Products, Inc., CA) were attached to some tray surface, tray bottom, and the shrimp inside the tray; and EC850A loggers (MicroLogPRO II, Israel) were placed in the refrigerator. Temperatures were recorded at 10-minute intervals.

Seven sampling points were implemented for each batch. Each sample included 3 shrimp for QIM, 14 shrimp for QDA and Torry methods, and another 5 shrimp for chemical and microbiological analyses (results not shown). Samples were taken on days 0, 2, 4, 6, 8, 9, and 10.

2.2. Sensory Assessment of Raw Shrimp Samples with QIM

Sensory evaluation of raw shrimp was conducted using QIM scheme for chill-stored whole black tiger shrimp developed by (Lien et al., 2011) by 3 panellists familiar with QIM, selected and trained in accordance with ISO 8586: 2012 (ISO, 2012).

The QIM assessment was carried out with 3 shrimp from each batch per sampling point, under stable conditions, i.e. in the same room, with minimised interruption and distraction, under white fluorescent light. Each QIM session worked with shrimp from 2-3 different batches. Every shrimp was coded with a random 3-digit number, placed in a random order and evaluated individually.

2.3. Sensory Assessment of Cooked Shrimp Samples with QDA and Torry Scheme

A panel of 7 members was used to evaluate cooked samples by both QDA and Torry methods. All judges were faculties, who have experience to work with QDA and Torry methods to assess seafood freshness, selected and trained in accordance with ISO 8586: 2012 (ISO, 2012).

Prior to the main study, a QDA description was developed by the panel under guidance of a panel leader. The listed QDA concepts included 11 odour attributes (O-): Characteristic, Sweet, Cooked starch, Ripe fruits, Fatty, Soil, Mud, Metallic, Urine/ammonia, Musty, and Rancid; 1 appearance attribute (A-): Black spots; 8 texture attributes (T-): Firm, Sticky, Soft-Tough, Fibre, Mushy, Crumbly-Firm, Dry-Juicy, and Brittle; and 8 flavour descriptors (F-): Meaty, Salty, Fatty, Pungent/bitter, Rancid, Acid, Acrid, and Spoilt/putrid. The intensity of each attribute was described by an unstructured scale of 0-100. Panellists were trained how to use the scale before sensory assessment.

A 5-to-0-point scale Torry scheme for "shrimp-cooked" (SEAFISH, 2010) was used in this study.

Each shrimp was shelled off, placed in an aluminium box cover with an aluminium foil, and steamed 95-100 °C for 7 minutes. In each session, every panellist received duplicate samples from 2 different storage days in a previously designed order using Latin square. This was to avoid the order effect. The samples were coded with random 3-digit numbers.

All sensory evaluation was carried out under standard conditions as required.

2.4. Data Analysis

Microsoft Excel 2010 (Microsoft, Redmont, WA, USA) was used to calculate means, standard deviations, conduct the regression with QI and Torry score, and to build graphs. One-way ANOVA (analysis of variance) with post hoc Tukey were conducted with the statistical analysis software SPSS version 17.0 (SPSS, Chicago, Il, USA) to compare the mean values for a statistical significant level of 0.05. Principal component analysis (PCA) was performed to study the main variance in the QDA data set.

3. Results and Discussion

3.1. Sensory Changes of Raw Whole Shrimp Evaluated by QIM

Sensory changes of raw shrimp were determined by QIM, the results were shown in Figures 1-3. It can be seen from Figures 1 and 2 that all the 7 QIM attribute scores increased over storage time. The development of melanosis at different parts of shrimp shell (head, body, and tail) and on the flesh, were described by the increasing of the corresponding attributes Head colour (C-Head), Body colour (C-Body), Tail colour (C-Tail), and Flesh colour (C-Flesh). Black spots on the head progressed the fastest, reaching the descriptor maximum score of 2 after 8 days. Black discolouration on body shell (C-body) was maximal after 10 days. Odour score also grew fast and reached the maximum score of 2 at day 9. Iced Thai black tiger shrimp was found with a progressive black discolouration on the head and tail, while its texture changed from firm to soft and mushy at rejection (Hanpongkittikun, Siripongvutikorn, & Cohen, 1995). For Pacific white shrimp, there was putrefactive odour and significant melanosis in the heads and tails (Li, Yang, & Li, 2017), which was mainly due to oxidation of phenols to quinones by polyphenol oxidase (Thepnuan, Benjakul, & Visessanguan, 2008).

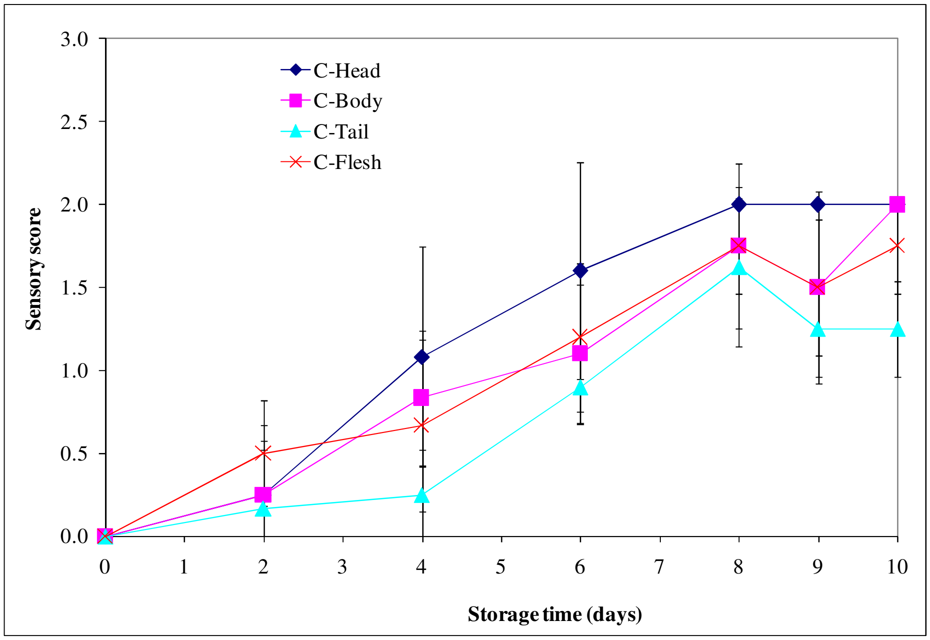

Figure 1: Changes of QIM shrimp colour attributes: Head colour (C-Head), Body colour (C-Body), Tail colour (C-Tail), and Flesh colour (C-Flesh) during storage at 1 ± 1 ℃

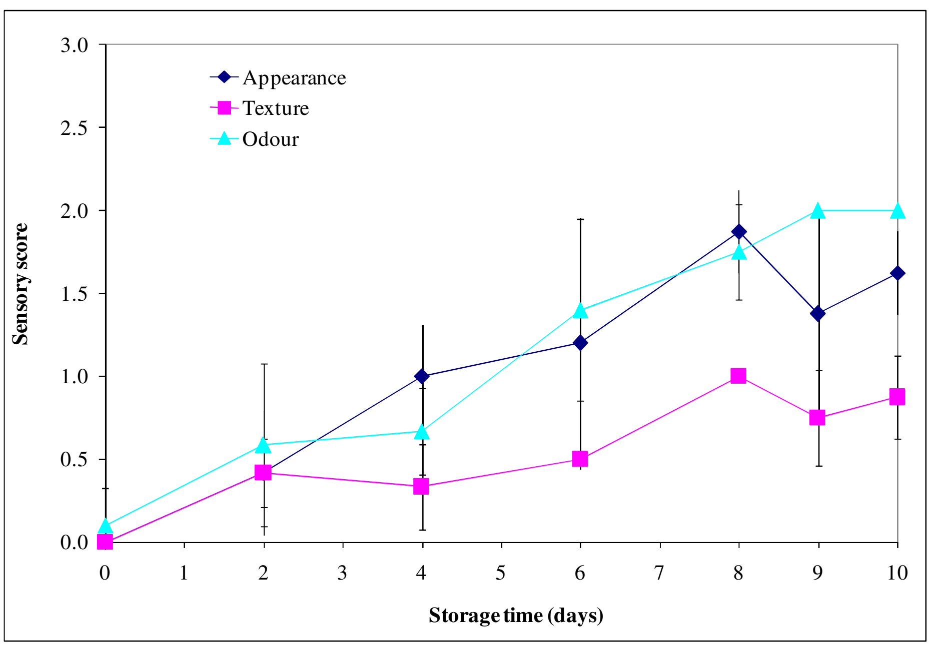

Figure 2: Changes of QIM shrimp attributes: Appearance, Texture, and Odour during storage at 1 ± 1 ℃

QI was linearly correlated with storage time (Figure 3) with the regression equation of QI = 1.207 * days + 0.281 and high coefficient of determination ($R^2 = 0.96$). These findings agreed well with other studies that there was a linear correlation between QI and storage time of other aquatic products, e.g. chilled skin-on *Pangasius* fillets (Bao, 2006), chill-stored skinless *Pangasius* fillets (Nga Thi Tuyet Mai, 2012), Atlantic herring in ice (Nga T.T. Mai, Martinsdóttir, Sveinsdóttir, Olafsdóttir, & Arason, 2009), iced arctic char (Cyprian, Sveinsdóttir, Magnússon, & Martinsdóttir, 2008), and iced farmed Atlantic salmon (Kolbrun Sveinsdottir, Hyldig, Martinsdottir, Jørgensen, & Kristbergsson, 2003), anchovy (*Engraulis anchoita*) stored in ice (Massa, Manca, & Yeannes, 2012), and European cuttlefish under ice storage (Sykes et al., 2009), showing that QIM is a good tool for freshness evaluation and shelf life estimation of fisheries products stored at low temperatures.

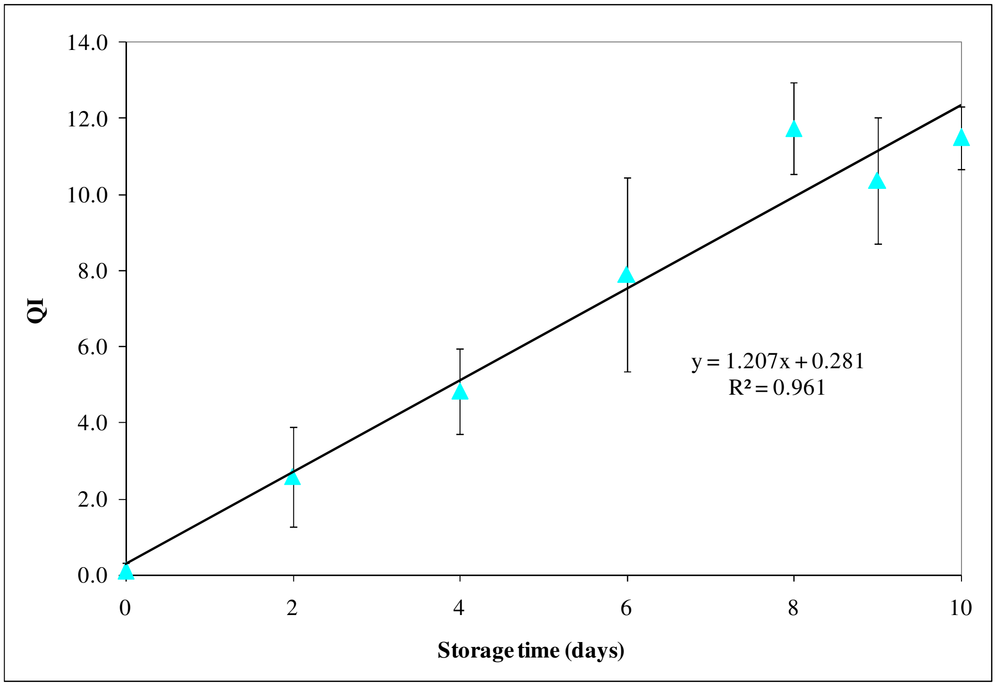

Figure 3: QI changes of raw whole shrimp during storage at 1 ± 1 °C

3.2. Sensory Changes of Shrimp Evaluated by QDA and Torry Methods

Sensory changes of shrimp assessed by QDA were shown in Table 1. It can be observed that all 11 odour attributes did not changed significantly ($p > 0.05$) over the course of storage. Black spots (A-Black spots) developed significantly ($p < 0.05$) after 9 days, when the shrimp became clearly ($p < 0.05$) less firm (T-Firm) and mushier (T-mushy). Texture was significantly ($p < 0.05$) crumbly (T-Crumbly-Firm) on day 6. Pungent and/or bitter flavour (F-Pungent/bitter) was obvious ($p < 0.05$) after 10 days. Other texture and flavour attributes did not evolve significantly ($p > 0.05$). The negative attributes such as black spots (A-Black spots) and mushy texture (T-mushy) exceeded the score of 20 after 9 days. It is generally recognized that if bad attributes reached the score of above 20, when most of panellists detected the spoilage characteristics, the shelf life is over (Bonilla et al., 2007; Cyprian et al., 2008; Odoli, 2009). This indicates that the maximum shelf-life for whole black tiger shrimp of size 30-40 (shrimp per kg) stored at 1 ± 1 °C was around 9 days, which is in accordance with the shelf life of that shrimp size stored in ice in previous study: 10 days at 0-1 °C and 9 days at 1-2 °C (Lien et al., 2011). Assessing sensory acceptance of iced Thai black tiger shrimp kept under 2 °C environment, using a 9-point hedonic scale with acceptance score of 5, gave a shelf life above 6 days for controlled harvest samples, and > 2 days for market samples (Hanpongkittikun et al., 1995). For whole Penaeus spp. shrimp from the east coast of Saudi Arabia stored in crushed ice kept at 4 °C, sensory evaluation using a 7-point hedonic scale, with unacceptable score of 3, resulted in a shelf life above 10 days. For tropical shrimp (*Penaeus notialis*), sensory analysis was conducted with a scale of three categories: 1 = good quality, 2 = marginal quality, but still acceptable, and 3 = spoiled, rejection time was the moment when 50% of the judges put the samples in category 3, giving shelf lives of > 9 days (216 h), > 7 days (168 h), > 3 days (72h), and 43 h at 0, 4, 7, and 15 °C, respectively (Dabadé et al., 2015). For Pacific white shrimp (*Litopenaeus vannamei*), sensory evaluation, using a 1- to 9-point scale with rejection limit of score 5, determined a shelf life of about 4 days (96 h) at 4 ± 1 °C (Li et al., 2017). The maximum shelf-life of 9 days was around the time (8-10 days) when QIM attributes, such as black spots on head (C-Head, head colour) and on body (C-body), and odour reached their maximum.

Attribute	Storage time (days)																				
	0			2			4			6			8			9			10		
O-Characteristic	63,86^{a}	±	22,05	62,54^{a}	±	18,20	65,89^{a}	±	16,56	65,70^{a}	±	18,39	61,07^{a}	±	17,69	59,08^{a}	±	14,15	50,19^{a}	±	21,71
O-Sweet	37,04^{b}	±	23,60	35,24^{b}	±	25,12	34,82^{b}	±	24,32	35,10^{b}	±	27,25	30,39^{b}	±	24,93	26,49^{b}	±	19,42	22,47^{b}	±	21,93
O-Cooked starch	47,02^{c}	±	28,65	48,01^{c}	±	26,51	46,78^{c}	±	28,56	49,41^{c}	±	27,11	45,55^{c}	±	24,90	44,84^{c}	±	23,40	39,45^{c}	±	22,21
O-Ripe fruits	15,14^{d}	±	23,34	21,38^{d}	±	26,32	23,01^{d}	±	25,05	28,17^{d}	±	27,29	24,31^{d}	±	25,37	28,15^{d}	±	24,37	19,16^{d}	±	20,99
O-Fatty	20,62^{e}	±	20,42	19,06^{e}	±	19,74	18,14^{e}	±	18,26	19,28^{e}	±	20,73	15,85^{e}	±	14,30	14,81^{e}	±	13,58	7,90^{e}	±	7,44
O-Soil	9,46^{f}	±	16,54	10,83^{f}	±	15,70	13,41^{f}	±	18,91	11,49^{f}	±	16,27	9,67^{f}	±	12,76	10,26^{f}	±	14,34	12,44^{f}	±	16,56
O-Mud	7,57^{g}	±	17,02	8,82^{g}	±	16,60	9,91^{g}	±	17,34	10,53^{g}	±	18,12	9,82^{g}	±	13,69	11,21^{g}	±	16,87	16,51^{g}	±	19,93
O-Metallic	7,00^{h}	±	11,00	5,98^{h}	±	8,89	9,44^{h}	±	17,41	10,26^{h}	±	13,25	7,33^{h}	±	8,21	7,95^{h}	±	7,02	7,71^{h}	±	6,80
O-Urine, ammonia	19,54^{i}	±	27,70	20,84^{i}	±	26,43	21,93^{i}	±	28,59	21,59^{i}	±	26,30	28,90^{i}	±	26,94	22,71^{i}	±	25,42	40,68^{i}	±	25,08
O-Musty	1,70^{j}	±	2,97	2,32^{j}	±	4,67	2,65^{j}	±	7,19	0,95^{j}	±	1,34	1,49^{j}	±	2,61	2,22^{j}	±	4,06	2,98^{j}	±	5,02
O-Rancid	1,32^{k}	±	1,72	1,63^{k}	±	4,72	2,77^{k}	±	9,46	2,01^{k}	±	5,66	1,92^{k}	±	3,63	5,72^{k}	±	8,88	1,66^{k}	±	3,67
A-Black spots	1,84^{l}	±	6,16	0,26^{l}	±	0,52	0,59^{l}	±	2,38	6,46^{l}	±	13,80	3,12^{l}	±	8,45	21,71^{m}	±	23,76	17,93^{m}	±	18,60
T-Firm	79,52^{a}	±	15,13	73,27^{ab}	±	19,56	73,44^{ab}	±	16,26	64,74^{abc}	±	16,87	64,05^{abc}	±	18,90	54,54^{c}	±	21,34	58,56^{bc}	±	17,67
T-Sticky	33,68^{a}	±	26,29	35,15^{a}	±	27,47	45,10^{a}	±	23,05	41,15^{a}	±	20,66	38,43^{a}	±	14,70	36,61^{a}	±	20,87	37,98^{a}	±	17,18
T-Soft-Tough	34,39^{b}	±	28,79	28,31^{b}	±	25,97	23,86^{b}	±	18,54	26,54^{b}	±	15,72	34,74^{b}	±	16,16	32,59^{b}	±	23,29	33,68^{b}	±	22,17
T-Fibre	47,45^{c}	±	32,63	45,79^{c}	±	31,98	40,35^{c}	±	28,30	36,66^{c}	±	26,41	34,63^{c}	±	24,84	29,90^{c}	±	24,83	32,07^{c}	±	25,67
T-Mushy	8,42^{a}	±	13,73	18,05^{ab}	±	21,72	15,11^{ab}	±	19,63	22,59^{ab}	±	21,14	20,27^{ab}	±	13,34	28,90^{b}	±	22,76	27,44^{b}	±	20,96
T-Crumbly-Firm	84,53^{a}	±	13,46	69,13^{ab}	±	25,72	65,21^{ab}	±	24,28	50,76^{b}	±	27,62	56,50^{b}	±	24,02	48,68^{b}	±	30,50	52,89^{b}	±	22,48
T-Dry-Juicy	59,51^{a}	±	25,36	55,39^{a}	±	26,43	51,32^{a}	±	23,77	47,21^{a}	±	24,50	46,03^{a}	±	22,58	45,46^{a}	±	27,49	47,87^{a}	±	20,62
T-Brittle	53,74^{b}	±	32,41	61,90^{b}	±	30,58	63,15^{b}	±	23,43	54,09^{b}	±	23,61	52,81^{b}	±	23,36	43,09^{b}	±	25,64	48,30^{b}	±	24,96
F-Meaty	65,47^{c}	±	24,67	66,39^{c}	±	19,54	68,19^{c}	±	18,18	61,94^{c}	±	20,63	58,82^{c}	±	20,98	58,33^{c}	±	22,46	50,95^{c}	±	22,58
F-Salty	3,41^{d}	±	5,07	9,84^{d}	±	17,28	11,40^{d}	±	22,28	10,67^{d}	±	15,82	12,51^{d}	±	15,47	12,25^{d}	±	17,80	10,97^{d}	±	14,29
F-Fatty	13,01^{e}	±	16,49	14,66^{e}	±	18,83	13,60^{e}	±	14,62	13,53^{e}	±	14,48	12,54^{e}	±	12,07	13,67^{e}	±	14,77	11,68^{e}	±	20,65
F-Pungent/ bitter	1,14^{a}	±	1,95	3,64^{ab}	±	10,02	5,58^{ab}	±	9,33	4,75^{ab}	±	5,83	6,10^{ab}	±	9,84	8,51^{ab}	±	8,32	11,16^{b}	±	14,49
F-Rancid	0,76^{a}	±	0,97	1,49^{a}	±	3,56	2,37^{a}	±	5,25	1,37^{a}	±	2,73	2,34^{a}	±	4,59	3,78^{a}	±	4,54	4,16^{a}	±	5,24
F-Acid	2,84^{b}	±	5,02	4,90^{b}	±	8,37	5,72^{b}	±	7,56	5,91^{b}	±	7,54	3,90^{b}	±	4,55	4,40^{b}	±	5,38	7,62^{b}	±	10,33
F-Acrid	1,09^{c}	±	1,83	1,77^{c}	±	4,67	2,37^{c}	±	5,10	2,25^{c}	±	3,14	3,41^{c}	±	4,55	3,69^{c}	±	5,48	4,92^{c}	±	7,28
F-Spoilt/ putrid	0,24^{d}	±	0,49	0,43^{d}	±	0,89	0,45^{d}	±	0,72	0,52^{d}	±	0,91	0,59^{d}	±	0,89	0,80^{d}	±	1,35	0,33^{d}	±	0,72

Table 1: QDA sensory changes of shrimp during storage at 1 ± 1 ℃
Prefixes O-, A-, T-, and F- stands for Odour, Appearance, Texture, and Flavour, respectively
Different letters in the same row indicate significant differences ($p < 0.05$)
in mean values of the corresponding attribute between storage days

Results of PCA the original QDA data set were shown in Figure 4. It can be seen that the first two principal components (PC1 and PC2) explained in total 76.1% of the variance. Nine attributes, namely 4 odour (Soil, Musty, Metallic, and Rancid), 2 texture (Sticky and Soft-Tough) and 3 flavour attributes (Salty, Fatty, and Acid), lied in the center of the two correlation circles, meaning that they did not correlated with the storage time. Thus, PCA was redone with the QDA data set excluded these 9 attributes, results were illustrated in Figure 5.

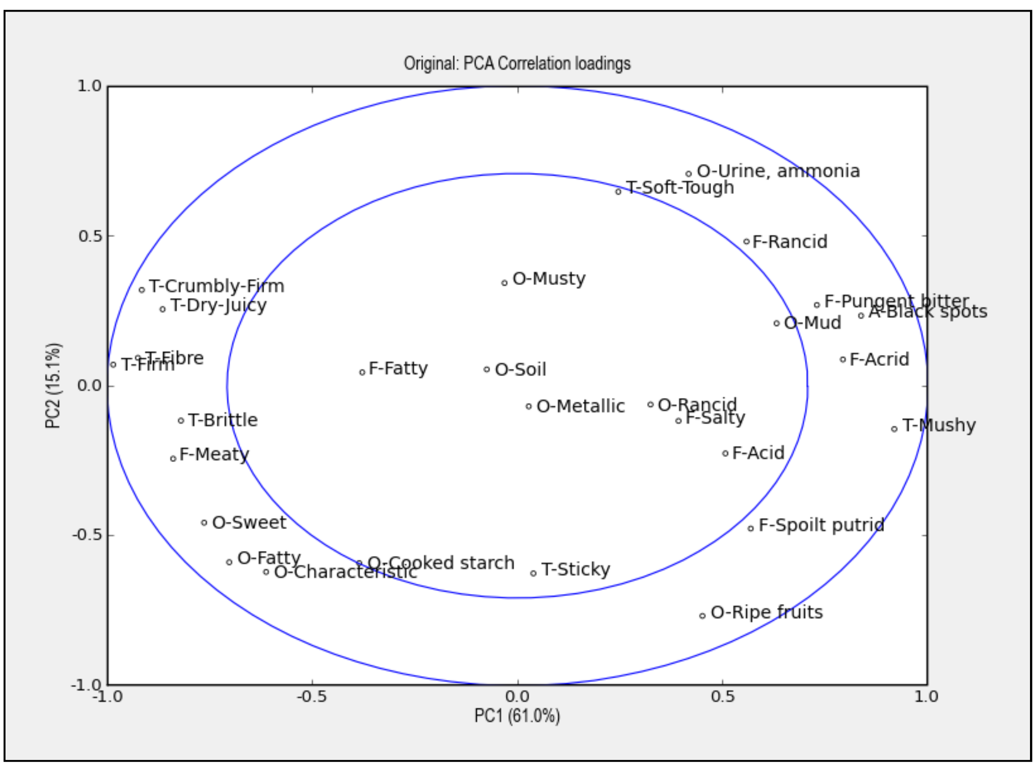

Figure 4: PCA correlation loadings of all 28 QDA attributes of shrimp during storage at 1 ± 1 ℃
Prefixes O-, A-, T-, and F- stands for Odour, Appearance, Texture, and Flavour, respectively

It can be observed from Figure 5 that the first two PC now explained the variance better (82.4%) compared to previous case (76.1%). PC1 and PC 2 explained 67.7 and 14.7% of the variance, respectively. Furthermore, 19 QDA attributes gathered into 2 groups: positive on the left and negative on right of PC1. Positive group included the following 10 attributes: O-Characteristic, O-Sweet, O-Cooked starch, O-Fatty, T-Firm, T-Fibre, T-Crumbly-Firm, T-Dry-Juicy, T-Brittle, and F-meaty, which characterised for fresh samples. Negative group included the following 9 descriptors: O-Ripe fruits, O-Mud, O-Urine/ammonia, A-Black spots, T-Mushy, F-Pungent bitter, F-Rancid, F-Acrid, and F-Spoilt/putrid, characterised. For farmed tilapia (*Oreochromis niloticus*) fillets, good attributes included sweet flavour, Arctic char flavour, and metallic flavour, while bad attributes were rancid and musty odours, mushy texture, pungent flavour, spoilage flavour, musty flavour, and rancid flavour (Odoli, 2009). PCA bi-plot (Figure 6) confirmed the trend that fresh samples located more to the left of PC1, and moved to right of PC1 with time (see the arrow).

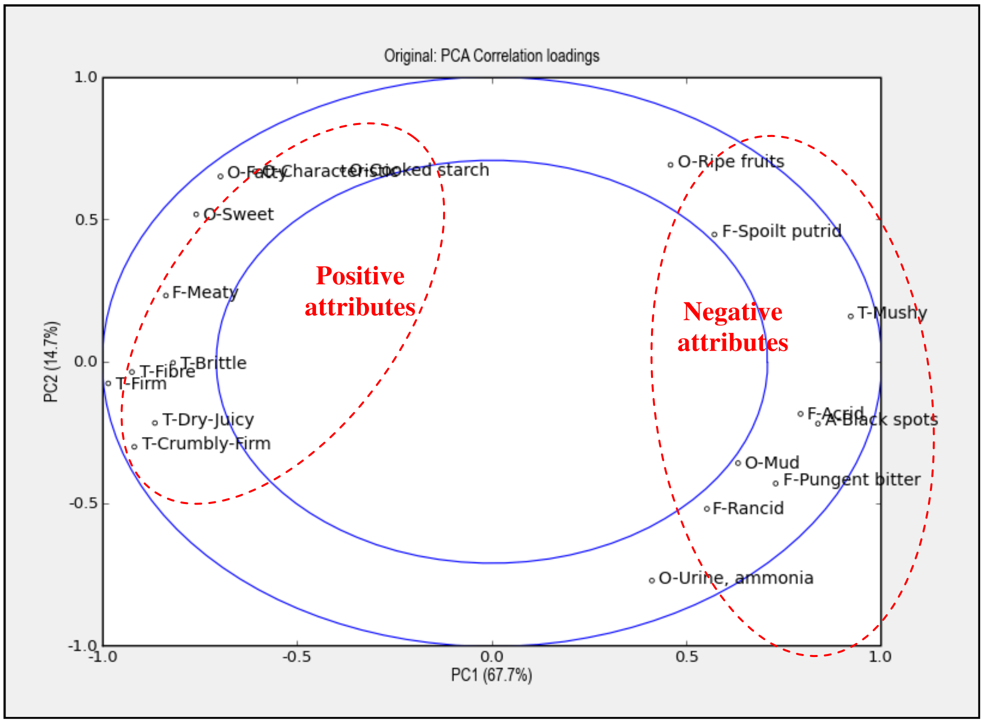

Figure 5: PCA correlation loadings of 19 QDA attributes of shrimp during storage at 1 ± 1 ℃
Prefixes O-, A-, T-, and F- stands for Odour, Appearance, Texture, and Flavour, respectively

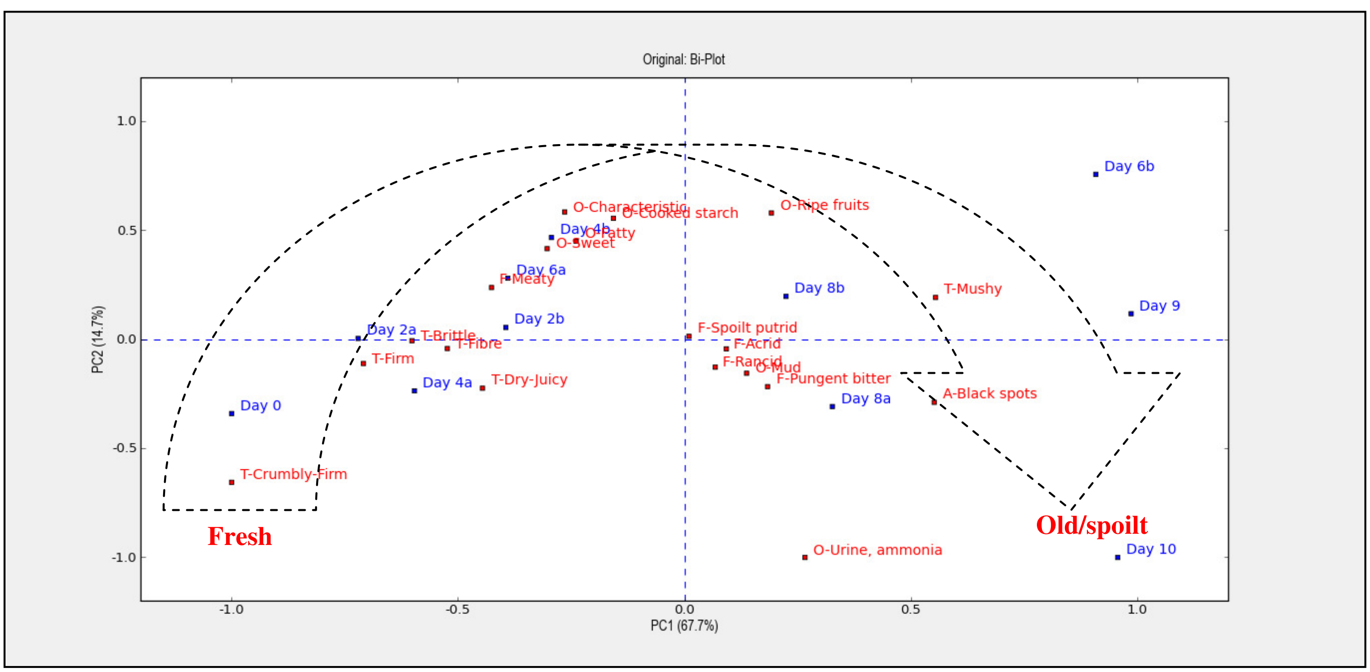

Figure 6: PCA bi-plot of 19 QDA attributes and samples of different storage days at 1 ± 1 ℃
Prefixes O-, A-, T-, and F- stands for Odour, Appearance, Texture, and Flavour, respectively;
Same storage days with different letters indicate different batches

Figure 7 shows the sensory quality changes of shrimp evaluated by Torry scheme. It can be observed that Torry score significantly decreased to around 3 (3.14 ± 0.77, to be exact) after 10 days, which was the time when QIM and QDA methods also detected the spoilage. There was a linear relationship between Torry score and storage time, with the regression of Torry score = -0.199 * Days + 4.493 and high coefficient of correlation (R^2 = 0.92). This negative linear correlation is similar for other aquatic products as described by (E. Martinsdóttir et al., 2001).
Of the 3 methods used, QIM showed to be the most simple and convenient to use because of no sample cooking and linear correlation with time. In addition, QIM is also reliable as it was developed for specific species and product type.

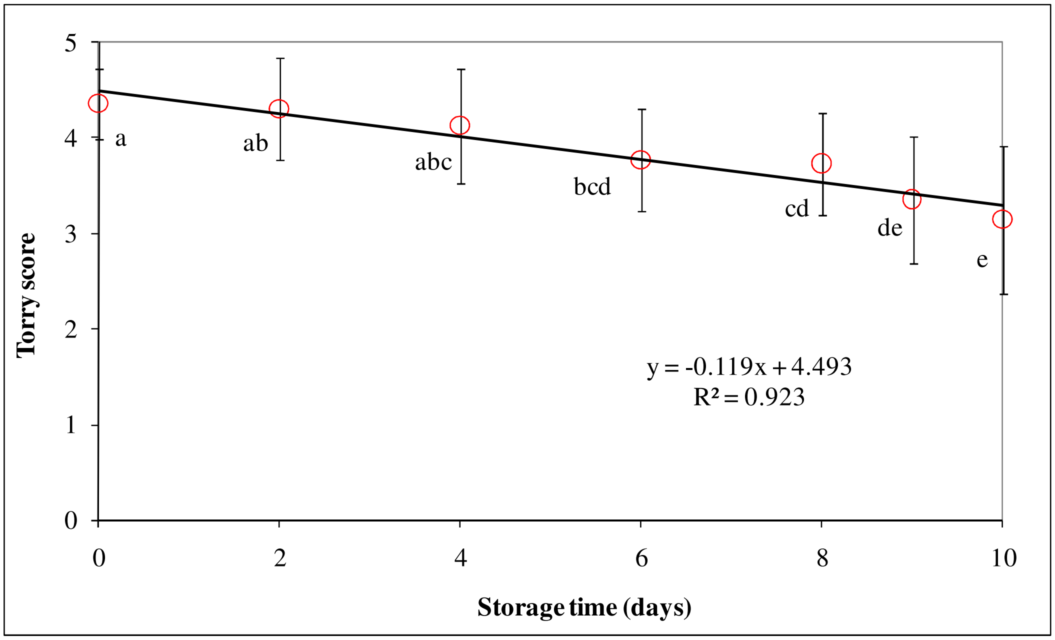

Figure 7: Changes of shrimp Torry scores during storage at 1 ± 1 °C

4. Conclusions

Sensory quality of whole black tiger shrimp stored at 1 ± 1 °C significantly changed after 8-10 days as evaluated by different sensory methods, namely QIM, QDA, and Torry. QIM showed to be a useful and convenient tool for freshness and (remaining) shelf-life determination.

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