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Studies on Freshness-lowering and Storage-life of Tiger Prawn, *Penaeus japonicus*, Muscle under Low Storage Temperature

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Abstract

The analysis of quality-lowering was done to investigate the keeping freshness period and practical storage life of tiger prawn, *Penaeus japonicus*, muscle under low storage temperature.

The K value of the sample corresponding with the excellent score on the sensory evaluation was equivalent to 10% and the VBN content was 10 mg/100 g.

The keeping freshness period was equivalent to the K value of 20% and VBN content of 18-19 mg/100 g, that it was the *sashimi* level freshness if the black spot did not appear.

The practical storage life (PSL) was equivalent to the K value of 30-32% and VBN content of 20 mg/100 g, and it was the safe line of the sample as the raw material of food. The PSL was also obtained in connection with the various low storage temperatures.

Tiger prawn in one of the important commercially valuable product in fisheries culture and fishing. Limit of quality keeping period during the distribution and processing is different with the chemical index of quality. The K value, one of the index of freshness, is related to decomposition of ATP related compounds, and ARAI[1] proposed that the main pathway of degradation of ATP in the muscle of prawn may be ATP→ ADP→ AMP→AdR →HxR→Hx, but the route passing through IMP may hardly be probable. And also it was shown the similar pattern in Gulf shrimp[2], pink and brown shrimp[3]. On the other hand, there is a report that the volatile base nitrogen (VBN) content, one of the index of freshness, in white shrimp muscle[4] increased during initial postmortem storage. It means the ammonia production can thus potentially take place.

Foot note:
The following abbreviation are used :

ATP : Adenosine triphosphate,	IMP : Inosine monophosphate,
ADP : Adenosine diphosphate,	AdR : Adenosine,
AMP : Adenosine monophosphate,	HxR : Inosine,
	Hx : Hypoxanthine.

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UCHIYAMA *et al.*[5] mentioned that the chemical index at stage of primary decomposition was decided to be 30 mg/100 g in VBN for imported frozen shrimps in Japan. Lately, SHABAN *et al.*[6] described that −40℃ is reasonable to keep the quality unchanged for a long-term storage, though −20℃ is low enough for a short-term storage up to a few months.

The present studies were undertaken to determine the practical storage life (PSL) at various storage temperatures according to initial freshness.

Materials and Methods

Materials

Alive cultured tiger prawn, *Penaeus japonicus*, (whole weight 15-20 g) were obtained and killed quickly by removal of the head portion with the hands to avoid struggling which may cause depletion of the inherent ATP. Prawn sample bodys were stored at 10, 5, 0, −3, −5, −10, and −20℃, controlled within 0.5℃, using the electric thermo-sensor. After samples were in constant storage temperature, a certain weight of muscle in duplicate was withdrawn at intervals time of storage for chemical analysis. In each sample, two determinations were made. Some photographs were taken after the separated head jointed to the body.

Chemical analysis

The K value was measured by anion exchange column chromatography. The ionexchanger used was Dowex 1x4, Cl^- form with a mesh of 100 to 200.

The volatile base nitrogen (VBN) content was measured by trichloroacetic acid extract, micro diffusion method (CONWAY's method). The TBA number was measured by using the method of SINNHUBER and YU[7,8].

Sensory evaluation

The prawns (shell on) were heated in closed polyethylene film bags in a boilling water bath for 5 min. The samples were served to the panelists and were asked to evaluate the prawn for odour, flavour, appearance and overall acceptability. An intensity of hedonic scale ranging from a high of 9 (highest value) to a low of 1 (lowest value) was used[9]. The median of intensity of hedonic scores were used in statistical analysis of sensory evaluation data in storage life[10].

Results and Discussion

Changes in K value, VBN content and TBA number of tiger prawn muscle during storage at various temperatures

The changes in K value of tiger prawn muscle during storage at various low temperatures are shown in Fig. 1. This figure shows that the change of K value is rapid up to about 30% and then occurred the flat change at around 30-40% for relative long period of time, especially on the sample stored at 0 and −3℃ and is followed by the rapid change.

The outline of the degradation of ATP in tiger prawn could be explained as follows. On the rapid change of K value up to 30% level, the ATP degradation is via AMP→IMP→HxR pathway, when the K value is in flat change, that pathway is in relative constant rate, while

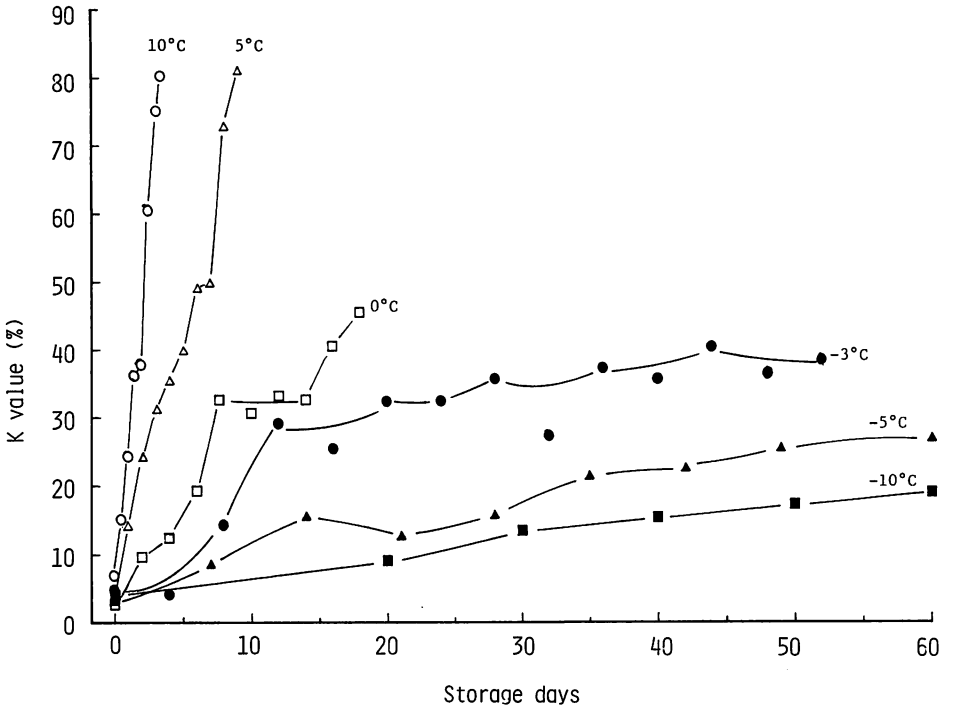

Fig. 1. Changes in K value of tiger prawn muscle during storage at various low temperatures.
(Initial K value ((instantly killed)) is roughly 4%).

the remain of AMP is dephosphorylated to AdR, and after the flat change is via AMP→IMP →HxR and AMP→AdR→HxR pathways.

The rate constant of freshness-lowering (k_f) on tiger prawn muscle is shown in Fig. 2. Lines of freshness-lowering in this figure indicated the first-order reaction. These reaction rates could be expressed by the Q_{10} temperature quatient using the eqn. $Q_{10}=K_{(t+10)}/K_t$, and is shown in Table 1. These Q_{10} suggest that the reaction rate on freshness-lowering in tiger prawn muscle falls by a factor of 7.37 on the reduction of temperature 10℃ from +10 to 0℃, by a factor of 14.50 on the reduction of temperature from 0 to −10℃, and by a factor of 10.0 on the reduction of temperature from −10 to −20℃. NISHIMOTO *et al.*[11] reported that the most effect of temperature on increasing in rate of freshness-lowering in mackerel, *Scomber japonicus*, muscle is by a coefficient of 20 occurring at temperature from −10 to 0℃. It means that the effect of temperature on coefficient increasing rate of freshness-lowering in mackerel muscle is 1.38 times bigger than that in tiger prawn muscle.

Changes in VBN content of tiger prawn-muscle during storage at various temperatures is shown in Fig. 3. On 30 mg/100 g level of VBN content, the storage time of sample at −3℃ was two times longer than that stored at 0℃.

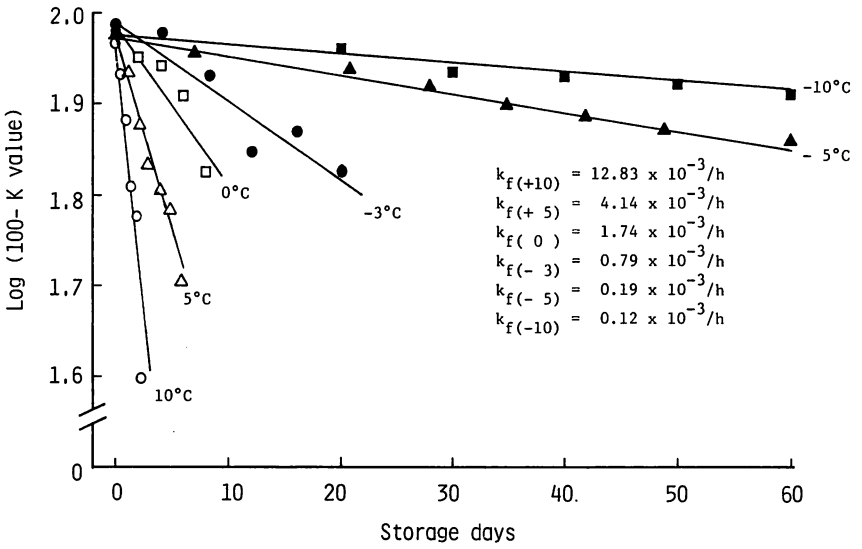

Fig. 2. First-order reaction rate on freshness-lowering (k_f) of tiger prawn muscle during storage at various temperatures.
(The k_f was obtained by using the eqn.
$\log (100-K_t)=\log (100-K_o)-k_f/2.303t$
where, $(100-K_t)$ is the value at any one time of the remaining amount of nucleotide.
$(100-K_o)$ is the initial value of the remaining amount of nucleotide.
k_f is the rate constant of freshness-lowering, t is the time in hour.).

Table 1. Rate constant (k_f) and temperature quotient (Q_{10}) of freshness-lowering in tiger prawn muscle.

k_f and Q_{10}	Temperature of storage (℃)				
	10	5	0	−5	−10
$k_f \times 10^3$ (h^{-1})	12.83	4.14	1.74	0.19	0.12
Q_{10}		7.34		14.50	
			21.79		

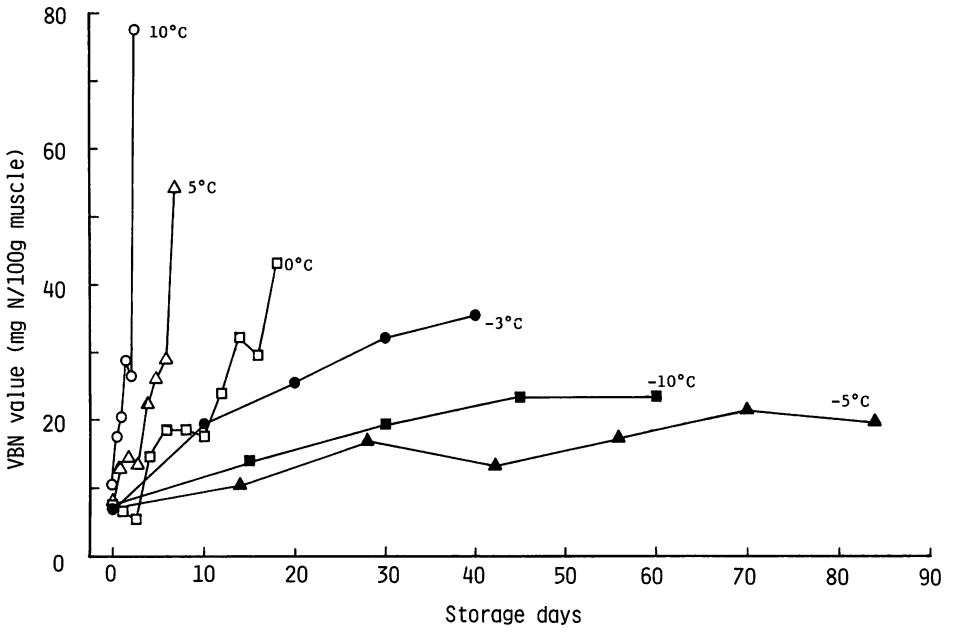

Fig. 3. Changes in VBN contents of tiger prawn muscle during storage at various temperatures.

Changes in TBA number (malonaldehyde : mg MA/1 kg muscle) of tiger prawn muscle during storage at various temperatures is shown in Fig. 4. Increment of TBA number was noted in the sample stored at 10, 5, 0, and −3℃ after 1.5, 4, 2, and 10 days, respectively, and then was followed by almost unchanged from 6 to 9 days during storage at 5℃, and from 4 to 14 days during storage at 0℃.

The TBA number express lipid oxidation in mg malonaldehyde (MA) per kg of muscle sample. This test therefore, only measure the MA as results of the dissociation of hydroperoxides formed during fatty acid oxidation. MA is an active compound that can react with various substances, including free amino acid. According to ANGEL *et al.*[12], because of free amino acids accumulate during storage at 0℃, it is possible that condensation of MA took place with this amino acids. The TBA value remained low level, almost all below than 1 mg MA/1 kg muscle during 4, 9, 18, 40 and 80 days of storage at +10, +5, 0, −3 and −10℃, respectively. The reason of this results could be due to the low level of lipid content at around 0.77-0.78 g/100 g sample.

Assessment of tiger prawn quality by sensory evaluation during storage at 0℃

The assessed scores of boiled tiger prawn by 17 panelists were treated statistically. The usual summary statistics, mean and standard deviation, have limited use measured of the hedonic response of a panel. The median, a more meaningful measure of the centre of the distribution was used.

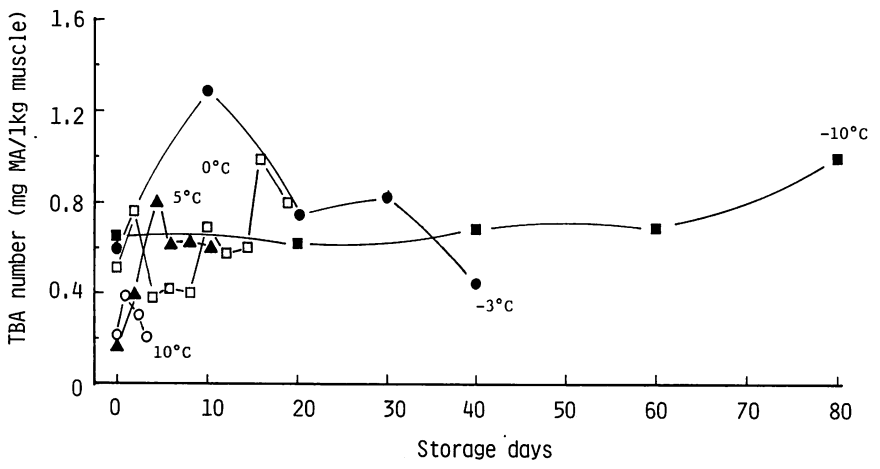

Fig. 4. Changes in TBA number of tiger prawn muscle during storage at various temperatures.

The median of scoring on appearance, odour and flavour of prawn muscle during storage at 0℃ are ploted to storage days. These correlations were shown as the coefficients (r) of −0.93, −0.87, −0.82, and −0.95 for the appearance, odour, flavour, and total assessment, respectively.

Limit of excellent acceptability on score 9 to 8 in sensory evaluation, the keeping freshness period (KFP) on score 7 to 6 and the practical storage life (safe line as food) on score 5, were shown in Table 2 as a whole.

In the raw prawn, the black spot appeared at around head and part of body-connect after 2 days of storage, they were expanded gradually at all part from 6 to 10 days of storage, and after further 12 days almost all of the body surface became black colour (plate Ⅰ-Ⅳ).

Relationship between the sensory evaluation and the K value or VBN content

The K value of the sample corresponding with the excellent score (9 to 8) was equivalent to 10%, and VBN content was 10mg/100 g. The over all of assessment score could be explained as shown on Table 2, and the K value and VBN content of sample corresponding to their score is illustrated in Figs. 1 and 3, respectively.

The equivalent of K value was 20% and its of VBN content was 18-19 mg/100 g in KFP, it was the *sashimi* level freshness if the black spot was not appear.

In the safe line as food, that is practical shelf life (PSL), the K value was equivalent to 30-32%, and the VBN content was 20 mg/100 g (Table 3).

As mentioned above, it gives fairly good quality with the index of chemical freshness, but for occur blackening on the body surface, the score of sensory assessment was low from the real quality. Therefore, we have to be judged the tiger prawn from thus view point.

Table 2. Assessment score of boiled tiger prawn after stored at 0℃ quality by sensory evaluation related to storage life (days).

Organoleptic properties \ Hedonic test score※	9 – 8 (Excellent)	7 – 6 (KFP)	5 (PSL)	Remark
Appearance	2	8	11	Black spot appear after 2 days, and after 10 days, it becomes almost black at head part. After 12 days, whole body become black colour.
Odour	2	11	18	
Flavour	2	8	11 – 12	
Over all	2	6	9	

KFP : Keeping freshness period, PSL : Practical storage–life. (Safe line as food)

※

Score	Appearance	Odour	Flavour	Over all
9	Transparent white	Very fresh prawn odour	Sweet, meaty, creamy	Like extremely
8	White meat	Fresh prawn odour	Sweet, meaty, characteristic	Like very much
7	Foggy	Very few fresh prawn odour	Weak neutral flavour	Like moderately
6	Pale	No fresh prawn odour and no off–odour	Insipid, flavourless	Like slightly
5	Faintly bluish white meat and detectable black spot	Detectable off–odour	Slightly sourness, slight musty, stale flavour	Neither like nor dislike
4 – 3	Severe black spot	Severe off–odour	Slight bitterness, sour, 'off'	Dislike slightly dislike moderately
2 – 1	Bluish white meat and severe black–spot	Pronounced ammonia odour	Strong bitterness, sour, sulphide	Dislike very much dislike extremely

Assessment of PSL of tiger prawn stored at various temperatures

From the results ; the increasing curve of VBN content in tiger prawn muscle during storage is shown a sigmoid type, and in the case of $k_f=1$ at 0℃ we obtained the coefficient of k_f, we presume the PSL for stored tiger prawn at various temperatures. We got the PSL based on the calculation of k_f.

The PSL ploted to the storage temperature is shown in Fig. 5. This figure would enables one to predict the PSL of tiger prawn which include the change of freshness and the degradation of quality by blackening of the surface.

Table 3. Hedonic scores vs. K value and VBN content during storage at 0℃.

Overall score	storage days	K value %	VBN cont. mg/100g muscle
9 − 8	2	10	10
7 − 6	6	20	18−19
5	9	30−32	20

Initial K value ca. 4%
Initial VBN cont. 8mg/100g

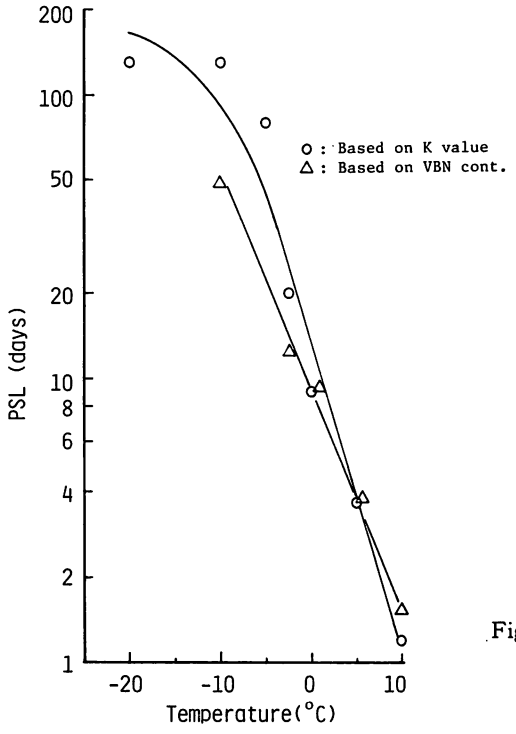

Fig. 5. PSL for tiger prawn as function of temperature.

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Plate Ⅰ. The appearance of tiger prawn immediately after killed.

Plate Ⅱ. The change in appearance of tiger prawn after 2 days stored at 0℃.

Plate Ⅲ. The change in appearance of tiger prawn after 10 days stored at 0℃.

Plate Ⅳ. The change in appearance of tiger prawn after 12 days stored at 0℃.