Chapter 5

CHANGES IN QUALITY ON FROZEN STORAGE

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5.7. References
5.1. Introduction

During frozen storage of fish, deterioration in quality due to microorganisms and some biochemical processes is decreased. Properly frozen and packaged good quality lean fish can normally be stored at –20°C to –30°C for more than 1 year without much loss in consumer acceptability. But the quality of fish deteriorates during storage as shown by organoleptic, chemical and physical changes. Frozen fish stored for extended period can have reduced palatability by loss of flavour or texture. The denaturation and aggregation of fish muscle proteins particularly myosin fraction are associated with the texture deterioration of frozen fish. Many factors influence the deterioration during frozen storage, like rate of freezing, temperature and time of frozen storage, post harvest history of fish prior to freezing etc.

In recent years, the production of cephalopods, mainly squid and cuttlefish from India, is on the increase amounting to greater than 56,000 metric tonnes in 2002. The export of frozen squid and cuttlefish in the same year was greater than 28,000 tonnes and formed second major seafood item exported from the country. The factories in Cochin account for roughly 60% of the production and around 24 factories are involved in the processing of cephalopods. Since in foreign market, this is considered as highly favoured seafood delicacy, high quality products are required for exports. Quality standard of frozen squid and cuttlefish were established by Indian Standards Institution in 1976 (IS 8076) and emphasis was laid on physical, sensory and bacteriological quality assessments. However, the quality evaluation based on objective indices has assumed greater importance in International trade in recent years. Many studies pertaining to the iced and frozen storage characteristics of squid and frozen cephalopods have been reported. Studies in squid have been reviewed by Thrower (1969). The present study is based on physical, sensory and bacteriological quality assessment of squid and cuttlefish samples to compare the acceptability of the products and thereby evaluate the duration of storage, which could remain in good quality.

5.2. Review of literature

The history of cephalopod trade dates back to 1920s (Vigor, 1928). Various studies on cephalopods especially squid have been reported and reviewed by Thrower (1969), Srinivasan (1978). Thrower (1969) noted that cephalopods could be kept for periods of eight months in ice, which is not the case for other seafood products. The storage of frozen seafood products is based on the microbiological and physical characteristics of the product. Several studies have investigated the effect of freezing on the quality characteristics of squid (Loligo duvauceli) and cuttlefish (Sepia officinalis). Earlier work by Dhananjaya (1977; Dhananjaya 1978) in his study on the changes of sensory characteristics of squid at different temperatures, reached the conclusion that the product could remain in good quality when stored for longer periods.
characteristics of squid and cuttlefish have been made, of which the major studies in squid have been done only on Loligo (Loligo duvaucelii) and no systematic work on needle squid (Doryteuthis sibogae) seems to be done. The present study surveyed the quality of two the species of frozen squid based on physical, sensory, chemical and bacteriological methods and compares the acceptability with the chemical parameters and the degree of protein denaturation.

5.2 Review of literature

The history of squid freezing was studied by Hansen and Aagaard (1969). Various authors have studied the importance of freezing cephalopods especially squid and the significance of squid in the international trade (Borgstrom, 1965; Learson and Ampola, 1977; Thrower 1978). Thrower (1978) found that the squid remained for a maximum period of eight months in the cold storage. James and Iyer (1998) have studied the quality of frozen squid and cuttlefish of export trade where the commercial samples of frozen squid and cuttlefish were evaluated by organoleptic, microbiological and biochemical means. Sophia and Sherif (2003) have investigated the effect of iced storage duration and treatment on frozen storage of cuttlefish fillets. Similar work has been carried out by Selvaraj et al., (1991) on the effect of ascorbic acid dip treatment on frozen storage of squid (Loligo duvaucelii). Several studies have been reported on the storage characteristics of iced and frozen stored squid and cuttlefish (Joseph et al., 1977; Dhananjaya et al., 1987; Joseph and Perigreen, 1988). Ke et al., (1979) in his study on the frozen storage life of Canadian squid at various temperatures, reached a conclusion that the round squid stored at – 30°C could remain in good condition for more than 18 months and the split
mantle for more than 12 months. Lakshmanan et al., (1993) have studied the quality levels of industrial samples of squid (*Loligo sp*) and Cuttlefish (*Sepia sp*) for export following sensory, biochemical and microbiological characteristics. Some studies pertaining to the iced and frozen storage characteristics of squid and cuttle fish have also been made (Raghunath, 1984, Sastry and Sirkar, 1985, Bykowski et al., 1990). Sanjeevan et al., (1987) Lakshmanan et al., (1993) and Varma et al., (1985) have studied the bacteriology of frozen cuttle fish and squid. Iyer et al., (1990) has investigated the presence of *Vibrio cholerae non–01* in fresh fish and was introduced into the product during handling. Various other workers have also studied the bacteriology of frozen squid (Joseph et al., 1977, Lakshmanan et al., 1993, Selvaraj et al., 1991).

The quality changes during the frozen storage of other marine species have been studied by many workers. Comparative effects of frozen storage on biochemical changes in pink perch and oil sardine were investigated by Sarma et al., (1998). Simeonidou et al., (1997) studied the effect of frozen storage on the quality of whole fish and fillets of horse mackerel. Engvang and Nielsen (2000) evaluated the activity of chymotrypsin from herring intestine during frozen storage. Rodriguez et al., (1998) in their study stated the importance of the reduction of TMAO for the evaluation of the quality of frozen fish. Shenoy and Pillai (1971) have studied the changes of *Sardinella longiceps* on frozen storage and Radhakrishnan et al., (1973) on Bombay duck.

The types of proteins and their functional status are the two factors that most influence the texture of cephalopod muscle. There are many publications concerning muscle protein solubility in moderate-ionic-strength saline (0.6M NaCl) and addition of muscle are related to Colmenro and Bonet. They are myofibrillar protein during frozen storage.

5.3. Materials and methods

5.3.1. Sample collection

Freshly collected needle squid (*Doryteuthis plei*) were gutted and skinned immediately and frozen after being sampled. The core temperature of each sample was checked with a digital thermometer (Casio, Japan) and maintained at –18°C for six months. Samples were packed in polythene bags and subjected to physico-chemical analysis. Samples were analyzed in the frozen state.

5.3.2. Expressible moisture

One cm² squared area of fillet was cut and pressed under a hydraulic press. The difference compared to the filamentous expressible moisture.
have studied the effect of frozen storage on Cuttlefish (Sepia officinalis) and Cuttlefish (Callia octopoda) (Raghunath, 1984). Other workers have studied the effect of frozen storage on fish and shellfish (Sanjeevan et al., 1998). Engvang et al., (1990) have studied the effect of frozen storage on Fresh fish and was marketed as frozen (Engvang et al., 1977). Other workers have studied the effect of frozen storage on herring and mackerel (Engvang et al., 1977). In their study stated that the quality of the quality of the frozen material was not affected by the changes of time of freezing (Engvang et al., 1973) on fish and shellfish.

The two factors which affect the quality of frozen storage are the temperature and the ionic strength of the saline (0.6M NaCl or KCl). In these studies, the functional properties of fish muscle are related to the solubility of the constituent proteins (Jimenez-Colmenro and Borderius, 1983; Hultin et al., 1995). The most affected ones are myofibrillar proteins and stroma proteins, which undergo aggregation during frozen storage (Sikorski et al., 1976; Jimenez-Colmenro et al., 1983).

5.3. Materials and Methods

5.3.1. Sample collection

Freshly collected Samples of Loligo squid (Loligo duvaucellii) and needle squid (Doryteuthis sibogae) (from 6-8hrs in ice after capture) were gutted and skinned. Tentacles were removed and the mantles were immediately frozen in a fluidized bed freezer at −40°C for 40-50 minutes. The core temperature of the mantle was recorded to be −18°C using a digital thermometer (Casio 168X). The frozen material was in a cold store at −20°C for six months. Samples of 100 to 200g were packed separately in 150gauge polythene bags and stored after packing in 7 ply corrugated master cartons. Samples were drawn on 0, 30., 60, 90, 120, 150 and 180 days and were subjected to physical, chemical and microbiological analyses. All the samples were analyzed in triplicate. The temperatures of the cold store and the frozen material were checked periodically.

5.3.2. Expressible moisture

One cm² squid piece was taken and placed between two filter papers and pressed under a fixed pressure (10kg/cm²) for 10 seconds. The weight difference compared to the weight before pressing in % reflects the expressible moisture.
5.3.3. Statistical analysis

The results of various quality parameters were analyzed statistically using two way ANOVA. Two- factor ANOVA was employed to compare the effect of each parameter like TMA-N, TVBN, alpha amino nitrogen, protein fractions and TPC, between species and days of frozen storage. The mathematical model was employed for this purpose was as follows:

\[ X_{ij} = \mu + \alpha_i + \beta_j + \varepsilon_{ij} \]

In the case of frozen storage, \(X_{ij}\) is the observed value corresponding to the \(i^{th}\) species on \(j^{th}\) day of storage. \(\mu\) is the overall effect, \(\alpha_i\) is the effect of \(i^{th}\) species and \(\beta_j\) is the effect of \(j^{th}\) day of storage and \(\varepsilon_{ij}\) is the random error.

5.4. Results

5.4.1. Total volatile bases

5.4.1.1. Total volatile base nitrogen

Figure 5.1. Changes in TVN content during frozen storage

5.4.1.2. Trimethylamine

Figure 5.2. Changes in TMA content during frozen storage of loligo and needle squid (exceeds 15 mg% by 150 days). Appr...
Figure 5.1 shows changes in TVN content of both the species during frozen storage. This also showed an increasing trend in both species. The TVN value did not exceed the limit of 30mg N/100g during the period of frozen storage. Appendix E.1 represents the ANOVA table for changes in TVN (which showed a significant difference between species and days) during frozen storage. The F values between species and days were 14.59 and 14.82 respectively. (p<0.001).

5.4.1.2. Trimethylamine

![Graph showing changes in TMA content during frozen storage](image)

Figure 5.2. Changes in TMA content during frozen storage

Figure 5.2. showed the variations in TMA content during frozen storage of loligo and needle squid. In both the species TMA content showed a gradual increase, but the rate of increase of TMA value was faster in needle squid (exceeded the limit by 90 days) than Loligo (exceeded the limit by 150 days). Appendix E.2. shows that there was a significant difference...
between species and days (p<0.001). Needle squid showed a significantly higher value, compared to loligo. LSD for the days was calculated as 3.18.

5.4.2. Alpha amino nitrogen

Alpha amino nitrogen also showed a gradual increase in both the species of squid during frozen storage (Figure 5.3.). In the beginning, it showed a decline and then a gradual increase. Appendix E.3. shows that there was no significant difference in alpha amino nitrogen content between the species, but there was a significant difference between days (p<0.001). The LSD was calculated as 14.11.

![Graph showing changes in alpha amino nitrogen content during frozen storage](image)

**Figure 5.3. Changes in Alpha amino nitrogen content during frozen storage**

5.4.3. Total Protein

Table 5.1. gives the variation in total protein content of loligo and needle squid during frozen storage. The decrease in protein content in loligo

<table>
<thead>
<tr>
<th>Days</th>
<th>Loligo</th>
<th>Needle</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>12.62</td>
<td>13.11</td>
</tr>
<tr>
<td>30</td>
<td>11.13</td>
<td>9.97</td>
</tr>
<tr>
<td>60</td>
<td>9.24</td>
<td>8.8</td>
</tr>
<tr>
<td>90</td>
<td>8.3</td>
<td>7.6</td>
</tr>
<tr>
<td>120</td>
<td></td>
<td></td>
</tr>
<tr>
<td>150</td>
<td></td>
<td></td>
</tr>
<tr>
<td>180</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
and needle squid on frozen storage up to 180 days, was 20% and 34% of the total protein before freezing respectively.

Table 5.1. Changes in Total protein content during frozen storage (%)

<table>
<thead>
<tr>
<th>Days</th>
<th>Loligo</th>
<th>Needle</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>20.71</td>
<td>20.83</td>
</tr>
<tr>
<td>30</td>
<td>19.25</td>
<td>18.28</td>
</tr>
<tr>
<td>60</td>
<td>18.55</td>
<td>16.31</td>
</tr>
<tr>
<td>90</td>
<td>18.2</td>
<td>15.1</td>
</tr>
<tr>
<td>120</td>
<td>17.8</td>
<td>14.9</td>
</tr>
<tr>
<td>150</td>
<td>17.2</td>
<td>14</td>
</tr>
<tr>
<td>180</td>
<td>16.6</td>
<td>13.8</td>
</tr>
</tbody>
</table>

Appendix E.4 shows the ANOVA table for protein changes, which revealed a significant difference between species and days (p<0.001).

5.4.4. Fractions of proteins

Table 5.2. Changes in various fractions of protein during frozen storage

<table>
<thead>
<tr>
<th></th>
<th>Sarcoplasmic Proteins %</th>
<th>Myofibrillar Proteins %</th>
<th>Denatured Proteins %</th>
<th>Stroma Proteins %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Days</td>
<td>Loligo</td>
<td>Needle</td>
<td>Loligo</td>
<td>Needle</td>
</tr>
<tr>
<td>0</td>
<td>12.62</td>
<td>11.75</td>
<td>9.82</td>
<td>8.68</td>
</tr>
<tr>
<td>30</td>
<td>11.13</td>
<td>10.2</td>
<td>7.24</td>
<td>6.84</td>
</tr>
<tr>
<td>60</td>
<td>9.97</td>
<td>9.17</td>
<td>6.12</td>
<td>5.9</td>
</tr>
<tr>
<td>90</td>
<td>9.24</td>
<td>8.35</td>
<td>5.3</td>
<td>5</td>
</tr>
<tr>
<td>120</td>
<td>8.8</td>
<td>7.83</td>
<td>4.9</td>
<td>4.7</td>
</tr>
<tr>
<td>150</td>
<td>8.3</td>
<td>7.2</td>
<td>4.27</td>
<td>4.01</td>
</tr>
<tr>
<td>180</td>
<td>7.6</td>
<td>6.8</td>
<td>4</td>
<td>3.95</td>
</tr>
</tbody>
</table>
Table 5.2 presents the changes in various protein fractions during frozen storage. In loligo, about 40% of sarcoplasmic protein was lost, but in the case of needle 43% was lost during storage.

Appendix E.5 represents ANOVA table for changes in sarcoplasmic protein during the frozen storage. There was a significant difference at the level of p < 0.001 for both species and days.

During frozen storage, there was an apparent loss of extractability of salt soluble proteins, which was 40% less from the zero day in loligo squid and about 45% less in needle squid. A significant difference between species and days (p<0.001) was observed (Appendix E.6). LSD was calculated to 0.618 and the degrees of freedom were as in the case of sarcoplasmic protein. Needle showed significantly lesser solubility of salt soluble proteins, when compared with loligo.

A gradual increase in the denatured protein content was observed during the frozen storage in both the species of squid. There was a significant difference between species (p < 0.05) and days (p < 0.001) during frozen storage (Appendix E.7).

A gradual decrease in stroma protein was observed during the period of frozen storage. The decrease was about 25% in loligo and 28% in needle from the initial value, showing a significant difference of p<0.001 between species and days of storage (Appendix E.8).
5.4.5. Organoleptic quality

Table 5.3. Changes in pH, organoleptic score and Expressible moisture content during frozen storage

<table>
<thead>
<tr>
<th></th>
<th>Needle</th>
<th>Grade</th>
<th>EM %</th>
<th>Loligo</th>
<th>Grade</th>
<th>EM %</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>6</td>
<td>7.5</td>
<td>30</td>
<td>6</td>
<td>8</td>
<td>25</td>
</tr>
<tr>
<td>30</td>
<td>6.3</td>
<td>7</td>
<td>35</td>
<td>6.2</td>
<td>8</td>
<td>28</td>
</tr>
<tr>
<td>60</td>
<td>6.4</td>
<td>6</td>
<td>39</td>
<td>6.3</td>
<td>8</td>
<td>34</td>
</tr>
<tr>
<td>90</td>
<td>6.5</td>
<td>5</td>
<td>47</td>
<td>6.4</td>
<td>7.5</td>
<td>40</td>
</tr>
<tr>
<td>120</td>
<td>6.6</td>
<td>5</td>
<td>54</td>
<td>6.5</td>
<td>7</td>
<td>45</td>
</tr>
<tr>
<td>150</td>
<td>7.1</td>
<td>3</td>
<td>58</td>
<td>6.8</td>
<td>7</td>
<td>48</td>
</tr>
<tr>
<td>180</td>
<td>7.5</td>
<td>2</td>
<td>60</td>
<td>7.1</td>
<td>6</td>
<td>53</td>
</tr>
</tbody>
</table>

E.M. Expressible moisture % in the muscle

The pH of both the species showed a gradual increase on frozen storage, while the organoleptic quality showed a gradual decrease (Table 5.3.). The needle squid lost its organoleptic acceptance by 3rd month of storage, but loligo retained the quality till the end of the storage. There was no correlation between pH and organoleptic quality, even though the pH showed a gradual increase towards the end of the storage. The expressible moisture showed a gradual increase in both the species and a higher retention of moisture was observed in loligo compared to needle squid.

5.4.6. Bacteriology

Table 5.4. Changes in Total Plate count during frozen storage at -20°C

<table>
<thead>
<tr>
<th>Days</th>
<th>Loligo</th>
<th>Needle</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1.75 X 10³</td>
<td>2.12 X 10³</td>
</tr>
<tr>
<td>30</td>
<td>1.83 X 10³</td>
<td>2.15 X 10³</td>
</tr>
<tr>
<td>60</td>
<td>1.86 X 10³</td>
<td>2.18 X 10³</td>
</tr>
<tr>
<td>90</td>
<td>1.89 X 10³</td>
<td>2.19 X 10³</td>
</tr>
<tr>
<td>120</td>
<td>1.9 X 10³</td>
<td>2.22 X 10³</td>
</tr>
<tr>
<td>150</td>
<td>1.91 X 10³</td>
<td>2.23 X 10³</td>
</tr>
<tr>
<td>180</td>
<td>1.93 X 10³</td>
<td>2.25 X 10³</td>
</tr>
</tbody>
</table>
The total plate count was calculated after converting the original value into its logarithm (Table 5.4.). In loligo, TPC 1.75 X 10⁵ was increased to 1.93 X 10⁵. But in the case of needle the count of 2.12 X 10⁵ increased to 2.25 X 10⁵. There was a significant difference between days and species (p<0.001). The F values were 752.2 for species and 11.56 for days (Appendix E.9).

5.5. Discussion

The TMA content is often used as an indicator for decomposition in fish. TMA production is believed to be the consequence of microbial action on TMAO present in marine species. The variation in the content of TMA can be related to the availability of TMAO for enzymic degradation or due to some inhibitory mechanism operating for TMAO degrading enzymes. In the present study, a steady increase in the TMA, TVN and alpha amino nitrogen content was observed in both the species on frozen storage, of which needle squid showed a higher rate of increase. According to Thrower (1978) squid could be stored in cold storage for a maximum period of 8 months. Ke et al., (1979) has reported that Canadian squid could be stored in good condition at -30°C for more than 18 months and split mantle for more than 12 months.

The TVN content showed an increase from 14mg N/100g tissue on zero day to 22.4mg N and 28mg N/100g tissue on 180 days, in loligo and needle squid respectively. Thus the TVN content was within the permissible level in both the species till 180 days of frozen storage. Studies on frozen storage characteristics of treated and untreated meat from mussel also showed a steady increase in TVN and TMA-N (Sawanth and Patange, 2002). Similar results have been reported from a study on the effect of freezing on the quality of fish fillet. Similar results have been reported from the study by Simeonidou (1995) who found that TMAO and TVN increased during the frozen storage. These studies also indicated that the taste reduced. Thus the TMAO and TVN concentration did not seem to be used as indices of quality of fish. But this opinion is not unanimous as there are many reports in the literature mentioned above and others, which also contradict this opinion.

The concentration of TVN increased from 15-20% during frozen storage. This increase is due to the formation of species being not soluble in water and remaining in the release from 15-20%. Alpha amino nitrogen content is a point of view of bacteria contamination and can be readily assayed using a colorimetric method. Fish. They contribute in the formation of TVN during pre-freezing treatment and TVN without direct contribution of TVN as an index was kept minimum.

The muscle pH increased from 7.4 to 7.34 in squids, but only to 7.28 in Loligo (Kelly and Papac, 1993). On frozen storage, the muscle pH increased from the 19th week, but seemed to increase rapidly. The use of polyphosphate (Joseph, 1977) and phosphates (Kelly and Papac, 1993) reduced the increase in muscle pH and consequently the final pH level.
2002). Similar results were reported by Sophia and Sherief (2003) in their study on the effect of different treatments on frozen storage of cuttlefish fillet. Similar results were reported by Rodriguez (1988), Sarma (1998) and Simeonidou (1997). According to latter, TMA-N and TVN increased during the frozen storage while sensory attributes like odour, texture and taste reduced. There are reports that mention TMA and hypoxanthine concentration did not change much during frozen storage and can therefore be used as indices of pre-freezing quality (Connell, 1969; Rodriguez, 1998). But this opinion that TMA-N does not change during frozen storage is a matter of conflict and does not agree with the present study and many other reported work.

A significant steady increase was observed in alpha amino nitrogen during frozen storage period of loligo and needle, the variations between the species being not significant. The protein content of cephalopod meat varies from 15-20%. Alpha amino constituents of NPN are important from the point of view of bacterial spoilage as they provide a source of nitrogen that can be readily assimilated by the micro flora associated with spoilage of fish. They contribute substantially to the flavour of the fish. In this study, during pre-freezing stage, the squid mantles were kept with GMP and without direct contact with ice and hence leaching of alpha amino nitrogen was kept minimum.

The muscle pH varied between 6.22 to 7.38 in cuttlefish and 6.17 to 7.34 in squids, but did not correlate with sensory scores (Lakshmanan et al., 1993). On frozen storage, the squid lost its organoleptic quality at the end of 19th week, but seems to be acceptable and good when treated with salt and polyphosphate (Joseph et al., 1977)
In general, the results show that the solubilization of sarcoplasmic and myofibrillar proteins in the respective extraction media decreased during frozen storage. In the present study, the concept of solubilization and that of denaturation, is that amount of the protein remaining in the supernatant solution after centrifugation. Similar results were obtained by Joseph et al., (1977) in frozen squid, Shenoy and Pillai, (1971) in sardine and Radhakrishnan, et al., (1973) in Bombay duck. The solubility in 0.6M KCl decreased with increasing time of frozen storage. The decrease in solubility reflects the increase in the number of cross bridges other than ionic bonds being formed during frozen storage.

Sarcoplasmic proteins, which are extracted by low ionic strength solution, also showed a decrease during frozen storage of both the species of squid. The high extractability of myosin and other structural proteins in squid has been confirmed in the previous chapters. The aggregation of these fractions due to the freeze denaturation can lead to lesser extractability during storage. The sarcoplasmic proteins in fish are not much affected during freezing and frozen storage. In various species of fishes like cod, plaice and halibut, the albumin fraction remained unaffected during frozen storage (Dyer and Dingle, 1961; Connell 1962). But Tomlinson and Geiger (1963) reported results different from this. Studies also showed that extractable myosin decreased gradually where as actin was unaffected for a long time during frozen storage (Connell, 1962). Creche et al., (1998) has observed that in cod stores at -20°C, there was a loss of protein solubility than the fish stored at -30°C. In this study also, there is a significant loss of protein content for which, loss of soluble protein and NPN in drip during thawing is also to be taken into account. Between the two species studied, needle squid showed higher fractions compared to denatured protein.

The rate of a similar change along with the normal TPC showed a slight increase. Staphylococci showed their counts to be detected in frozen storage their counts detected in frozen storage their counts detected in frozen storage.

5.6. Conclusion

When comparing the different squid, could preserve the protein fractions in order to preserve the initial composition of the freezing. The objectives of this study will vary considerably for different species. Squid mantles have the potential to use minimum contact freezing, and the changes during frozen storage are primarily responsible for which the protein modification with heat treatment if the samples are frozen.
needle squid showed lesser extractability of sarcoplasmic and myofibrillar fractions compared to loligo sp; thus explaining the high content of denatured protein fraction during the frozen storage period.

The rate of survival of different types of faecal organisms like E-coli along with the normal flora in the frozen squid mantles has been studied. TPC showed a slight increase during storage, whereas Coagulase positive staphylococci showed a gradual decrease. Towards 60 days of frozen storage their count dropped to nil and Salmonella and Vibrio sp were not detected in frozen samples. Similar observations were reported by Joseph et al., (1977) in their study of iced and frozen stored squid (Loligo sp)

5.6. Conclusion

When compared with ice storage and chill storage, frozen storage could preserve the squid mantles for a longer period. For onboard vessel in order to preserve the material before processing, most effective method is the freezing. The quality of individual lots of the different species of squid will vary considerably depending on the initial quality of the raw material. Their proper processing and preparation for freezing is very important. Squid mantles handled with Good Manufacturing Practices and with minimum contact with ice and water could retain its quality parameters during frozen storage. While chemical and physical changes in the proteins are primarily responsible for quality changes, the results of this study confirm the protein aggregation during frozen storage modifying the water-holding capacity and extractability of the proteins. This leads to the texture modification with less tenderness and development of undesirable flavours if the samples are frozen stored beyond the recommended period.
5.7. References


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Learson, R.J. and Hultin, H.O., (1966) Fish muscle protein -


*Not referred in original