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QUALITY DETERMINATION OF COMMERCIAL FROZEN PRAWNS USING NUCLEOTIDE-BASED PRODUCTS, SENSORY ASSESSMENT AND TEXTURE MEASUREMENTS

by

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ABSTRACT

The nucleotide degradation profile of two species of farmed shrimps, kept in ice and frozen storage showed high AMP and IMP accumulation for a prolonged period. Quality of frozen shrimp during storage was evaluated by measuring the levels of AMP, IMP, inosine, hypoxanthine and K-value. Sensory assessment and instrumental texture measurements were also employed to assess the quality of prawns. Prawns in their prime quality had AMP and IMP levels $>3\mu\text{mol/g}$ each. K-value below 25% indicated prime quality. The overall acceptability score was closely related to IMP level or the sum of (AMP+IMP), Hx and also K-value. For acceptable quality prawns, K-value should be in the range of 40-46% and the sum of (AMP+IMP) values should be $>2\mu\text{mol/g}$. Based on these findings, a number of commercial frozen prawns from the industry were evaluated for their quality. These samples were grouped into grade I, II and III based on organoleptic assessment, K-value and levels of nucleotide components. Thus, 30% of the frozen shrimp (HL, PD or PUD) from the industry was rated as grade I (K-value $\leq 25\%$), 50% as grade II (K-value = 36.5 to 43.6%) and 20% as grade III (K-value $\geq 60\%$). Instrumental texture measurements were compared with organoleptic rating.

INTRODUCTION

Frozen shrimp is one of the most valuable fishery products in international trade. Through the export of frozen prawns, India is realizing a huge amount of foreign exchange. Frozen prawn exports from India earned over 750 million US dollars during 1996-97. However, the quality of seafood is of paramount importance in the global trade. In the fish industry quality is generally assessed by standard sensory methods. However, in international trade, objective methods of quality evaluation are considered to be more reliable. Nucleotide based methods have assumed importance in the assessment of freshness of fish in recent years (Amu and Disney, 1973; Martin *et al.*, 1978; Jacob and Rand, 1982). Individual nucleotides and nucleotide ratios (K-value) have been used to indicate quality in many species of fish (Gill *et al.*, 1987; Green *et al.*, 1990; Price *et al.*, 1991; Hattula and Kiesvara, 1992; Ryder *et al.*, 1993 and Lakshmanan *et al.*, 1996). This is based on the fact that in most finfish species nucleotide breakdown proceeds as follows:



Ehira (1976) remarked that K-value as proposed by Saito *et al.* (1959) was one of the most appropriate indicators of freshness.

However, very little information is available on the nature of nucleotide degradation in shrimp and how it affected the quality and undesirable flavours in shrimp. Arai (1966) indicated that marine shellfish degrade ATP in a different way compared to finfish. He proposed two pathways for the breakdown of ATP in the Japanese prawn, *Pandalus hypsinotus*. One involves the direct deamination of AMP to IMP; while the second involves the dephosphorylation of AMP to adenosine followed by deamination to inosine. Both

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changes would lead to the production of bitter, off flavour hypoxanthine. A reliable, objective test to assess the quality of shrimp when it reaches the factory or at the time of processing would be useful to the industry.

The objective of the present study was to follow the kinetics of nucleotide degradation in the two species, *Penaeus indicus* and *P. monodon* during storage in ice and the frozen state so as to assess the quality before freezing and the changes taking place under frozen storage. The objective indices would be used to validate the sensory assessment and to evaluate the quality of frozen prawns from the industry.

MATERIALS AND METHODS

The commercially important prawns, *P. indicus* and *P. monodon* were procured from the culture farm of Kerala Agricultural University at Puthuvypin. The samples were caught live, headed and iced immediately. One lot from each sample was frozen in a block of 500 g. and kept in cold storage below -18°C. *P. monodon* had weights in the range of 60-70 g and *P. indicus* weighed in the range of 10-15 g. Prawns were iced in the ratio 1:2 and re-iced every day during storage, in an insulated box. Samples were drawn at different intervals of time for the determination of nucleotide catabolites, volatile base-nitrogen (VB-N), pH, texture measurement and sensory evaluation. Frozen material was sampled - every month for a period of 1 year for the analysis. Commercial frozen prawns of different forms, namely headless shell on (HL), peeled (PUD), peeled and deveined (PandD) and grades were procured from eight fish processing factories in Cochin - over a period of one year. A total of 142 samples were collected under different forms. They were evaluated for quality following the same procedure adopted for experimentally frozen prawns.

The nucleotides and related compounds in the muscle were determined by High Performance Liquid Chromatography (Ryder, 1985). Extraction of the muscle was done using 0.6M perchloric acid at 0°C and neutralised using IM KOH. It was then filtered through a Millipore (.45µm) syringe filter. Nucleotide standards and potassium phosphates were obtained from Sigma Chemical Company. All other reagents and water used were of HPLC grade. A Hewlett Packard HPLC (model 1090) and a computing integrator (model 3392 A) were used. Other conditions were the same as reported earlier (Lakshmanan, *et al.*, 1996). The individual nucleotides were calculated and K-value was computed as defined by Saito *et al.* (1959). Volatile base nitrogen (VB-N) was determined by the micro-diffusion method of Conway (1962). The sensory evaluation was carried out in raw and steamed samples by a panel of 6-8 trained staff members. The samples were tasted for flavour, texture and appearance and scored on a 10 point hedonic scale. The texture (cutting and piercing strength) was measured using a Rheotex (SD-305).

RESULTS AND DISCUSSION

The results of the study are presented in Tables 1 to 7. The values are a mean of three determinations. The initial levels of nucleotide concentration in the two species of cultured prawns were respectively, 13.45 µmoles/g (*P. indicus*) and 16.03µmol/g (*P. monodon*).

a) Iced storage:

Table1 describes the sensory characteristics including taste panel results of iced prawns. The variations in AMP, IMP, inosine, hypoxanthine and K-value in *P. indicus* and *P. monodon* during iced storage are given in Table2.

The initial levels of ATP and ADP in *P. indicus* were respectively, 1.72 and 2.39 µmol/g and in *P. monodon* higher levels of 4.69 and 4.86 µmol/g were obtained. However, after 1 day storage in ice, both ATP and ADP declined rapidly, and reduced to insignificant levels in both the species. They are not further discussed, but the values were used in the calculation of K-value.

During the same period, AMP increased rapidly in both species and reached maxima, (9.93±1.59) and (10.68±0.8) µmole/g in *P. indicus* and *P. monodon*, respectively. Unlike in finfish there was high accumulation of AMP in prawns. By 2 days in ice IMP level also increased (Table2) and reached its peak.

In *P. indicus*. IMP level reached 5.75 μ mol/g in 3 days and in *P. monodon* 5.12 μ mol/g at 2 days. After 24 hr AMP level declined sharply to around 5.6 μ mol/g in both the species. After 4 days in ice, both AMP and IMP levels decreased gradually, and were running in parallel (Table 2). By 10 days storage in ice AMP level fell to 2.19 and 1.8 μ mol/g in *P. monodon* and *P. indicus*, respectively. The IMP concentration also decreased gradually, in both the species, however, retained >1 μ mol/g at 14 days in *P. monodon* and 12 days in *P. indicus*. At the end of 18 days ice storage, IMP concentrations were reduced respectively to 0.53 (*P. monodon*) and 0.42 μ mol/g (*P. indicus*).

Hypoxanthine content increased slowly from an initial level of 0.04 μ mol/g, in *P. monodon* to 1.03 in 10 days, 1.71 in 14 days and reached a limiting value of 2 μ mol/g in 18 days ice storage. A similar pattern of accumulation of Hx was found in *P. indicus* as well. Thus, Hx level reached 1 μ mol/g in 10 days 1.60 in 14 days and a higher value of 2.59 μ mol/g in 18 days storage. A rapid increase of Hx in *P. indicus* at 18 days might probably be attributed to spoilage microbial activity. The inosine content also increased in the same pattern as Hx, at least upto 14 days and then decreased to 1.14 and 0.89 μ mol/g at 18 days storage, in *P. indicus* and *P. monodon*, respectively.

The K-value (KV) in the prawn muscle increased linearly with time. However, the rate of increase of KV was faster in *P. indicus* than in *P. monodon*. Thus, in *P. indicus*, KV reached around 20% in 6 days, 30% in 8 days, 40% in 10 days, 58% in 14 days and over 70% in 18 days ice storage. In *P. monodon*, the rate of increase of KV was relatively slower than in *P. indicus*. Thus, KV reached 20% in 8 days, 28% in 10 days, 46% in 14 days and over 60% in 18 days ice storage. In both species, KV increased linearly with time and hence form an index of quality. In general, KV below 25% indicated very good quality in these prawns.

According to taste panel, *P. indicus* and *P. monodon* retained their prime quality up to 6 and 8 days on ice when muscle KV reached 21.72 and 19.68% respectively. After these periods, they had reduced freshness, however, were rated good and acceptable up to 12 (*P. indicus*) and 14 days (*P. monodon*) when their K-values were respectively 44.22 and 46.52%. The prawns in prime quality had high levels of AMP and IMP, and the minimum quantity should be above 3 μ mol/g. The decline in the levels of AMP and IMP seemed to reduce flavour in the prawn muscle. Hashimoto (1965) and Jones *et al.* (1964) had observed that purine nucleotide, nucleosides and bases contribute to the flavour of fish. The prawns were acceptable to the panelists when both AMP and IMP levels were >1 μ mol/g each of muscle. Hence we would suggest that knowledge of the levels of AMP, IMP and K-value of raw prawns would determine their initial quality. For acceptable quality prawns, the K-value was in the range 40-45% in combination with (AMP+IMP) values above 2 μ mol/g. The VB-N values did not indicate any particular trend in these species. The value remained between 14 -21 mg/100g. of muscle for about 8 days and then increased to a value around 30mg/100g. However, the increase was not regular.

Saito (1964) and Suwetja *et al.* (1989) studied the accumulation of IMP and AMP in crustaceans. With no or less AMP deaminase in marine invertebrates, these authors concluded the major pathway of ATP degradation in marine invertebrates proceeds, via the adenosine pathway. Saito (1964) stated that crustaceans accumulate relatively high amounts of AMP at ice storage; which compliments the present findings. Fatima *et al.* (1981) observed an accumulation of IMP in the shrimp *P. merguensis* and established a correlation between IMP concentration and flavour as well as total sensory score.

The relatively low initial levels of IMP observed in the two species seemed to be due to low AMP deaminase activity. From the processing point of view, it has a beneficial effect in that AMP would form a continued reserve for IMP and hence would retain the sweet meaty flavour for a longer period. Sakaguchi *et al.* (1991) while studying the ice storage characteristics of oyster, observed the accumulation of AMP and IMP in the adductor muscle and proposed that two pathways are operating in ATP degradation. One involves the direct deamination of AMP to IMP, while the second involves the dephosphorylation of AMP to adenosine, then to inosine and Hx.

The high level of AMP accumulation in prawn muscle observed in the present study might be attributed to a low level of AMP deaminase in these species and we presume that both the above pathways operate in these species as AMP and IMP concentrations ran in parallel during ice storage.

b) Frozen storage:

Table 3 shows the average variations in AMP, IMP, Hx and K-value in *P. indicus* and *P. monodon* during frozen storage. In frozen samples also there were high AMP and IMP accumulations, in both the species. The maxima were observed during the first month and thereafter both the components started declining, AMP more sharply than IMP. The pattern of nucleotide changes were similar in both species. AMP and IMP levels remained high during frozen storage and in *P. monodon* their levels were around 1.5 $\mu\text{mol/g}$ each and in *P. indicus*, their levels were respectively, 1.16 and 0.74 $\mu\text{mol/g}$. Hx concentration increased steadily, but slowly in *P. indicus* from an initial level of .08 to 2.2 $\mu\text{mol/g}$ in 12 months storage. In *P. monodon* it rose from 0.06 to 1.78 $\mu\text{mol/g}$ during the same period. K-value in both the prawns increased slowly and steadily; reached around 20% in 3 months (Table 4). In *P. indicus* KV reached 32.8% in 5 months 46.3% in 8 months and over 60% during 1 year of frozen storage. In *P. monodon*, the KV was 33% in 5 months, reached 40.31 in 8 months and 58.6% during 1 year frozen storage. Instrumental texture measurements showed toughening of texture in prawn muscle during storage (Table 3). The muscle pH also increased in both the prawns during frozen storage - from 6.60 to 7.60 during 1 year period (Table 3). TVB-N values did not exhibit a regular increase; after an initial increase during the first month, the values fluctuated between 25 to 30 mg/100g upto 10 months in both the species (Table 5), probably due to the inactivation of spoilage organisms. Cutting and piercing strength in cooked prawns increased considerably during storage period (Table 3).

Sensory evaluation (Taste panel study) of the steamed samples judged them as good with sweet meaty flavour and soft firm texture, when the samples had high IMP and AMP levels ($>2 \mu\text{mol/g}$) in them. Both the species retained their characteristic flavour and texture upto 8 months when the K-values were 40.3% in *P. monodon* and 46.3% in *P. indicus*. However, the samples were acceptable to the panelists up to 12 months.

Regression analysis of storage time and overall acceptability score with K-value showed significant relations in both the species (Table 7). KV showed significant positive correlation with storage time and negative correlation with sensory scores. A good correlation exists between overall sensory score and IMP level, the sum of (AMP+IMP) and Hx level. K-value and the concentrations of IMP and AMP seemed good indices of prawn quality. The level of AMP and IMP in the muscle of frozen prawns would also indicate the initial quality of the raw material before freezing. Kiesv. ara-et al (1990) also remarked that K-value and IMP concentrations can determine the quality of fish.

c) Commercial frozen prawns

The quality of commercial samples of frozen prawns was evaluated by determining nucleotide degradation products, K-value and sensory assessment and classified into three grades. The criteria used in grading the prawns were sensory characteristics including score and objective parameters, namely AMP, IMP, Hx levels and K-value. Samples with K-value $<25\%$ with AMP and IMP levels $\geq 3 \mu\text{mol/g}$ are classified as grade I. These samples are excellent in appearance and have, sweet flavour and soft firm texture. In grade II samples K-value is proposed to be in the range of <25 to $\leq 45\%$ with good sweet meaty flavour soft firm texture. Samples with K-value in the range of <45 to $\cong 60\%$ was classified as grade III. The sample is fair to bleached appearance, has slight rancid flavour and tough texture. In all cases, the K-value in combination with AMP and IMP levels helps validate the sensory scores.

The results of the study are presented in tables (6 a and b). In general, frozen prawns from the industry consists in 30% grade I; 50% grade II and 20% grade III, taking the three forms together. The HL prawns had retained much of the quality attributes compared to FUD and PD prawns. Around 40% of the Frozen HL prawns were rated grade I quality. They had higher levels of both AMP and IMP ($>4 \mu\text{mol/g}$ each) and an average sensory score of 8.4. The Hx content ($\cong 0.74 \mu\text{mol/g}$) and TVB-N (28.4 mg/100g) were below the threshold limit. In grade II, (47.41%) HL prawns, the average K-value was 43.6% with significant amounts of AMP and IMP; and had sweet meaty flavour. However, 12.6% of Fz HL prawns were rated grade III, with bitter flavour and tough and rubbery texture. The bland taste may be due to the low levels of AMP and IMP ($<1 \mu\text{mol/g}$) in the muscle. K-value had reached around 60% with high TVB-N value (average=37.13 mg/100g). The percentage contributions of PUD and PandD prawns to the three grades indicate that more

samples were shifted to grade II and III compared to HL prawns (Table 6a and b). The levels of nucleotide products and TVB-N were relatively lower in PUD and PD prawns and consequently a reduced sensory score. In general, frozen HL prawns from the trade had higher levels of flavour attributes (AMP and IMP content) and hence a better sensory score than the other two forms.

Matsumoto and Yamanaka (1990) found that there was a linear increase of K-value in Kuruma prawns, with storage and hence could be useful as index for freshness of prawns. Yamanaka and Shimada (1996), while studying the ice storage life of Japanese spiny lobster, observed that AMP accumulated in the muscle, immediately after storage, while IMP, Inosine and Hx increased during storage. They proposed that K-value and ornithine were useful as potential indices for freshness and decomposition of Japanese spiny lobster.

The overall acceptability score in the prawns was closely related to IMP level or sum of (AMP+IMP) and K-value. A high level of IMP and AMP indicated shrimp of good quality and as Hx content or % K-value increase, the quality tend to become poorer. It would appear that measurement of IMP, AMP and K-value would prove good objective quality indices for the Seafood Industry to validate the sensory assessment.

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Table 1. Changes in the sensory characteristics of *P. indicus* and *P. monodon* during iced storage.

| Days | 0 | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 18 |
|--------------------------|---|-------------------------------|--------------------------------|--------------------------------|---------------------------|------------------------------|------------------------------|---|--|
| <i>P. indicus</i> | | | | | | | | | |
| Raw | Bright, shining, fresh sea | Bright, shining | Appearance and odour very good | Slightly tough, good odour | No discoloration | Slightly faded, no off odour | Slightly bleached appearance | Bleached appearance, slight off odour, few black pieces | Bleached appearance, soft blackening |
| Cooked | Sweet, juicy, soft and firm | Sweet, meaty, soft and firm | Flavour and texture good | Appearance and odour very good | Appearance and odour good | Good appearance | Slightly faded appearance | Odour and appearance satisfactory | Bleached appearance, few black spots, slight off odour |
| Overall score | 9.4±.5 | 9.10±.6 | 8.50±.5 | 8.0±.4 | 7.6±.5 | 6.8±.6 | 6.1±.6 | 5.6 | 4.4±.5 |
| <i>P. monodon</i> | | | | | | | | | |
| Raw | Bright, shining, fresh sea, weedy odour | Bright, shining | Appearance and odour very good | Appearance and odour good | Appearance and odour good | Good appearance | Slightly faded appearance | Odour and appearance satisfactory | Bleached appearance, few black spots, slight off odour |
| Cooked | Sweet, juicy, soft, firm | Very good flavour and texture | Sweet, soft and firm | Good flavour and texture | Sweet, soft and firm | Good flavour and texture | Slightly tough, bland | Bland, no off odour, tough texture | Tough texture, slight off odour |
| Score | 9.6±0.4 | 9.0±0.5 | 8.6±0.6 | 8.2±0.4 | 7.9±0.5 | 7.1±0.4 | 6.6±0.5 | 6.0±0.6 | 4.8±0.5 |

Table 2. Changes in AMP, IMP, inosine, hypoxanthine ($\mu\text{mol/g}\pm\text{S.D}$) and K-value (%) in prawns, *Penaeus indicus* and *P. monodon* during ice storage.

| Parameter | Time (days) | | | | | | | | | |
|-------------------|--------------------|---------------------|--------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|
| | 0 | 1 | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 18 |
| P. indicus | | | | | | | | | | |
| AMP | 5.82 ± 1.90 | 9.93 ± 1.60 | 5.60 ± 0.72 | 3.82 ± 0.60 | 3.09 ± 0.47 | 2.71 ± 0.43 | 1.80 ± 0.12 | 1.09 ± 0.11 | 0.68 ± 0.10 | 0.45 ± 0.03 |
| IMP | 3.19 ± 2.32 | 3.79 ± 2.21 | 5.14 ± 0.81 | 4.07 ± 0.55 | 3.43 ± 0.51 | 2.68 ± 0.20 | 1.79 ± 0.27 | 1.26 ± 0.14 | 0.72 ± 0.08 | 0.42 ± 0.02 |
| Inosine | 0.33 ± 0.29 | 0.42 ± 0.14 | 0.48 ± 0.18 | 0.55 ± 0.16 | 0.77 ± 0.10 | 1.14 ± 0.08 | 1.33 ± 0.10 | 1.17 ± 0.30 | 1.26 ± 0.40 | 1.14 ± 0.20 |
| Hypo-xanthine | 0.12 ± 0.10 | 0.19 ± 0.12 | 0.36 ± 0.12 | 0.62 ± 0.10 | 0.85 ± 0.05 | 0.89 ± 0.08 | 0.98 ± 0.04 | 1.19 ± 0.06 | 1.60 ± 0.10 | 2.59 ± 0.18 |
| K-value | 2.59 ± 2.73 | 4.28 ± 2.15 | 7.35 ± 0.94 | 13.35 ± 2.44 | 21.72 ± 1.45 | 32.18 ± 3.70 | 40.71 ± 1.62 | 44.22 ± 1.65 | 49.10 ± 2.10 | 74.57 ± 1.54 |
| P. Monodon | | | | | | | | | | |
| AMP | 5.45 ± 0.17 | 10.68 ± 0.82 | 5.58 ± 0.75 | 4.21 ± 0.31 | 3.49 ± 0.45 | 3.08 ± 0.11 | 2.12 ± 0.23 | 1.75 ± 0.12 | 1.45 ± 0.12 | 1.12 ± 0.03 |
| IMP | 0.60 ± 0.24 | 3.52 ± 2.00 | 5.12 ± 0.25 | 3.70 ± 0.14 | 3.42 ± 0.30 | 2.94 ± 0.32 | 2.29 ± 0.40 | 1.87 ± 0.12 | 1.38 ± 0.12 | 0.53 ± 0.02 |
| Inosine | 0.04 ± 0.02 | 0.21 ± 0.11 | 0.57 ± 0.19 | 0.68 ± 0.20 | 0.80 ± 0.15 | 0.88 ± 0.07 | 1.03 ± 0.24 | 1.31 ± 0.09 | 1.44 ± 0.09 | 0.89 ± 0.02 |
| Hypo-xanthine | 0.04 ± 0.12 | 0.12 ± 0.05 | 0.31 ± 0.06 | 0.57 ± 0.04 | 0.60 ± 0.07 | 0.94 ± 0.12 | 1.03 ± 0.10 | 1.25 ± 0.05 | 1.71 ± 0.05 | 1.96 ± 0.05 |
| K-value | 0.30 | 2.10 ± 1.54 | 7.13 ± 0.14 | 12.74 ± 0.40 | 16.10 ± 0.24 | 19.68 ± 1.28 | 27.90 ± 0.50 | 35.85 ± 1.64 | 46.50 ± 1.30 | 63.40 ± 1.45 |

Table 3. Changes in the physical and sensory characteristics of *P. indicus* and *P. monodon* during storage at -18°C.

| <i>P. indicus</i> | | | | | | | | | | | | |
|----------------------------|------------------------------------|-------------------------------|------------------------------------|------------------------------|--------------------------|-----------------------------|----------------------------|-----------------------|-----------------------|--|--|--|
| Months | 0 | 1 | 2 | 3 | 5 | 6 | 8 | 10 | 12 | | | |
| 1. pH | 6.60 | 6.94 | 7.05 | 7.14 | 7.20 | 6.98 | 7.18 | 7.3 | 7.40 | | | |
| 2. Textro meter reading | | | | | | | | | | | | |
| a. Cutting strength, g | 54±8.6 | 66 ±6 | 48.8±6.5 | 56.7±5 | 50±4 | 46±6 | 44±11 | 40±10 | 36±8 | | | |
| Raw | 365±18.4 | 460±12 | 416±6 | 487±12 | 501±8 | 494±7.5 | 514±16 | 519±11 | 526±14 | | | |
| b. Piercing strength, g | 54±6.5 | 46±8 | 56±4 | 44±6 | 52±5 | 48±6 | 47±8 | 41±8 | 42±6 | | | |
| Raw | 78±5.6 | 98±5 | 101.4±10.2 | 93±8 | 96±6 | 94±5 | 97±7 | 103±14 | 97±8 | | | |
| Cooked | Very good flavour, soft and firm | Very good flavour and texture | Good flavour, soft and firm | Sweet flavour, soft and firm | Good flavour and texture | Good flavour and texture | Less sweet, slightly tough | Bland, Slightly tough | Tough Slightly bitter | | | |
| 3. Sensory characteristics | 9.4±.5 | 8.8±.6 | 8.4±.5 | 8.0±0.7 | 7.6±0.8 | 7.1±0.6 | 6.8±0.5 | 6.0±.6 | 4.8±.6 | | | |
| 4. Average score | | | | | | | | | | | | |
| <i>P. monodon</i> | | | | | | | | | | | | |
| 1. pH | 6.68 | 7.04 | 7.12 | 7.16 | 7.20 | 7.24 | 7.30 | 7.4 | 7.6 | | | |
| 2. Textro meter reading | | | | | | | | | | | | |
| a. Cutting strength, g | 58±13.7 | 56.3±12.5 | 48.6±4.8 | 52.6±5 | 59.7±9.9 | 64±7 | 440.7±6.5 | 9.7±9.8 | 54.7±16.5389 | | | |
| Raw | 320±25 | 345±18 | 449±38.6 | 480±36 | 477±44 | 493±23 | 511±18 | 523±12 | ±17 | | | |
| b. Piercing strength, g | 44±3.4 | 35.4±9.8 | 40±7.9 | 39.6±6 | 40.4±4.1 | 25.7±5.9 | 30.5±6 | 44±7.9 | 40.4±7.6 | | | |
| Raw | 78±6.3 | 86.7±21 | 90.4±15.7 | 88.4±7 | 104.2±12 | 94.2±12 | 102.45±27 | 105±6.5 | 93.4±21 | | | |
| Cooked | Sweet meaty flavour, soft and firm | Very good flavour and texture | Sweet meaty flavour, soft and firm | Sweet flavour, soft and firm | Good flavour and texture | Good flavour, soft and firm | Less sweet, slightly tough | Slightly tough | Bland, tough | | | |
| 3. Sensory characteristics | 9.6±0.4 | 9.0±.6 | 8.5±0.7 | 8.2±0.5 | 8.0±0.55 | 7.5±0.5 | 6.8±0.6 | 6.1±0.4 | 5.1±0.5 | | | |
| 4. Score | | | | | | | | | | | | |

Table 4. Changes in AMP, IMP, inosine, hypoxanthine ($\mu\text{mol/g} \pm \text{S.D}$) and K-value (%) in the prawns *Penaeus indicus* and *P. monodon* during frozen storage below (-18C).

| Parameter | Storage time, months | | | | | | | | | |
|--------------|----------------------|--------------------|---------------------|---------------------|--------------------|--------------------|--------------------|--------------------|---------------------|--|
| | <i>P. indicus</i> | | | | | | | | | |
| | Initial (0) | 1 | 2 | 3 | 5 | 6 | 8 | 10 | 12 | |
| AMP | 8.41 ± 1.60 | 6.69 ± 2.12 | 5.67 ± 1.30 | 4.48 ± 1.15 | 2.81 ± 0.75 | 2.24 ± 0.35 | 1.48 ± 0.21 | 1.20 ± 0.24 | 0.74 ± 0.13 | |
| IMP | 4.60 ± 1.20 | 5.74 ± 0.80 | 5.11 ± 0.60 | 4.64 ± 0.78 | 4.03 ± 0.65 | 3.64 ± 0.44 | 2.75 ± 0.38 | 1.92 ± 0.50 | 1.16 ± 0.12 | |
| Inosine | 0.28 ± 0.08 | 0.81 ± 0.20 | 1.33 ± 0.28 | 1.34 ± 0.40 | 1.67 ± 0.50 | 2.09 ± 0.60 | 1.90 ± 0.48 | 2.02 ± 0.45 | 1.58 ± 0.34 | |
| Hypoxanthine | 0.08 ± 0.03 | 0.35 ± 0.08 | 0.62 ± 0.12 | 0.85 ± 0.20 | 1.16 ± 0.24 | 1.35 ± 0.30 | 1.60 ± 0.31 | 1.94 ± 0.40 | 2.20 ± 0.42 | |
| KV | 2.60 | 8.2 | 14.6 ± 1.1 | 21.7 ± 1.2 | 32.8 ± 1.4 | 38.4 ± 1.4 | 46.3 ± 1.6 | 52.2 ± 1.5 | 60.2 ± 2.1 | |
| | <i>P. monodon</i> | | | | | | | | | |
| AMP | 5.40 ± 1.23 | 6.80 ± 1.35 | 5.20 ± 1.10 | 4.12 ± 0.83 | 2.38 ± 0.46 | 1.88 ± 0.44 | 1.65 ± 0.30 | 1.52 ± 0.24 | 1.48 ± 0.20 | |
| IMP | 0.46 ± 0.10 | 4.57 ± 0.80 | 4.01 ± 0.65 | 3.56 ± 0.74 | 2.74 ± 0.38 | 2.30 ± 0.24 | 1.96 ± 0.20 | 1.70 ± 0.20 | 1.53 ± 0.28 | |
| Inosine | 0.04 ± 0.06 | 0.66 ± 0.10 | 0.90 ± 0.22 | 1.60 ± 0.25 | 1.46 ± 0.30 | 1.44 ± 0.20 | 1.44 ± 0.20 | 2.01 ± 0.22 | 3.33 ± 0.24 | |
| Hypoxanthine | 0.06 ± 0.06 | 0.31 ± 0.06 | 0.56 ± 0.10 | 0.82 ± 0.16 | 1.10 ± 0.22 | 1.25 ± 0.21 | 1.40 ± 0.18 | 1.63 ± 0.20 | 1.78 ± 0.34 | |
| KV | 1.50 | 7.57 | 12.92 ± 0.74 | 22.60 ± 1.45 | 33.11 ± 1.8 | 35.90 ± 1.6 | 40.30 ± 2.4 | 48.74 ± 2.8 | 58.60 ± 2.60 | |

Table 5. Changes in TVB-N (mg/100g) values in *P. indicus* and *P. monodon* during ice and frozen storage.

| Time (days) | Iced storage | | Time (months) | Frozen storage | |
|-------------|-------------------|-------------------|---------------|-------------------|-------------------|
| | <i>P. indicus</i> | <i>P. monodon</i> | | <i>P. indicus</i> | <i>P. monodon</i> |
| Initial(0) | 16.60 \pm 0.8 | 14.59 \pm 0.5 | Initial (0) | 16.60 \pm 0.8 | 14.59.0.5 |
| 1 | 17.82 \pm 0.6 | 16.45 \pm 0.4 | 1 | 18.40 \pm 1.2 | 21.67 \pm 0.7 |
| 2 | 16.90 \pm 0.5 | 17.10 \pm 0.6 | 2 | 23.64 \pm 0.7 | 24.75 \pm 0.6 |
| 4 | 18.45 \pm 0.4 | 17.84 \pm 0.5 | 3 | 28.30 \pm 1.1 | 26.67 \pm 0.5 |
| 6 | 20.60 \pm 0.5 | 21.75 \pm 0.7 | 5 | 30.43 \pm 0.5 | 28.50 \pm 0.5 |
| 8 | 22.47 \pm 0.6 | 20.90 \pm 0.8 | 6 | 29.60 \pm 0.8 | 29.70 \pm 0.7 |
| 12 | 25.71 \pm 0.8 | 22.40 \pm 0.7 | 8 | 30.50 \pm 1.1 | 28.60 \pm 0.6 |
| 14 | 27.50 \pm 0.6 | 25.36 \pm 0.4 | 10 | 33.70 \pm 1.3 | 32.40 \pm 0.7 |
| 18 | 30.25 \pm 0.7 | 28.94 \pm 0.6 | 12 | 37.85 \pm 1.2 | 38.75 \pm 0.6 |

Table 6 a. Quality levels of commercially frozen prawns collected from the Industry.

Physical and Sensory Characteristics

| Product | Sensory characteristics (Cooked) | Texture Measurements | | Overall score | Frequency (% sample) |
|-----------------------------|--|--------------------------|-----------------------|---------------|----------------------|
| | | Cutting strength 'g' | Piercing strength 'g' | | |
| HL Prawns (n=38) Grade I | Excellent appear. sweet meaty flavour. soft and firm texture | *R =58±13.7 *C=420±25 | R=54±03.4 C=78±6.3 | 8.4 ±.3 | 40 |
| Grade II | good. Sweet and meaty flavour . Sl. tough texture | R= 66±6 C=460±12 | R=46±8 C=98±7 | 6.8 ±.4 | 47.4 |
| Grade III | Fair to poor. sl. bitter flavour tough and rubbery | R=75±6.8 c=510±6.5 | R=28±6 C124±8 | 4.8 ±.3 | 12.6 |
| PUD (n=60) Grade I | Very good appear. Sweet meaty flavour firm and soft texture. | R=72±11 C=408±8 | R=35±4 C=87±6 | 8.10 ±.34 | 30 |
| Grade II | Good. Less sweet sl. Soft texture | R=89±13 C=509±10 | R=47±5 C116±7 | 6.60 ±.35 | 51.7 |
| Grade III | Fair to bleached appear. Sl rancid flavour rubbery texture Fair to poor. | R=86±14 C=511±12 | R=45±4 C=128±6 | 4.5 ±.4 | 18.3 |
| PandD (n=44) Grade I | Very good appearance. Sweet and meaty flavour good texture | R=69±7 C=416±6 | R=56±8 C=1014 | 8.14 ±.20 | 18.2 |
| Grade II | Good, less sweet. Sl. Tough texture | R=74±8 C=469±11 | R=47±4 C=126±12 | 6.20 ±.31 | 54.5 |
| Grade III | Fair to poor sl. Rancid flavour hard and rubbery texture | R=77±8 C=530±14 | R=48±5 C=148±6 | 4.10 ±.20 | 27.3 |

*R - raw sample

*C - cooked.

Table 6 b. Quality levels of commercially frozen prawns collected from the Industry.

Chemical characteristics

| Product | μmol/g | | | | KV(%) | mg/100g TVB-N |
|----------------------------|---------------|---------------|---------------|---------------|---------------|------------------|
| | AMP | IMP | Inosine | Hx | | |
| <u>HL-Prawns</u> (n=38) | | | | | | |
| Grade I | 5.97 ±1.56 | 4.15 ±1.60 | 1.24 ±0.40 | 0.74 ±.25 | 24.6 ±7.2 | 28.4 ±2.1 |
| Grade II | 2.00 ±.72 | 1.74 ±0.84 | 1.76 ±0.44 | 1.23 ±.34 | 43.6 ±8.5 | 35.2 ±2.5 |
| Grade III | 0.77 ±0.48 | 0.62 ±0.40 | 2.08 ±0.36 | 1.70 ±0.64 | 59.5 ±7.8 | 37.1 ±3.3 |
| <u>PUD(n=60)</u> | | | | | | |
| Grade I | 3.76 ±1.36 | 4.06 ±1.50 | 1.50 ±0.30 | 0.42 ±.22 | 22.9 ±6.2 | 21.5 ±2.2 |
| Grade II | 1.68 ±0.57 | 1.96 ±1.60 | 1.86 ±0.44 | 0.92 ±0.48 | 38.5 ±7.6 | 25.3 ±3.4 |
| Grade III | 0.64 ±.40 | 0.46 ±0.38 | 1.78 ±.54 | 1.72 ±.67 | 61.5 ±11.3 | 38.5 ±3.7 |
| <u>PandD</u> (n=44) | | | | | | |
| Grade I | 3.54 ±1.30 | 3.94 ±1.40 | 1.58 ±0.28 | 0.58 ±.30 | 24.5 ±5.2 | 23.7 ±3.2 |
| Grade II | 1.60 ±0.60 | 1.68 ±1.30 | 1.74 ±.80 | 0.96 ±.54 | 36.5 ±8.6 | 28.4 ±3.5 |
| Grade III | 0.72 ±.38 | 0.52 ±0.32 | 1.69 ±0.76 | 1.78 ±0.60 | 57.84 ±9.2 | 34.2 ±5.4 |

Table 7. Correlation coefficient of storage time, sensory score, K-value and nucleotide degradation products in *P. indicus* and *P. monodon* during ice storage.

| | Overall score | Storage time |
|--------------------------|----------------------|---------------------|
| <i>P. indicus</i> (n=27) | | |
| K-value | -0.9605 ^a | 0.9886 ^a |
| IMP level | 0.9220 ^a | - |
| (IMP+AMP) | 0.9150 ^a | - |
| Hx | -0.8890 ^b | - |
| <i>P. monodon</i> (n=27) | | |
| K-value | -0.9624 ^a | 0.9896 ^a |
| IMP level | 0.8276 ^b | |
| (IMP+AMP) | 0.8535 ^b | |
| Hx | -0.9549 ^a | |

Level of significance a = 0.1%, b = 1.0%.