# PRESERVATION OF PRAWNS IN ICE AND THE ASSESSMENT OF THEIR QUALITY BY OBJECTIVE STANDARDS

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Prawns and other crustaceans contribute about 15% of the total marine fish landings in India. Our present annual production of prawns is over 100,000 tons, ranking next only to that of the U.S.A. Large quantities of prawns are preserved by sundrying after previously boiling in salt solution for the internal market as well as for export to Ceylon, Burma and Malaya. A relatively small fraction is sent in ice to inland towns by rail or other conveyance. In recent years a considerably valuable trade in export of frozen prawns and lobsters to the U.S.A. has developed. Adequate supplies of prawns in prime condition to meet the demand of the several freezing plants on the West Coast are required. The existing prawn fishery is based mainly on the backwaters and saline lake areas; the marine fishery is little developed and is restricted to coastal waters not exceeding 10 fathoms depth. But there are possibilities of obtaining commercial catches from deeper water (30–40 fathoms) by modern trawling methods. Besides the marine resources, the paddy-field prawn cultivation also affords vast possibilities of increasing our prawn production. The increasing exploitation of these resources has to be accompanied by the adoption of modern preservation methods such as freezing, canning, etc., in order to derive the maximum benefit. In the inshore fishing conditions the prawn landings are scattered along the coast and this necessitates their transport in ice to the processing plants. Catches of prawns made by vessels operating farther off from land need to be iced on board in order to prevent their spoiling during the return voyage. Extensive use of ice for preserving prawns is necessary not only for providing good quality raw material for the processing plants engaged in the export trade but also for increasing the consumption of prawns in our own country. For, as Panikkar (1937) mentioned even as early as in 1937, .... in popularising prawns in Indian markets methods which will enable their being sold fresh are likely to meet with better results than the dried material.....'

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The flavour and palatability of prawns stored in ice undergo changes during storage. The need for objective assessment of the quality of prawns stored in the ice has been felt by the industry for effecting a proper distribution and processing of the available material. Quality control is essential at all stages in the production of frozen prawns for export. Fieger and his associates (Fieger and Friloux, 1954; Bailey, Fieger and Novak, 1956; Alford and Fieger, 1952; Bailey and Fieger, 1954; Fieger, Bailey and Novak, 1956) have carried out considerable work on these aspects of the shrimp industry in the U.S.A. Deteriorative changes occurring in ice storage are related to the duration of storage and are also influenced by the treatment of the prawns before icing, the species and the environment from which they are taken. Hence it appeared necessary in the first instance to carry out observations on the keeping quality of Indian prawns stored in ice and the applicability of some of the objective tests for quality employed by the U.S.A. workers. The results of an exploratory study made on these lines are reported in this paper.

## Materials and Methods

The prawns used in these studies were obtained fresh from landing places near Mandapam and also from Cochin on the West Coast. The prawns were washed with freshwater before storing in ice. The prawns were stored with the head and shell on except when otherwise stated. At suitable intervals the prawns were sampled and the trimethylamine (TMA), total volatile nitrogen (T.V.N.) content and the bacterial count determined according to procedures described in a previous publication (Velankar, 1952). The free $\alpha$-amino acid nitrogen and the acid-soluble orthophosphate were determined as follows:

(*a*) Free $\alpha$-amino acid nitrogen: An accurately weighed quantity (ca 20 g.) of the muscle was minced with 50 ml. of distilled water in a Waring blender for 2 minutes. The pasty mass was transferred quantitatively into a 500 ml. beaker with the help of distilled water, 20 ml. of an aqueous solution of trichloroacetic acid added and mixed well by stirring. It was then filtered into a 250 ml. standard flask and the precipitate washed repeatedly with 1% trichloroacetic acid solution. The filtrate and washings were made up to 250 ml., and a 50 ml. aliquot of this solution was neutralised to thymolphthalein with N sodium hydroxide. The $\alpha$-amino acid nitrogen was then determined in this aliquot by the method of Pope and Stevens (1939).

(*b*) Orthophosphate: 5 ml. of the trichloroacetic acid extract from (*a*) above was diluted to 50 ml. in a standard flask with distilled water, 0·5 ml. aliquot of this was diluted further to 100 ml. and the orthophos-

phate in this final dilution was determined by the method described for sea-water by Harvey (1945). The correction factor described for the salt contained in sea-water was not applied. The colour was compared visually since the values thus obtained were found to be in good agreement with values obtained employing the photoelectric colorimeter.

## RESULTS

The observations on two batches of prawns obtained locally and stored in ice in the whole condition for about a week are shown in Tables I and II.

TABLE I

*Prawns* (Penæus indicus) *from Dhanushkodi iced 4 hours after landing, kept whole*

(Count: 40 to the lb.)

| Days in ice | *TMA (mg. N/100 gm. muscle) | T.V.N. | Bacterial Count (per gm. muscle) | % Darkened |
|---|---|---|---|---|
| 0 | 0–1·2 | 9·7–14·5 | .. | Nil |
| 1 | 0–0·5 | 8·0–21·0 | .. | Less than 5 |
| 2 | 0–0·8 | 11·0–23·0 | .. | ,, |
| 3 | 0–0·5 | 10·0–17·2 | 2,330 (Sea-water agar) Less than 100 (Freshwater agar) | 5 |
| 6 | 0–0·8 | 9·0–21·0 | | |
| 6 | 0–0·8 | 9·0–21·0 | 29,000 (Sea-water agar) 1,000 (Freshwater agar) | 15 |

* Four individual prawns sampled.

The TMA, T.V.N. and the bacterial count were determined during the storage. While the TMA values of individual prawns showed some scattering the increase during one week was negligible. The T.V.N. also did not increase. The bacterial count remained low. Some darkening of the prawns was perceived from the third day of storage and in one week about 40% had darkened. No off-odours were noticed at the end of the week's duration.

TABLE II

*Prawns from near Mandapam* (P. indicus), *kept whole in ice*

(Count: 38 to the lb.)

| Days in ice | *TMA (mg. N/100 gm. muscle) | T.V.N. | Bacterial Count (per gm. muscle) | % Darkened |
|---|---|---|---|---|
| 0 | 0–1·0 | 9·0–12·0 | .. | Nil |
| 5 | 0–0·6 | 10·0–13·2 | 83,000 (Sea-water agar) 9,000 (Freshwater agar) | 20 |
| 8 | 0–0·65 | 8·0–17·5 | 134,000 (Sea-water agar) 12,000 (Freshwater agar) | 25 |

* Four individual prawns sampled.

In a second series batches of prawns were kept in ice in whole condition and the observations were carried out for about two weeks, and the acid-soluble orthophosphate was determined in addition to the TMA, T.V.N. and the bacterial count. The results are given in Tables III, IV and V. The bacterial count reached the order of 1 million per gm. after about 15 days' storage; the TMA increased very slowly and some irregularity was also seen in the TMA values in one experiment, *i.e.*, after 25 days' storage no TMA was found. The phosphate decreased very rapidly in the first four or five days and values reached after this period were less than 100 mg. P/100 gm. muscle. In one experiment, however, the values remained about 100 up to 10 days. In prawns kept at 3° C. (without ice) also, phosphate decreased during storage.

In the third set of observations the prawns were brought from Cochin from catches made by the Norwegian* mechanised vessels operating about 4 miles South-West of Cochin port, at 9–10 fathoms depth. These prawns were iced immediately on board the vessel and transported in ice in an insulated box by rail to Mandapam (nearly 24 hours transit period). This catch consisted mainly of *Metapenæus affinis*, with *Penæus indicus* next in abundance. On reaching Mandapam, 48 hours after being taken from the sea, the prawns

* The vessels operated under the Indo-Norwegian Project.

TABLE III

*Prawns from near Mandapam* (P. indicus) *kept whole in ice*

(Count: 40 to the lb.)

| Days in ice | *Phosphate *(mg. P/100 gm. muscle) | *TMA (mg. N/100 gm. muscle) | T.V.N. | Bacterial Count (per gm. muscle) | % Darkened |
|---|---|---|---|---|---|
| 0 | 218·3 | Nil | 9·5 | .. | Nil |
| 1 | 163·5 | .. | .. | .. | ,, |
| 3 | 105·6 | .. | .. | .. | 5 |
| 4 | 96·4 | .. | .. | .. | ,, |
| 5 | 90·6 | Nil | 10·2 | 32,000 | 10 |
| 6 | 72·5 | .. | .. | .. | ,, |
| 8 | 66·8 | Nil | 12·5 | 144,00 | 30 |
| 10 | 45·2 | .. | .. | .. | ,, |
| 11 | 36·7 | .. | .. | .. | 40. |
| 15 | 23·5 | 2·2 | 13·0 | 1,250,000 | Over 70 |

* Composite sample of the muscle of three prawns.

were in excellent condition and tasted quite fresh when eaten. One lot was kept in the round, and another with the heads removed, in ice for storage studies. Duplicate lots of round and headed prawns were also kept at 3° C. (without ice) for a comparative study. Observations were carried out as in the previous experiment (Table VI).

The TMA did not increase significantly during nearly two weeks and the T.V.N. did not increase to more than 20 mg. N./100 gm. even in three weeks. The bacterial count increased significantly after two weeks. There were no significant differences in the round and headed prawns kept in ice during the two-week period except in the incidence of blackening. The headed prawns showed little discolouration even after two weeks, but over 70% of the round prawns had darkened in 8 days. Even in the lot kept at 3° C. (without ice) the headed prawns were affected to a much less extent than the round prawns. The phosphate decreased during the storage as in the previous experiments. The prawns kept at 3° C. were obviously

TABLE IV

*Prawns from near Mandapam* (P. indicus) *kept whole in ice*
(Count: 37 to the lb.)

| Days in ice | *Phosphate (mg. P/100 gm. muscle) | *TMA (mg. N/100 gm. muscle) | T.V.N. | Bacterial Count (per gm. muscle) | % Darkened |
|---|---|---|---|---|---|
| 0 | 131·6 | Nil | 6·7 | .. | Nil |
| 1 | 138·1 | .. | .. | .. | ,, |
| 2 | 116·7 | .. | .. | .. | 5 |
| 3 | 146·0 | Nil | 12·4 | .. | ,, |
| 4 | 110·6 | .. | .. | .. | 10 |
| 6 | 112·2 | 0·4 | 9·5 | 25,000 | ,, |
| 7 | 95·0 | .. | .. | .. | 15 |
| 8 | 63·4 | Nil | 8·4 | .. | 20 |
| 9 | 96·2 | .. | .. | .. | ,, |
| 10 | 101·0 | 0·47 | 12·0 | 79,000 | 30 |
| 11 | 75·7 | .. | .. | .. | 35 |
| 14 | 59·3 | .. | .. | .. | 40 |
| 15 | 51·2 | 1·2 | 13·6 | 2,300,000 | over 50 |
| 17 | 40·7 | .. | .. | .. | over 70 |

* Composite sample of the muscle of 3 prawns.

TABLE V

*Prawns from near Mandapam* (Penæus indicus) *kept whole in ice and at* 3° *C. (without ice)*
(Count: 38 to the lb.)

| No. of days | TMA (mg. N/100 gm. muscle) | T.V.N. | Orthophosphate (mg. P/100 gm. muscle) | Bacterial Count (per gm. muscle) | % Darkened |
|---|---|---|---|---|---|
| 0 | Nil | 11·5 | 137·3 | .. | Nil |
| 1 (ice) | 0·5 | 13·5 | 87·04 | .. | ,, |
| 3° C. | 0·6 | 20·0 | 92·06 | .. | ,, |
| 3 (ice) | 0·3 | 13·6 | 90·56 | .. | 10 |
| 3.3° C.* | 0·8 | 16·0 | 112·60 | .. | 50 |
| 5 (ice) | 0·4 | 15·6 | 87·0 | 66,000 | 20 |
| 8 (ice) | 0·8 | 14·5 | 62·8 | 180,000 | 30 |
| 14 | 1·0 | 19·2 | 46·67 | 189,000 | 75 |
| 17 | 1·8 | 17·2 | 47·35 | 2,500,000 | All dark |
| 25 | Nil | 8·2 | 23·4 | .. | .. |

* Prawns kept at 3° C. gave bad smell. *Discarded.*

TABLE VI

*Cochin prawns kept whole and beheaded in ice and at* 3° *C.* (*Mainly* Metapenæus affinis, *with* Penæus indicus *next in abundance*)

(Count: 26 to 28 to the lb.)

| Days in ice | | Phosphate (mg. P/100 gm. muscle) | TMA (mg. N/100 gm. muscle) | T.V.N. | Bacterial Count (per gm. muscle) | % Darkening |
|---|---|---|---|---|---|---|
| 2. | | 180·9 | Nil | 12·0 | .. | Nil |
| 3. | Whole (ice) | 90·14 | Nil | 11·0 | 13,300 | Less than 5 |
| | Headed (ice) | 88·82 | .. | .. | .. | Nil |
| | Whole 3° C. | 81·7 | Nil | 12·5 | 12,500 | 20 |
| | Headed ,, | 93·9 | .. | .. | .. | Nil |
| 5. | W. (ice) | 83·8 | 0·98 | .. | .. | 10 |
| | H. ,, | 88·8 | 0·70 | .. | .. | Nil |
| | W. 3° C. | 94·84 | 1·01 | .. | .. | 70 |
| | H. ,, | 87·94 | 0·91 | .. | .. | Nil |
| 7. | W. (ice) | 75·63 | 0·98 | .. | 89,000 | 35 |
| | H. ,, | 56·79 | 0·59 | .. | .. | Less than 5 |
| | W. 3° C. | 65·34 | 1·98 | .. | 980,000 | Over 80 |
| | *H. ,, | 78·87 | 1·00 | .. | .. | 10 |
| 8. | W. (ice) | 69·7 | .. | .. | .. | 50 |
| | H. ,, | 80·17 | .. | .. | .. | Less than 10 |
| 9. | W. (ice) | 40·14 | .. | .. | .. | Nearly 70 |
| | H. ,, | 53·53 | .. | .. | .. | Less than 10 |
| 10. | W. (ice) | 49·6 | 0·2 | 16·4 | 103,000 | Over 80 |
| | H. ,, | 46·1 | 0·15 | 12·7 | 93,000 | Less than 20 |
| 15. | W. (ice) | 38·47 | 0·41 | 19·36 | 940,000 | All darkened |
| | H. ,, | 43·05 | 0·36 | 11·26 | 300,000 | Less than 20 |
| 18. | W. (ice) | 33·32 | .. | .. | $3{\cdot}4 \times 10^8$ | .. |
| | H. ,, | 24·52 | .. | .. | $1{\cdot}2 \times 10^8$ | Less than 20 |
| 23. | W. (ice) | .. | 5·83 | 18·69 | .. | .. |
| | H. ,, | .. | 2·95 | 13·77 | .. | Less than 20 |

* Bad smell in the prawns kept at 3° C. *Discarded.*

spoiled after 1 week as seen from the foul odour and were discarded. The water resulting from the melting ice was very dark in the case of the whole prawns while that from the headed lot was almost clear.

In the fourth set of experiments a batch of prawns obtained from Cochin as in the previous experiment was kept in ice storage with the heads removed on arrival at Mandapam. A batch of local prawns was kept in ice and observations were made. In this series in addition to the other determinations the free α-amino acid nitrogen was estimated. The results are shown in Tables VII and VIII. Two additional batches of local prawns were also

TABLE VII

*Cochin prawns (Batch No. 2)* (Metapenæus dobsonii *mainly; other spp. present* M. affinis, M. monoceros *and* Penæus indicus) *kept beheaded in ice*

(Count: 23 to 26 to the lb.)

| Days in ice | *Phosphate (mg. P/100 gm. muscle) | *Amino N. (mg. N/100 gm. muscle) | TMA (mg. N/100 gm. muscle) | *T.V.N. (mg. N/100 gm. muscle) | Bacterial Count (per gm. muscle) | % Darkened |
|---|---|---|---|---|---|---|
| 2 | 95·11 | 181·5 | .. | .. | .. | Nil |
| 3 | 82·19 | 160·0 | Nil | Nil | 147,000 | ,, |
| 4 | 96·67 | 126·6 | .. | .. | .. | ,, |
| 5 | 73·86 | 112·03 | .. | .. | .. | ,, |
| 6 | 89·14 | 102·04 | .. | .. | .. | ,, |
| 7 | 53·93 | 63·85 | Nil | 8·9 | .. | ,, |
| 8 | 59·26 | 58·25 | .. | .. | .. | 5 |
| 9 | 70·76 | 55·11 | .. | .. | .. | ,, |
| 10 | 51·81 | 52·79 | 1·11 | 8·9 | 679,000 | ,, |
| 11 | 49·41 | 43·81 | .. | .. | .. | ,, |
| 12 | 44·98 | 27·77 | .. | .. | .. | ,, |
| 16 | 40·49 | 29·41 | | | | 20 |
| 17 | .. | .. | 3·1 | 9·3 | 88 million | ,, |
| 20 | 21·43 | 4·38 | .. | .. | .. | ,, |

* Composite sample of six prawns.

TABLE VIII

*Mandapam prawns* (Penæus indicus) *kept beheaded in ice*

(Count: 36 to 38 to the lb.)

| Days in ice | *Phosphate (mg. P/100 gm. muscle) | *Amino N | *TMA (mg. N/100 gm. muscle) | *T.V.N. | Bacterial Count (per gm. muscle) | % Darkene |
|---|---|---|---|---|---|---|
| 0 | 147·1 | 282·8 | .. | .. | .. | Nil |
| 1 | 169·7 | 246·9 | .. | .. | .. | ,, |
| 2 | 158·9 | 187·6 | .. | .. | .. | ,, |
| 3 | 81·3 | 171·9 | Nil | Nil | 107,000 | ,, |
| 4 | 90·95 | 146·2 | .. | .. | .. | ,, |
| 5 | 60·95 | 110·5 | .. | .. | .. | ,, |
| 6 | 53·34 | 75·53 | .. | .. | .. | ,, |
| 7 | 64·76 | 69·9 | .. | .. | .. | ,, |
| 8 | 52·79 | 50·19 | .. | .. | .. | 2 |
| 9 | 54·44 | 55·86 | .. | .. | .. | ,, |
| 10 | 53·92 | 29·88 | Nil | 12·5 | 638,000 | 5 |
| 11 | 40·93 | 27·77 | .. | .. | .. | ,, |
| 13 | 30·31 | 31·45 | .. | .. | .. | ,, |
| 16 | 29.22 | 17.43 | 3.4 | 13·5 | Over 100 millon | ,, |
| 20 | 18·36 | 4·3 | .. | .. | .. | ,, |

* Composite sample of six prawns.

kept in ice storage subsequently and the orthophosphate and the free α-amino acid N determined in these. The fall in the amino nitrogen and in the orthophosphate in the four batches (one from Cochin and the rest from Mandapam) is shown in Figs. 1 and 2. The phosphate, TMA, T.V.N. and the bacterial count trends are similar to those found in the previous experiments. The amino N decreased rapidly in the first few days of storage, the values falling from 300 gm. N/100 mg. muscle (initially) to below 100

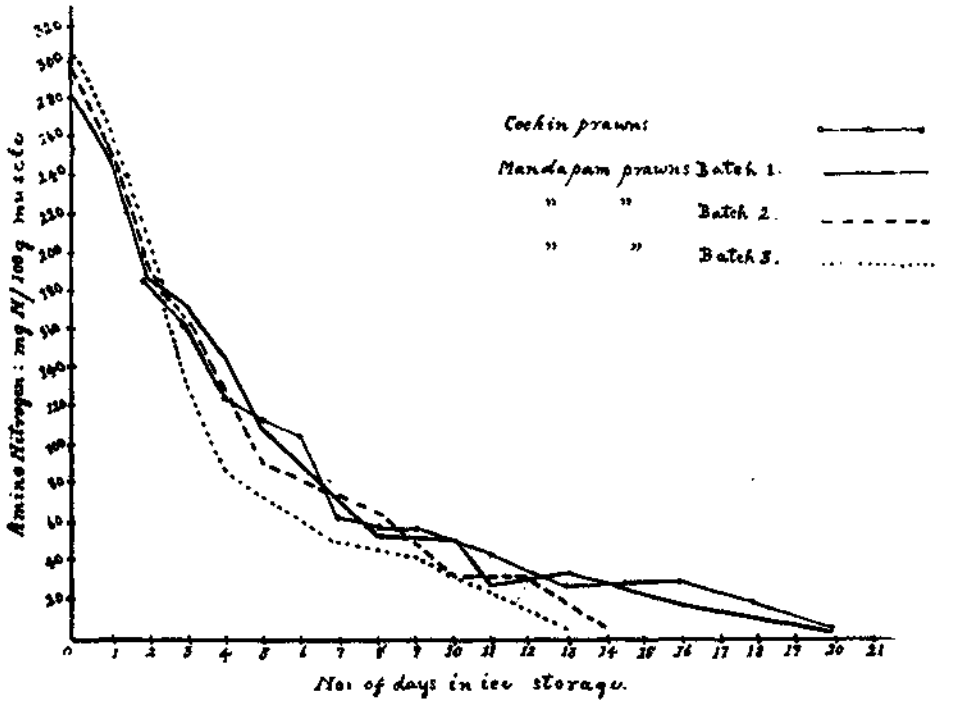


FIG. 1. Changes in amino-N content during storage in ice.

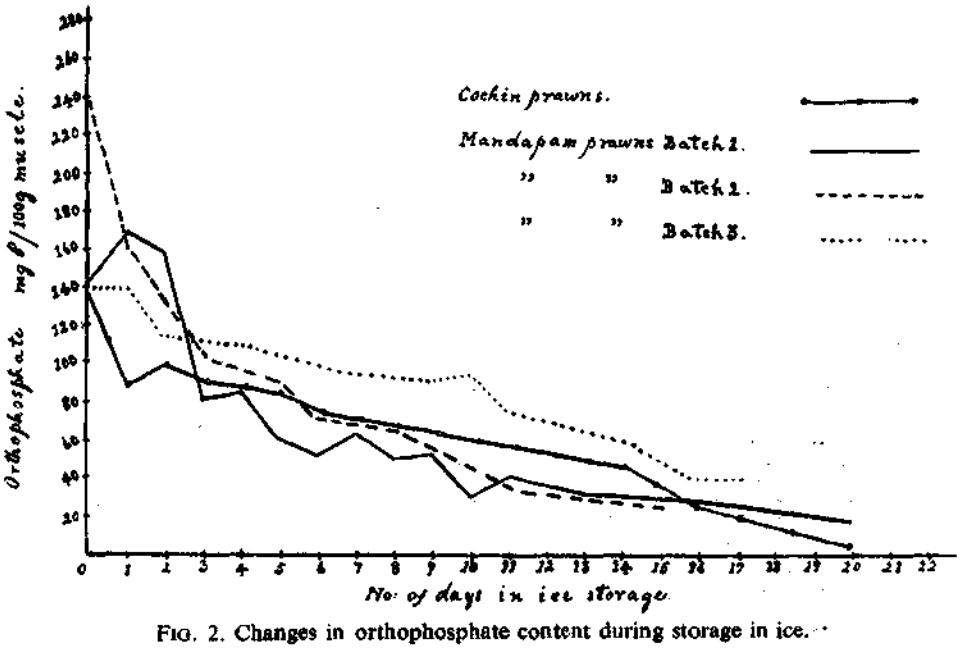


FIG. 2. Changes in orthophosphate content during storage in ice.

in one week's period. The remarkable agreement in the amino values of the prawns from Cochin and Mandapam after equal duration in ice indicated possibilities of employing the amino N estimation for assessing the number of days elapsed in ice storage. The headless Cochin prawns remained in good condition till 15 days while a control batch kept in the whole condition had blackened within a week. Darkening of the Mandapam prawns was less pronounced.

An experiment was carried out to ascertain whether leaching by melting ice was responsible for the decrease in the amino N and also in the orthophosphate content of the prawns kept in ice storage. Twenty-five prawns (whole) were kept in ice in a tray. After 24 hours the total quantity of water resulting from the melting of the ice was collected and the free amino N and the phosphate determined. The ice was renewed every 24 hours and the observations continued for several days. The results are shown in Table IX. In another experiment a batch of prawns was kept at 3° C. (without

TABLE IX

*Amino nitrogen and orthophosphate content of the water melted from ice (in contact with prawns) per day. Whole prawns* (Penæus indicus) *kept in ice*

(Count: 36 to the lb.)

| No. of days | Amino N (mg. nitrogen/ 100 gm. muscle | Orthophosphate (mg. phosphorus/ 100 gm. muscle |
|---|---|---|
| First day .. | 70·04 | 4·678 |
| Second day .. | 78·27 | 7·496 |
| Third day .. | 30·38 | 3·946 |
| Fourth day .. | 40·26 | 5·93 |
| Fifth and Sixth days (2 days) .. | 120·6 | 11·77 |
| Seventh day .. | 53·86 | 7·18 |
| Eighth day .. | 54·26 | 3·987 |
| Ninth day .. | 24·26 | 2·221 |
| Tenth day .. | 20·3 | 0·29 |
| Eleventh day .. | 13·98 | 2·01 |
| Twelfth, Thirteenth and Fourteenth days (3 days) | 26·97 | 1·26 |
| Fifteenth day .. | 7·3 | Nil |

ice) and the amino N estimated as before. These results are shown in Table X. Leaching appears to be the cause of the loss in amino N, but the cause of the phosphate loss is not clear.

The changes occurring in the free α-amino N in the muscle of fish during ice storage was examined for comparison with the prawn studies. The results are shown in Table XI.

TABLE X

*Changes in the Amino N in prawns stored in ice and in prawns kept at* 3° *C. (without ice). Whole prawns* (Penæus indicus) *used*

(Count: 24 to the lb.)

| No. of days | In ice | At 3° C. (without ice) |
|---|---|---|
| 0 | Initial value: 295·8 mg./100 gm. muscle | |
| 2 | 219·3 | 319·0 |
| 4 | 186·9 | 295·0 |
| 6 | 107·3 | 312·8 |
| 8 | 112·7 | 288·2 |
| 10 | 94·04 | 298·3 |

TABLE XI

*Amino nitrogen content of fish muscle kept in ice* (Caranx leptolepis)

| Days in ice | Amino N. (mg. N/100 gm. fish muscle) |
|---|---|
| 0 | 45·3 |
| 1 | 46·65 |
| 2 | 35·93 |
| 4 | 37·65 |
| 6 | 24·22 |
| 7 | 15·32 |
| 8 | 15·69 |
| 9 | 15·37 |
| 10 | 15·27 |

TMA: 0·35 T.V.N.: 11·4. (The Values of Fresh Prawns)

## Discussion

The duration of storage of prawns in ice till spoilage sets in appears to be about two weeks, judging by chemical and bacteriological standards, both in the case of the Cochin prawns which comprise the fishery exploited for the frozen prawn export trade and the Mandapam prawns. Bailey *et al.* (1956) have described three stages in the quality of ice stored shrimps: the prime quality phase lasting for the first 4–5 days, followed by a phase of lowered quality but when the shrimps are still edible till the end of about two weeks and the spoilage phase after the two-week period. Fieger and Friloux (1954) differentiated the quality into two stages: good quality phase lasting up to the end of the first week and a second quality phase when the shrimps have a flat taste but are still edible which lasts for the second week in ice. The indications from the objective tests used in our studies are in agreement with the above findings and the Indian prawns belonging to different species appear to have similar keeping qualities as the Gulf shrimps studied by the U.S.A. workers.

The darkening of the prawns which is a major commercial problem can be minimised by heading the prawns before they are placed in ice. In commercial shrimp trawling operations this practice is usually followed. The headed prawns remain remarkably free from darkening even up to two weeks though changes in palatability obviously continue to take place. The discolouration had no influence on the TMA, T.V.N., phosphate, amino N content or the bacterial population. This is not unexpected since the blackening of prawns is known to be an enzymic (Alford and Fieger, 1952) process which does not involve bacterial action. The progress of the darkening appears to be related to the species and/or size of the prawns as seen from the different rates at which prawns from Mandapam and Cochin respectively darkened. The larger prawns appeared to be more susceptible to the discolouration. If the prawns have to be kept in the whole condition the use of chemical inhibitors such as sodium bisulphite, as suggested by Fieger *et al.* (1954) for prevention of the melanosis, is necessary. The headed prawns are suitable for freezing and also for processing by other methods, but these may not be acceptable in the local fresh fish market as the consumers prefer the fresh prawns in the whole condition. Since headed prawns do not darken rapidly unlike the whole prawns when kept in ice objective tests are necessary for assessing the number of days elapsed in ice storage particularly in the case of the former. The close agreement in the amino N values after equal durations of storage in ice in the case of prawns belonging to different species and taken from different environs, as seen from the fourth set of experiments, indicates the utility of estimating the amino

N for this purpose. The decrease in the amino N is due to leaching by contact with melting ice as shown by the analysis of the melted ice-water (Table IX). Also when prawns were kept at 3° C. (without ice) for comparison it was seen that the amino N did not decrease unlike in the iced prawns (Table X). The amino N content of fish muscle also decreased during ice storage but the changes are not very significant as the initial content of the free amino acid N in fish is much less than in the crustaceans (Velankar and Govindan, 1958) (Table XI). Our observations on the amino N changes are in general agreement with those of Fieger and Friloux on Gulf shrimps (1954); the free amino acid N content of the Gulf shrimps reported by them is also in agreement with the levels of free amino N found in prawns and other crustaceans by the authors (1958). Campbell and Williams (1952) had however recorded an increase in the amino N content during ice storage of Gulf shrimps and their data indicate a low initial content of amino N. Bailey *et al.* (1956) attributed the differences in their observations and those of Campbell and Williams to possible differences in the bacterial flora of the shrimps. But as our studies show the decrease in the amino N is due to leaching and is probably not influenced by bacterial activity since the bacterial population is not large during the initial days of storage when the fall in amino N is most rapid. The loss of free amino acids during ice storage probably contributes to a lessening of the flavour and palatability of the prawns. When some of the iced prawns were frozen a decrease in the amino N occurred probably due to freezing out of some of the water containing the free amino acids, but during subsequent frozen storage there was no further decrease noticed.

The determination of orthophosphate also appears to be useful for assessing the early stages of deterioration of prawns preserved in ice. Our observations indicate that other mechanisms besides loss through leaching are possibly involved in this decrease.

The increase in the TMA during the first 10 or even 15 days of ice storage is not significant enough to indicate the loss in quality or the number of days elapsed in storage. Its determination however is very useful for detecting the onset of spoilage. Similarly the bacterial population of the prawn muscle reaches significant magnitudes only after 10–15 days in ice and the bacterial count therefore can be regarded as an indication of spoilage and loss of edibility. These findings are in close agreement with those of Fieger and Friloux (1954) on Gulf shrimps.

The bacterial flora of iced prawns consisted predominantly of Gram-negative achromic rods and coccobacilli, with yellow and orange pigmented rods and micrococci, occurring in this order of decreasing abundance.

Sporeformers were not encountered in these studies unlike in the studies on iced fish reported previously from this laboratory (Velankar *et al.*, 1956). The flora of the Cochin prawns and Mandapam prawns respectively differed in the abundance of saccharolytic and chromogenic strains both being more common in the Mandapam prawns. None of the isolated cultures produced gas from glucose or any other sugars. A few cultures were luminous. The counts on sea-water agar were far greater than those on freshwater agar. The flora of iced prawns will be described in detail separately.

The bacterial count of prawn muscle is generally high compared with the counts of iced fish muscle (Velankar and Kamasastri, 1956). The greater availability of free amino acids in prawn muscle compared with fish muscle (Velankar and Govindan, 1958) probably accounts for this difference, since native proteins are not accessible to bacterial attack. The reported ineffectiveness of chlorotetracycline in prawn preservation, unlike in fish preservation (Farber, 1954), may also be to some extent due to the presence of free amino acids in considerable quantity in prawn muscle.

## Summary

Observations were made on the trimethylamine, total volatile nitrogen, acid-soluble orthophosphate and free amino acid nitrogen contents and bacterial counts of Indian prawns (*Penæus indicus*, *Metapenæus affinis*, *M. dobsoni*) preserved in ice. The prawns were found to have a keeping quality of about 10-15 days before spoilage set in. The period of prime quality as seen from the objective tests employed did not exceed one week. Heading the prawns prior to icing minimised the incidence of black discolouration (melanosis) peculiar to prawns and appears to be an essential step if the desired storage duration is more than 1 or 2 days. Trimethylamine and total volatile nitrogen changes are not significant during the first 10 or even 15 days, and are useful for indicating distinct spoilage. Phosphate and more particularly the free amino nitrogen content reflected the number of days elapsed in ice storage and might be used in assessing the changes in iced prawns before the onset of spoilage. The decrease in the amino nitrogen is due to loss of free amino acids through leaching and since free amino acids are present in crustacean muscle in considerable quantity compared with fish muscle, their loss through leaching may be a contributing factor in lessening the flavour of prawns kept in ice for extended storage periods. The bacterial flora of the iced prawns consisted mainly of Gram-negative achromic rods and coccobacilli, and to a lesser extent, of orange and yellow pigmented rods and micrococci.

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