REVIEW OF LITERATURE
2.1 Crab

2.1.1 Biological aspects, catching and handling

The seasonal variability mainly appears to be an inhibiting factor for organised fishery in India; Reports by Rai (1933), Hora (1935), Chopra (1936, 1939), Anon (1951), Prasad & Thampi (1951, 1953), Jones & Sugasingani (1953), Menon (1952), Wealth of Indian Raw materials, C.A.I.R. (1950), Radhakrishnan (1979, 1980), Mohanty (1973) and Vedavyasa Rao (1973) provide valuable information on the nature and prospects of crab fishery in India including the bionomics, species composition, seasonal variations, methods of fishing and marketing. According to Rao et al. (1973), 640 species of crab occur in Indian waters of which only 8 species are at present considered to be commercially exploitable. They stated that crabs are cheap food consumed mostly by the coastal inhabitants and do not fetch high
prices as other edible crustaceans and fishes do. This obviously is a reason for the scattered and unorganised nature of the fishery. This condition has totally changed during the last decade.

Shelton Duane, D. (1965) recorded spectacular growth rate in the king crab fishery industry in the United States with the overall catch for 1963 was 244 million pounds. The fishing season in India and methods implemented for their exploitation are given by Vedavyasa Rao (1973) and Radhakrishnan (1980) and in U.K. by Edwards & Earley (1967). Radhakrishnan (1980) gave a descriptive account of crab landings in 10 states of India for the years 1973-1978.

Crab Landings in metric tons

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><em>M. tons</em></td>
<td>1,508</td>
<td>2,571</td>
<td>2,391</td>
<td>10,662</td>
<td>19,893</td>
<td>25,496</td>
</tr>
</tbody>
</table>

The commercial production of blue crabs increased from about 7.5 million pounds in 1880 to almost 155 million pounds in 1960 in New Jersey (David H.B. Ulmer, 1964). The information given by Edwards & Earley (1967),

*Source: Reports of the Central Marine Fisheries Research Institute
Marlin E. Tagatz (1965), George H. Rees (1963) and Robert Young (1957) about moulting cycle and relative growth rate in crabs, its fishery, fishing methods and gear used in U.K., Florida etc are worth mentioning. According to George Rees (1963) the number of times that a crab moults during its life time and the length of time between moults varies among species and is affected by such factors as temperature and amount of food available.

2.1.2 Nutritive value of crab meat

The work of Heath (1970) on the biochemical composition of crab - Carcinus maenas during moulting cycle, Badawi (1971) on the chemical composition of Portunus pelagicus, and of Addison et al. (1972) on the lipid content of the queen crab - Chinocetes opilio are worth mentioning.

Robert N. Farragert & Mary H. Thompson (1966) observed variations in body constituents according to season in body meat and claw meat. They reported that the oil and moisture changed inversely in the body meat but not in claw meat.

Nelson Richard & Claude E. Thursten (1965) observed high protein and low oil contents and higher quantities of sodium and potassium in Dungeness crab (Cancer magister).

Velankar & Mahadeva Iyer (1961) studied the amino acid pattern of crab - Neptunus pelagicus and Chatbar &
Velankar (1979) studied the vitamin B\textsubscript{12} content in crab *Scylla serrata*.

Allen (1971) gave an account of the amino acid and fatty acid composition of the tissues of Dungeness crab.

The studies of George (1968) on the effect of salinity changes on the weight and respiratory rate on *Portunus sanguinolentus* and Venkatachari & Vasantha (1973) on the variations in the protein content in different tissues of freshwater crab as a function of salinity adaptation are worth mentioning.

De Koning (1970) studied the phospholipids extracted from marine and freshwater crabs, Porter (1968) studied the acid soluble nucleotides in King crab muscle, Kanupandi & Paul Pandian (1975) studied the electrophoretic pattern of blood and muscle proteins of the crab *Scylla serrata*.

The work of Radhakrishnan & Natarajan (1979) on the nutritive value of crab *Podophthalmus vigil* reveal that in young ones more protein and less fat and carbohydrate and vice versa in older ones. Mukundan et al. (1981) studied the nutrient content and calorific value of crab *- Scylla serrata* in comparison with fish and prawn.

2.1.3 Biochemical changes during preservation and processing

When shellfish is decomposed ammonia is formed which
2.1.4 Canning is an important method of food preservation throughout the world. It requires thorough knowledge of its technological aspects. Four factors are to be controlled to get a canned product (Dungeness crab) with the taste, colour and texture of freshly cooked crab meat was given by Farber (1953) and Tanikawa et al. (1953) made an attempt to can crab meat \( (Erimacrus isenbeckii) \) from different parts of the body separately and compared its quality. He concluded that in the processing of canned crab meat it is better to use sea water or freshwater with an addition of salt than freshwater alone.

Previous works on handling and processing methods employed in U.S.A. (Empey, 1954) and in British Columbia (Dewberry, 1959) clearly indicated that the success of operation depends upon using live healthy and vigorous crabs with prompt butchering and processing in a hygienic condition. All surfaces and utensils that come in contact with the meat should be made of Stainless steel, Aluminium or Monelmetal to prevent contamination (Herman S.Jron-inger & John A. Dassow (1964), Melvin E. Waters (1970), Edwards & Early (1967). The brine floatation method or U.V. light was employed to remove or identify shell

The optimum precook time was worked out in order to get maximum yield for canning by Blackwood et al. (1969), Dewberry, B. (1959) and Dewberry, E.B. (1970).

The work of Gangal & Magar (1967) on the effect of canning and storage on the loss of water soluble constituents and flavour bearing compounds and prevention of detrimental effects by the incorporation of antioxidants and of Varga et al. (1970) on the effect of post-mortem spoilage on the quality of heat processed crab meat are worthy to mention.

Several workers observed blueing, blackening and browning in canned crab meat and studied the possible reasons responsible to such phenomenon and tried preventive methods (Herman S.Groninger & John A.Dassow, 1964), Yuki Tamikawa (1971) and Inoue & Motohiro (1970a,b,c,d,e 1971, 1971a). The cause and mechanism of blue discoloration in canned king crab meat was studied in detail by Inoue & Motohiro (1970a,b,c,d,e, 1971a) and established a relationship between the copper content in the meat and incidence of the blue discoloration.

The effects of citric acid for the prevention of blueing in heat processed crab meat was established


The preprocess age of the raw material is one important factor affecting the shelf-life of the canned product. This aspect was studied in detail by Varga et al. (1969; 1970). Eiichi Tanikawa (1971) had given an account of the formation of abnormal odour, flat sour and swelling during storage of canned crab meat and also remedial steps to avoid such quality defects.

2.1.5 Studies on freezing of crab meat

With reference to freezing preservation of crab meat earlier works provide much information. The studies of Papsow (1950) on freezing and canning of king crabs, Gangal and Magar (1963) on freezing of crab meat, Collins and Brown (1965) on the effects of freezing of the meat of P. camtschatica and the deteriorative changes taking place in crab meat during long periods of frozen storage resulting in loss of characteristic flavour, appearance of stringy texture, yellowing of the bright red pigment and drip loss (Anon, 1966) are worth mentioning.
Blackwood et al. (1969) used live crabs for processing and worked out the advantages compared to dead crabs and studied the quality loss and defects observed in ice stored and frozen stored crab meat. Varga et al. (1970) studied the quality loss in frozen and heat processed meat of crab (Geryon quinquedens).

Strasser & King (1971) reported the effect of heat processing on crab meat. Paparella et al. (1971) studied the keeping qualities of blue crab claws. The method of extracting crab meat using centrifugal force by Lockerby (1971) provide valuable and useful information in this field.

2.1.6 Microbial changes during crab meat processing

It is a general practice in food microbiology to test for certain human pathogens before the material is certified as fit for human consumption. Most of these pathogens are present either as carriers or as normal flora of certain parts of the body of man or animals. Berry (1942) studied the growth of E. coli in crab meat and found that this organism grew well at 25°C and that although the numbers decreased at 5°C, viable organisms were present at 5°C even after 15 days.

E. coli has been isolated from the hands of workers handling crabs (Tobin & Mc Cleskey, 1941).
Presence of faecal streptococci on the utensils and on the palms of workers in a crab meat processing plant has been reported by OstroLENK et al. (1947).

In a study conducted by Olson & Shelton (1973), in 46 crab meat processing factories, the log average MPN coagulase positive Staphylococci per gm of the 'lump' and special crab meat was 38 and 29 respectively in the processing factories having 'good' hygienic status.

Occurrence of Salmonella in the incoming picked crab meat has been reported by Anderson et al. (1971).

In a study comprising 140 crabs caught in England (off the Devon & Cornish coasts) Cann (1977) found V. para-
haemolyticus to be present only in one of the samples, although it was present in 10 out of the 47 samples of sand and seawater examined from the same area. Isolation of this organism (V.P.H.) from frozen crab meat stored at -15°C and -30°C after 30 days and 60 days respectively has been reported by Johnson & Liston (1973).

2.2 Mussels

2.2.1 Biological aspects and fishery

Because of the sedentary habits and easy accessibility, the attention has been diverted to mussels, which is
next in importance to fish and prawn. Information regarding the resources and fishing methods are given by Hornell (1917), Rao, K.V. (1958), Jones, 1950, 1968a,b) and Jones & Alagaraswamy (1973). Holland & Spain the two leading countries in mussel production yield about 80% of the total world catch. But in India that much importance is not given. Two species of mussels are available in India, the green mussel and brown mussel of the family *Perna*. The former is widely distributed on the east as well as the west coast, but the latter has a restricted distribution in the Kanyakumari-Tinnevelly coast of the Madras State and South Kerala coast. Almost all the rocky stretches including backwaters and piles laid by man along the coast from the shoreline to a depth of 6-8 m harbour mussels and the west coast contains more mussel beds than the east coast because of the existence of vast areas of creeks, muddy bays, rocky inshore regions estuaries and backwaters suitable for them to thrive well.

Mussels attain the commercial size of 75 mm in an years time under culture conditions (Andreu, 1968).

2.2.2 The fishing methods are comparatively simple and can be grouped under three categories.

1. Collecting mussels from the rocks on the shore.
2. Swimming to reach the rocks and
3. By going in boats or canoes and diving.

The fishing implements are an iron chisel or a wooden wedge.

2.2.3 Nutritive value and seasonal variation

Very little information is available on the nutritional quality of mussel meat. According to Waterman (1969) the quality of the meat varies during the year. They are at their best in the late autumn and winter months but become poor during and after spawning in March or April. The work of Waterman (1969) on proximate composition, Suryanarayan & Alexander (1972) on chemical composition and calorific value, Gopakumar & Nair (1972) on the fatty acid composition of mussel lipid, Joyner & Spinelli (1969) on mussel meat as potential source of high quality protein for FPC preparation and isolation of peptidases from Mytilus edulis by Berg (1954) are worthy to mention.

2.2.4 Preservation and processing of mussel meat

The studies on changes due to freezing and cold-storage of cooked frozen mussel by Waterman (1969) and Banks & House (1958), effect of processing on nutritive value of mussels by Korobkina et al. (1970) are worth mentioning.

The details of the process employed for the
utilization of mussel meat as canned, smoke cured and pickled products are given by Balachandran & Unnikrishnan Nair (1975) and Muraleedharan et al. (1979 & 1982).

2.2.5 Bacteriological aspects

Food poisoning appears to be the major microbiological problem associated with mussels (Ernest A. Fieger & Arthur F. Novak, 1961). A single instance of mussel pollution near Calicut was reported (Venkataraman & Sreenivasan, 1955), in that case faecal pollution has been observed during southwest monsoon period. Quantitative estimation of the bacterial load of the brown mussel (Perna indica) cultured at Vizhinjam has been shown as $10^6$. The occurrence of *Coliforms*, *Escherichia coli*, *Faecal streptococci* and coagulase positive *Staphylococci* are reported. *Pseudomonas*, *Vibrio* and *Micrococcus* are seen as normal flora of mussel and seawater (Thankappan Pillai, 1980).

Enteropathogenic *E. coli* has been isolated from freshwater mussels by Stephen et al. (1975).

Butiaux (1962) stated that edible oysters, mussels and shellfishes were very often infected with salmonellae because the most essential sanitary precautions were neglected in the culture areas. Gevaudan & Gay (1958) came to the conclusion that the concentration of salmonella in mussels varied with the number of salmonella present in the surrounding water.
A simplified system of mussel purification was outlined by Reynolds (1956), Dewberry, E.B. (1953), Waterman (1969) and Connell (1980). The method is based on the natural action of the bivalves cleaning their alimentary canals in clean chlorinated seawater during a period of 48 hours. The mussels rid themselves of all harmful organisms thus making them safe for human consumption by this process of depuration.

2.3 Clams

Clams are one of the most popular and important shellfish in the world. They are produced abundantly in Canada, United States, Argentina, Chile, China, Japan and Korea.

2.3.1 Biological aspects and fishery

A survey of the literature on the Indian molluscan resources, shows that Mr. James Horrell has contributed much to our knowledge. His works (1917, 1922 & 1949) on the Indian molluscs remain to date the most authentic report on many aspects of Indian shell fisheries. Rai (1932) made a survey of the coast of the then Bombay Presidency and made available valuable data on the oyster and clam industry of that area. There are several other publications that give some information on the abundance and the economic importance of the clams. Some of which are Rao, H.S.

Among clams those belonging to the family Veneridae are by far the most important in the Indian waters, nine species contribute to the fisheries of commercial importance. There is no system at present of collecting data for the molluscs, as for the fishes and crustaceans.

Along the Kerala coast, *Meretrix casta* is one of the important clams occurring in almost all the estuaries and backwaters. *Villoreita cyprinoides* is available in the Cochin area and at several other places to its south. According to Sebastian (1970) nearly 2,400 metric tons of clam meat is obtained annually from the Vembanad lake alone.

2.3.2 The clams are exploited in Kerala for their shell. It is extensively used in cement industries. The clam meat is in fact a byproduct of this industry. Clams are usually hand picked in shallow waters at low tides. Very rarely any mechanical devices are employed for them except small bagnets or dredges operated from canoes (Alagarawamy & Narasimham, 1973).

Molluscan shells for lime are gathered from the estuaries and backwaters in considerable quantities. During
monsoon when large quantities of dead shells are drifted ashore by the currents, they are collected and made use of for the purpose (Rao, K.V., 1958). In Kerala its importance emerges from the occurrence as extensive subfossil deposits in the Vembanad lake, which are used as raw material in the cement industry at Kottayam (Algaraswamy & Narasimham, 1973).

2.3.3 Nutritive value of clam meat

India faced with the problem of food shortage sometime back, being systematically investigating the resources around her to solve the problem. Clams are a good source of protein, fat, glycogen and minerals, with all the essential amino acids are easily digestible. Only very limited information is available on nutritive value of clam meat and the seasonal influence on chemical composition. The chemical composition of clam meat by Venkataraman & Chari (1951) clearly indicates variations in moisture, protein, fat and minerals. Viswanathan Nair et al. (1976) studied the lipid and fatty acid composition of clams - *Villosita cyprinoids*. 50-71% of the total lipid content was phospholipids and about 6% C_{17} saturated fatty acids. Of the phospholipids, phosphatidyl choline (40.7%) and phosphatidyl ethanolamine (28.4%) are found to be the major constituents.
2.3.4 The studies of Baruch Rosen (1966) on soft clams frozen in plug-top metal cans, then cold stored revealed an increase in lactic, acetic, propionic and pyruvic acids and bacterial count increased at an exponential rate.

Studies on causes of can swelling and blackening in canned baby clams by Tanikawa et al. (1966 & 1969) and Hardy (1953) about colour change observed in canned razor clams and precautions to be taken for obtaining good quality product and Motohiro (1974) on the utilization of shellfish in Japan such as boiled, seasoned, smoked and canned clams are worth mentioning.

The processing of clams in the United States as canned minced clams, clam nectar, clam chowder, clam extract, in Japan as canned whole hen clams and in Canada about the process employed for preparing good quality canned clam meat was described by Tanikawa & Doha (1965).

2.3.5 Microbiology of clam meat processing

Bacteriological study of the coliform group in clams stored under normal conditions was made by Sandholzer & Arcisz (1946). Rice (1929) isolated 33 species of organisms from clams; the Bacillus and Pseudomonas groups were the most common bacteria present. In an investigation of several Japanese baby clam canneries Amano (1948) found
heat-tolerant microorganisms of the genera *Bacillus* and *Clostridium* in the soils, rubbish, factory wastes, sand and sea water surrounding the processing plants. No *Clostridium botulinum* or any related toxins were present. Apparently anaerobic bacteria are the principal viable organisms in the shells of the living baby clams. A heat resistant anaerobe related to *Clostridium bifermentans* was isolated from fresh clam meat of the species *Venerupis Philippinarum*.

The occurrence of paralytic shell fish poisoning on the United States west coast was summarised by Pivnick (1951).

The polluted shellfish can be made safe for human consumption by the process of purification has been adequately demonstrated by Fabre-Domergue (1916), Wells (1916), Dodgson (1928) and Connell (1980).

2.3.6 The effect of radiation pasteurization on shelflife and changes in free amino acid contents and organoleptic qualities of soft shell clam meats was illustrated by Brooke & Steinberg (1964), Connors & Steinberg (1964) and radiation processing and storage effects on head gas components in clam meats was studied by J.M. Mendelsohn & Brooke (1968). According to them the dimethyl sulphide was found to be the most dominant head gas component and to be the source of the typical clam odour.
2.4. Proximate chemical composition of fish

Water, protein and fat are the major constituents of fish with non-protein nitrogenous substances, carbohydrates and salts occurring in small amounts. Since muscle proteins are the main solids of fish, it is a protein food stuff, particularly if it is lean.

Moisture, protein, fat and calorific value of 44 species of fish and shell fish in the British coasts was given by Reay et al. (1943). A detailed account of chemical composition and changes due to season in different varieties of fish and shell fish muscle was given by Raymond Jacquot (1961). Chemical constituents such as high protein and low fat, moderate quantities of calcium, phosphorus, iron and B group vitamins were analysed in Sepia orientalis and Loligo vulgaris by Pandit & Magar (1972). The variations in composition of Atlantic halibut, mackerel, tuna and sword fish during spawning migration was observed by Mannan et al. (1961); while low oil and sodium contents and high protein content in halibut meat was noted by Anon (1959). The proximate chemical composition and seasonal and local variations in chemical composition, the effect of salinity of water on chemical composition in oyster meat was given by Paul S. Galtsoff (1964).
Proteins are perhaps the most important constituent of fish muscle, constituting more than 80% of the dry weight.

Based on the differences in their physical-chemical properties, the proteins are broadly categorised as sarcoplasmic and myofibrillar proteins, stroma and denatured fractions (Warrier et al. (1975); Paul et al. (1966); Baliga et al. (1962 & 1969); Sayre (1969); Carpenter & Saffle (1965); Connell (1962); Sayre & Briskey (1963) and Yuji Maruyama & Taneko Suzuki (1968).

The sarcoplasmic proteins forming approximately 15-20% of the total proteins depending on the fish species, are generally soluble in water or buffers of low ionic strength. To this class of proteins belong enzymes of the glycolytic pathway (Tarr, 1966), Nagayama (1967), Gould (1965) Martin & Tarr (1961) and autolytic reactions (Siebert, 1958); Siebert & Bottke (1963); Bird et al. (1969) Warrier et al. (1972a,b). Most of these are low molecular weight proteins.

The myofibrillar proteins consisting 60-80% of the total proteins are soluble only in salt solutions of high ionic strength and have molecular weight in the range of \(4 \times 10^5\) to \(6 \times 10^5\). The remaining portion about 3-10% is
insoluble even in dilute solutions of hydrochloric acid or sodium hydroxide and has been called stroma. It is derived from connective tissue. Fibrillar proteins play an important role in contributing textural quality of the flesh.

The textural qualities associated with muscle such as fibrousness, water holding capacity, plasticity and gel forming ability are controlled by the myofibrillar proteins.

All the major myofibrillar proteins isolated from meat namely, actin, myosin and tropomyosin have been found in fish also. Preparation of fish myosin in pure state is very difficult since actin gets extracted easily with myosin (Connell, 1962; Mackie & Connell, 1964). The contamination with actomyosin can be minimised by using acidic extraction media (Hamoir, 1955) or extractants containing Adenosine triphosphate (Hamoir et al., 1960) or pyrophosphate (Connell, 1954, 1960, 1962). The most important biochemical characteristics of myosin is its enzymatic activity with respect to hydrolysis of adenosine triphosphate (ATP) and is related to the ATP-ase activity of reconstituted actomyosin (Barany, 1967) and to the interaction between actomyosin and ATP (that is molecular contraction (Mommaerts, 1950, 1966; Davies, 1963). At higher temperatures there will be an appreciable decrease in activity (Connell, 1960; Sawant & Magar, 1961).
Interaction of actin with myosin is the main reaction involved in muscle contraction. The relaxing protein (tropomyosin-troponin complex) also plays a significant role in this by regulating the Ca\(^{+2}\) and Mg\(^{+2}\) concentration. Globular (g) actin to Fibrous (F) actin transformation has been extensively investigated by different workers (Mommaerts, 1951; Laki et al. 1951; Strohman (1959). The interaction of actin and myosin forming actomyosin and the dissociation of actomyosin in presence of ATP was soon recognised as the fundamental reaction involved in muscle contraction. Fish actomyosin have been prepared from different species of fish by different workers and its properties studied (Shizunori Ikeda & Takeshi Taguchi, 1968; Horie et al. 1975; Murozuka et al. 1976; Dingle & Hines (1960).

The third group of proteins in fish muscle is the connective tissue which is insoluble in 0.1 N sodium hydroxide or hydrochloric acid, which is constituted mainly by collagens which are rich in hydroxy proline (Sayre, 1968; Paul et al. 1966). Fish muscle contains very little stroma or connective tissue compared to meat; and are noted for their heavy gelatinization. The low content of stroma in fish muscle and its easy gelatini- zation are important properties which confer the characteristic texture to fish muscle.
2.4.2 Non-protein nitrogenous constituents

This fraction is said to account for 10-20% of the total nitrogen content in the fish. The compounds occurring in this fraction have been grouped as follows:

a) Volatile bases (ammonia, mono-di and trimethyl amine).

b) Trimethylammonium bases (trimethyl amine oxide, betaines).

c) Guanidine derivatives (creatine and arginine).

d) Imidazole or glyoxaline derivatives (histidine, carnosine and anserine).

e) Miscellaneous (urea, amino acids and purine derivatives) (Shewan, J.M. (1951) and Raymond Jacquot (1961).

The non-protein nitrogen in fish muscle was measured after trichloracetic acid (TCA) precipitation (Sayre & Briskey (1963) and Wood (1958) studied the non-protein nitrogenous constituents of the muscle of sockeye salmon during spawning migration.

2.4.3 Fat of Lipids

The chief storage form of available energy in the animal cell is the lipid molecule. When the calorie intake exceeds utilization excess food is invariably stored as fat.
Jafri (1973) made an attempt to describe the variation in total fat and water contents of the flesh of a popular cat fish and Gopakumar & Nair (1966, 1967 and 1972) studied the fatty acid composition of the lipids extracted from oil sardines, mackerel, pomfret, kilimeen, jew fish and eight other species of Indian marine fish. The concentration of fat is subjected to seasonal variations. Sen & Gracy Mathew (1973-74) reviewed the work on fish lipids, fatty acid composition and phospholipids of fishes and shell fishes of Indian waters.

2.4.4 Sugar and sugar phosphates

The storage of polysaccharide of animal tissues is glycogen. The occurrence of glycogen in fish muscles was investigated first by Dill (1921) and subsequently in more detail by MacLeod & Simpson (1927). Tomlinson & Geiger (1962) had pointed out that many species of fish have a muscle glycogen content which compares favourably with that of warm-blooded mammals.

Tarr & Leroux (1962) studied the free sugar contents in fish skeletal muscle and the possible mechanism for their formation. The studies on seasonal variations in glycogen contents in oyster muscle by Paul S. Galtsoff (1964), the concentration of ribose, glucose, ribose-1-phosphate, glucose-1-phosphate, glucose-6-phosphate,
fructose monophosphate and fructose 1,6-diphosphate in muscle extracts of aquarium kept cod by Burt (1961); liver glycogen levels of salmon during spawning migration by Violet M. Chang & Idler (1960); the free sugar contents in fish skeletal muscle and the possible mechanism for their formation by Tarr & Leroux (1962) are worth mentioning.

2.4.5 Phosphorus

Our knowledge on phosphorus compounds in fish muscle is comparatively recent and their study was initiated by Tarr (1950a) who determined these compounds in the skeletal muscle of starry flounder, lingcod, tomcod, whiting and blue perch.

Phosphorus is essential to cell metabolism and has got more functions than any other single mineral. Most of the phosphorus is concentrated to the nucleus. It combines to form phosphoproteins which initiate muscle metabolism and phospholipids are essential in lipid metabolism. The blood of fish is rich in organic acids of soluble phosphorus compounds, but flows as inorganic phosphoric acid in the blood stream.

There are three closely related phospholipids, these being esters of phosphatidic acids and nitrogen containing alcohols (Choline, ethanolamine and serine). The one derived from choline is the well known lecithin isolated
from a great number of fishes. Glycerophosphatides have been identified in several fishes and are characterized by the presence of appreciable and frequently high proportions of C_{20} and C_{22} highly unsaturated acids chiefly arachidonic and clupanodonic (Lovern & Olley, 1953a,b).

2.4.6 Minerals

Conor Reilly (1977) had given an account of the role of minerals in muscle metabolism. Calcium and magnesium which are the principal metals in bone and sodium and potassium which are concentrated in blood and other body fluids are included among the major elements.

Paul S. Galtsoff (1964), based on his studies on American oysters, reported that many bivalves have the ability to accumulate various heavy metals such as zinc (Zn), copper (Cu), iron (Fe), manganese (Mn), lead (Pb) and arsenic (As). The problem is of importance because in polluted coastal waters shellfish may store substances that may be dangerous to human health.

Connell (1975) stated that mercury (Hg), cadmium (Cd), lead (Pb), selenium (Se) and arsenic (As) are cumulative poisons, repeated ingestion of small amounts cause injury to health.
2.5 Fish flavours

Flavour is a complex concept involving primarily aroma and taste but also appearance, behaviour on manipulation, feel in the mouth and even the sounds emitted in chewing (Nursten, 1975). The sense of taste is relatively simple, there being four basic qualities, bitter salt, sour and sweet.

While much information has accumulated concerning the chemistry of fish much of it has not been correlated directly to flavour (Jones, 1961). Much of the sweetness of fresh fish results from the initial concentrations of glucose. The loss of sweetness and meatiness from very fresh fish correlates well in some species to the disappearance of free glucose, the hexose phosphates and inosine-5'-monophosphate which possess those flavour characteristics from the muscle. The progressive development of fishiness, pungency, sourness, bitterness etc. can be accounted for by the presence of well characterised compounds in the fish. The importance of inosinic acid in enhancing the flavours of flesh foods is well known principally as a result of Japanese investigations (Kuninaka et al., 1964; Wagner et al., 1962).

The loss of flavour commonly associated with the short-term chill storage of fish derives partly from leaching losses into ice melt water, and partly due to a great
extent from the actions of autolytic systems which cleave
flavourous compounds present in the muscles (Jones, 1962).
Inosine-5'-monophosphate, a major flavourous component is
cleaved rapidly with formation of Inosine. This compound
is hydrolysed or phosphorylated in cod muscle to form
hypoxanthine which contribute much of the bitterness chara-
ceteristic of staling fish; Glycolysis in chill stored muscle
produces changes in the concentrations of hexose phosphates
which are also important to flavour. Sugar-amino reactions
occurring in processed fish muscle produce, meaty and bit-
ter flavours (Jones, 1962). Dimethyl sulphide is an impor-
tant odour constituent in edible shell fish and it is deri-
ved from dimethyl-β-propiothetin, a compound found in cer-
tain of the algae ingested by filter-feeders (Anon, 1967;
1968).

2.6 Causes of deterioration

When the fish dies, the balance between the process
of body maintenance is upset. The enzymes instead of act-
ing on the food normally taken in, continue actively to
digest any of the particular type of materials such as
fats, carbohydrates or proteins - thus a reversal of nor-
mal process of digestion and assimilation is occurred.
Enzymes are secreted by the bacteria which act in the same
general manner and their attack is facilitated by the fish
enzyme actions.
A second cause for deterioration in quality of fish results from oxidation and rancidity. The oxidation and rancidity of fats can be caused by the simple or combined action of tissue enzymes, bacterial enzymes and exposure to air. Oxidation, besides causing rancidity can cause other changes in fish, the fading of pigments, and the development of off colour and browning.

Bacteria are usually the most important causes for deterioration in fish as in other protein foods. They are present in air, water and soil in innumerable forms, shapes and species each with a characteristic method of attacking, which although we do not see with the naked eye can be noted by the odours, flavours or colours imparted to the material on which they are acting.

2.6.1 Thus a proper evaluation of the factors involved in spoilage is essential to the proper handling, storage, transportation and proper processing of food products (H.O. Triebold & L.W. Aurand).

2.6.2 One of the main factors determining the onset of spoilage in freshly caught fish is rigor mortis, a stiffening of the body which develops some 1-7 hours after death. (Ludorff, 1957). Rigor mortis passes quickly in very active fish and slowly in inert fish. Rigor mortis passes
quickly in fishes which resisted the catch than in fishes caught without struggle (Ludorff, 1957).

When an animal is slaughtered, Mg-ATP (magnesium-adenosine triphosphate) which is present in the muscle fibres is decomposed by an enzyme present in the sarcoplasm. There is a large release of energy which is used up in causing the actin filaments in the myofibrils to slide in between the myosin filaments. As this interdigitation takes place the actin filaments became rigidly attached to the myosin filaments causing a large decrease of extensibility and giving rise to the well known phenomena of rigor mortis (Ferguss Hill, 1967).

2.6.3 As fish spoils, an easily recognisable spoilage pattern can be noticed according to the development of a regular succession of different odours. Four stages can be recognised in the spoilage of fish.

1) the muscle has a characteristic fresh fish or sea fish odour.

2) the muscle loses some of the fresh fish odour but has no spoilage odours.

3) development of the first spoilage odours, which vary according to the season of the year.

4) fish is rotten or putrid according to the development of spoilage compounds such as hydrogen sulphide (H₂S), indole, ammonia etc (Castell, 1957).
The loss of sweetness or meatiness from very fresh fish correlates well in some species to the disappearance of free glucose, hexose phosphates and inosine-5'-monophosphate which possess those flavour characteristics from the muscle (Jones, 1960).

Fish muscle contains very active cathepsins capable of splitting protein and also very rich in peptidases. Proteolytic enzymes in fish muscle are abundant enough to suggest that they play an important role specially in the early stages of spoilage by degrading fish muscle proteins and by furnishing amino acids and peptides for the growth of microorganisms (Siebert, 1961).

Fraser et al. (1961) showed that struggling reduced the muscle glycogen with accumulation of lactic acid and concluded that the time of onset, the degree and duration of rigor mortis were dependent upon a number of factors, the most important being the method of catching (MacLeod & Simpson, 1927; Sharp, 1934; Black et al. (1961). An enzymic breakdown of adenosine-triphosphate (ATP) by actomyosin ATP-ase or apyrase occurs in fish muscle (Partman, 1954).

After death lactic acid is produced by anaerobic glycolysis and creatine phosphate (Cr-p) concentration decrease (Buttkus & Tomlinson, 1966). Jones (1959)
estimated about 0.67 mg% of pyruvic acid in the muscle of freshly killed trawled codling. It is the penultimate stage of glycolysis in muscle, a key compound yielding energy through the tricarboxylic acid cycle and an intermediate in the biosynthesis of alanine.

The post-mortem degradation of glycogen undoubtedly contribute to both the flavour and texture of fish and the free ribose in fish muscles arises largely from the post-mortem degradation of ATP (Tarr, 1966).

The freshness of fish depends principally on its temperature and the time that has elapsed since death. The higher the temperature the faster the bacteria living in the fish multiply (Anon, 1960).

The muscle protein solubility was grossly altered by the conditions of both temperature and pH which existed at the onset of rigor mortis or during the first few hours after death (Sayre & Briskey, 1963).

2.6.4. Though sensory methods are likely to remain the most versatile and sensitive way of measuring freshness, chemical tests have a role also (Anon, 1977).

A continuing problem in fisheries research is the lack of an objective test for the freshness of fish (Edith Gould, 1969).
A satisfactory test for the detection of spoilage in fish must meet certain definite requirements. It should provide an accurate measure of the degree of spoilage and should be based on the most characteristic change occurring in the product as spoilage progresses. Finally the test should be rapid and simple to perform (Dyer et al., 1944).

2.5.4.1 Hypoxanthine concentration rises as fish stale, so the increase in hypoxanthine concentration in muscle during storage has been suggested as an objective measure of quality (Jones, 1962, 1964; Edith Gould, 1959; Anon, 1977; Fraser et al., 1968).

2.6.4.2 Histamine developed 40-50 hours after death, and this is used as a quality index by Hughes (1959).

2.6.4.3 The increase in tyrosine value was taken as a measure of spoilage in fish meat by Ota & Ajiska (1953) and Dyer et al. (1944).

2.6.4.4 The pH of fish muscle has been proposed as an index of spoilage by Van Deurs & Hoff-Jorgensen (1936), Shaikmahamud & Magar (1965) and Nazir & Magar (1963).

2.6.4.5 The amount of trimethylamine (TMA) which is the reduction product of the oxide TMAO is widely adopted as an index of spoilage of fish (Velankar et al., 1961);
Venkataraman & Chari, 1953; Wierzchowski et al. 1953; Shaikhmahamad & Magar, 1965; Nazir & Magar, 1963; Bose, A.N., 1954; Dyer et al. 1944.

2.6.4.6. A combination of trimethylamine, volatile acid number and bacterial count indicates the potential keeping quality more accurately than visual examination of fish (Velankar et al. 1961).

2.6.4.7 Among physical tests, refraction of the eye fluids and redox potentials were useful tests (Joseph Denfel, 1963).

2.6.4.8 Nazir & Magar (1963) followed pH, glycogen, lactic acid, inorganic phosphorus, creatine phosphorus, adenosine triphosphate, trimethylamine and barium acetate non-precipitable ribose, in order to study the biochemical changes in fish muscle during rigor mortis.

2.6.4.9 F. Shaikhmahamud & Magar (1965) found that the suitable tests for freshness of fish were determinations of pH, total bacterial count, trimethylamine, glycogen lactic acid and vitamin B contents.

2.6.4.10 Muscle protein solubility appeared to be one of the factors affecting the juice retaining properties of the muscle (Sayre & Briskey, 1963).
2.6.4.11 Geetha Ramanathan & Moorjani (1973-74) estimated peroxide value, carboxyl value, dicarbonyl compounds and malonaldehyde in order to study the oxidative action in fish products and found that malonaldehyde is an index of rancidity.

2.7 Studies on spoilage pattern of fish and shellfish during different storage conditions.

2.7.1 Room temperature storage

Velankar et al. (1961) studied the spoilage pattern of prawns at ambient temperature by following chemical, bacteriological and organoleptic changes. They found that a combination of trimethylamine, volatile acid number, bacterial count and organoleptic conditions indicate the potential keeping quality more accurately than the visual examination.

2.7.2 Refrigerated storage at 0°C

No significant changes occurred in the phosphorus content of the phospholipid, ribo nuclie acid or deoxyribo nuclie acid fractions of sterile lingcod muscle stored at 0°C, but in the acid soluble fraction, the portion of total phosphorus accounted for by inorganic phosphorus increased to 96% from 75% (Neil Tomlinson et al. (1960).
Jones & Murray (1962) observed during the course of their studies on degradation of adenine and hypoxanthine nucleotides in the muscle of chill stored trawled codling that the adenosine 5' triphosphate remaining in the muscle at the time of death was rapidly converted to inosine 5'-monophosphate. This is dephosphorylated to inosine which is itself cleaved to hypoxanthine and either ribose or ribose 1'-phosphate.

Burt (1961) studied free sugars and sugar phosphates in muscle of chill stored aquarium cod. He observed that rested cod muscle contains more free sugars and sugar phosphates than trawled cod muscle.

The studies on free sugars in chill stored codling by Jones (1958) revealed that glucose is the only free sugar present in fresh codling muscle, and ribose appears during chill storage.

2.7.3 Ice storage

Icing is the most common method of preservation of fishery products. For transportation of fresh fish over long distances to the interior parts of the country icing is preferred.

Very little information is available on the changes in protein fractions of fish muscle during ice storage.
In India Moorjani et al. (1962) and Baliga et al. (1962, 1969) have attempted to follow the changes in muscle proteins of freshwater fishes during ice storage.

Moorjani et al. (1962) followed the changes in protein fractions such as fibrillar, non-protein nitrogen and stroma in freshwater fish during storage in crushed ice.

Baliga et al. (1962) followed the changes in soluble protein nitrogen in Ophicephalus sp. stored in crushed ice.

Baliga et al. (1969) fractionated the muscle proteins of freshwater fish stored in ice. They observed that the amount of actin that was not reconvertible to 'F' actin increased during storage of the fish. Also viscosity of the buffer extracts increased during the period of development of rigor and decreased on further storage.

Devadas & Nair (1970, 1971) followed changes in the major protein nitrogen fractions such as sarcoplasmic, myofibrillar and stroma of prawns, sardines, mackerel and lactarius during ice storage. Myofibrillar proteins were found to get denatured at a rapid rate than sarcoplasmic protein fraction, and the presence of free fatty acids in the muscle which can inhibit the extraction of muscle proteins.

Sakaguchi et al. (1982) observed little change in
the levels of most free amino acids in white muscle of yellow tail during ice storage for over 40 days, but in the dark muscle the levels of almost all free amino acids except taurine increased significantly over a period of 33 days.

Liston et al. (1961) followed organoleptic and chemical tests to study the spoilage pattern of Pacific coast rock fish stored in ice. Odour, flavour, rancidity, total volatile acid and total volatile base agreed with spoilage and a sharp cut off point was apparent between the organoleptically edible and inedible fish.

Shewan & Jones (1956) had given an account of the chemical changes occurring during spoilage of chilled fish and their relation to freshness tests. Changes in some of the constituents for example, anserine, some amino acids, nucleotides and sugars are due to autolysis, while changes in volatile bases, other amino acids and trimethyl amine oxide are the results of bacterial action, and considerable leaching losses occurred during ice storage.

Lahiry et al. (1963) studied the factors influencing the keeping quality of freshwater fish in ice.

2.7.4 Changes during freezing and storage

2.7.4.1 The most noticeable change in frozen stored fish
is the development of a tough texture. This is attributed to protein denaturation, that leads to loss in water holding capacity (WHC). The term WHC is used to express the ability of meat or fish to hold water during the application of force like pressing, centrifugation etc (Warrier et al. 1975).

Hamm (1960) has suggested that only 4-5% of the total water of muscle is tightly bound to the muscle proteins and is not influenced by changes in the structure and charges of proteins. Most of the remaining water is termed as free water and is retained within the protein structure.

According to Love (1962) when an animal is frozen, the constituent water usually separates out as pure ice. At first, before much denaturation has taken place, such separated water is reabsorbed by the protein gel. When the tissue is thawed, the ability to reabsorb water diminishes during the course of denaturation.

Awad et al. (1969) observed a decrease in water holding capacity of freshwater white fish muscle during frozen storage at -10°C.

2.7.4.2 The changes due to freezing and storage make the fish less palatable, and vary according to species, freshness, treatment prior to freezing, freezing method and the storage conditions (Nikkila & Linko, 1954). The changes
caused by a denaturation of proteins results in a drier and coarser muscle texture than fish muscle. The denatured proteins lose their ability to swell, retain muscle juice and return to their original condition after defrosting. He observed that the muscle frozen in rigor mortis and subjected to cold storage is more likely to become denatured during defrosting than that muscle frozen after the resolution of rigor mortis. Freezing causes a change in the condition of the native proteins and make them more liable to denaturation. If the storage time and defrosting temperature were increased, the myosin became increasingly less soluble in salt solution.

Experimentally the denaturation of proteins was studied best by changes in the solubility characteristics of proteins (Dyer et al., 1950). Anderson et al. (1963) have cast serious doubts on accepting solubility as a criterion of protein denaturation. The best approach so far to the problem of determination of protein denaturation in frozen fish has been to study the loss of solubility in a neutral salt solution of high ionic strength. Bate Smith (1934, 1937) and Reay (1933, 1934, 1935) observed that during frozen storage of fish, there is a progressive loss in solubility of its muscle proteins, especially the globulins. Dyer et al. (1950) improved the extraction procedure by the introduction of a blending technique, which
has subsequently become a standard method for determining protein solubility in frozen fish.

Variations were considerably diminished in the percentage of total protein soluble in 5% sodium chloride solution when certain myotomes freed from myocommata were assayed rather than whole minced fillets (Ironside & Love, 1958).

Love & Ironside (1958) followed changes in the percentage of soluble proteins during frozen storage of fish and found that during 20 weeks at -14°C the value declined steadily from 85% to 23%, after reaching this stage no further decrease was observed.

Love (1958) measured the proportion of soluble protein in cod muscle which had been frozen at various speeds and storage for different times at different temperatures.

Love (1962) followed opacity measurements to study the denaturation of proteins, but the seasonal variation in fat content interferes in the opacity measurements.

Love & Mackay (1962) followed the development of cell fragility method during cold storage. The cells of fish muscle during cold storage gradually develop an increasing resistance to destruction by a mild homogeniser. The homogenate contains a greater or lesser number of
intact cells according to the extent of cold storage denaturation and the proportion of these is assessed by measuring the optical density of the homogenate in a colorimeter. An increase in the number of intact cells results in a decrease in optical density. Here also fat affects the opacity of the homogenate by forming an emulsion with the formaldehyde.

Love (1962) studied the effect of onset and resolution of rigor mortis on protein denaturation.

Love & Elerian (1962) studied the temperature of maximum denaturation in cod and found that the rate of denaturation was maximal at a temperature close to -15°C. According to Love et al. (1965) the changes in extractability are the consequence of a binding together of the structural protein molecules and perhaps myofilaments, while a binding together of myofibrils is the agent causing changes in cell fragility readings.

Love (1970) stated that the properties of the myofibrillar proteins gradually change during freezing and frozen storage of fish, that is an uncoiling of the molecular helix leading to cross linking between the adjacent parallel molecules; the actomyosin complex becomes steadily less soluble in 5% sodium chloride solution after increasing time of storage.
Love & Maslemuddin (1972) studied the protein denaturation by measuring the cell fragility based on pH effects.

Connel (1960 & 1962) studied the changes in the actin and myosin of cod flesh during storage at -14°C. 70-80% of the myosin became non-extractable at a rate similar to that at which the total myofibrillar protein of the flesh became non-extractable. The remainder became non-extractable at a very much slower rate. Upto 52 weeks pure myosin was extractable from cod muscle stored at -14°C, and actin had been prepared for upto 127 weeks. The amount of sarcoplasmic proteins remained virtually unchanged during prolonged storage.

According to Connell (1962) the principal mechanism involved in the development of toughness, rubbery texture and loss of water holding capacity during storage of frozen cod is the formation of increased numbers or increased strength of bonds between the constituent myofibrillar proteins.

The actomyosin insolubilisation in fish held in frozen storage is due to free fatty acid accumulation in the muscle as a result of lipid hydrolysis (June Olley & Duncan, 1965; Dyer & Fraser, 1959; Devadasan & Nair, 1971; Seagram, 1958); but according to Raymond Jacquot (1961)
denaturation was usually more rapid in the non-fatty species than in the fattier species. Elerian (1965) followed the changes in the refractive index of muscle juice or whole muscle tissue of cod to measure the deterioration. According to King (1966) myosin was more sensitive to freezing induced denaturation than actin; Awad et al. (1969) followed the solubility criterion of actomyosin to study the frozen storage deterioration in freshwater white fish muscle and Moritoshi Oguni et al. (1975) studied the physicochemical characteristics of freeze-denatured carp actomyosin. Banks et al. (1977) suggested that the protein damage may be due to a number of different interrelated physical and chemical changes, that vary with species and methods of processing storage and handling.

2.7.4.3 Adenosine triphosphatase activity (ATP-ase) of Myosin and Actomyosin

The most important biochemical characteristics of myosin is its enzymatic activity with respect to the hydrolysis of ATP (Engelhart et al. 1939). The activity of purified myosin is related to the ATP-ase activity of reconstituted actomyosin (Barany, 1967) and to the interaction between actomyosin and ATP in vivo (that is muscular contraction) (Mommaerts, 1950; 1966 and Davies, 1963). By using the loss of enzyme activity as a measure of denaturation trout myosin was about 23 times more
stable than cod myosin, but lost its activity about 25 times more rapidly than rabbit myosin (Buttkus, 1966). Substantial differences in the ATP-ase activity of myosins were observed from the skeletal muscle of various species (Bailey, 1942; Perry, 1960; Quass & Briskey, 1968; Morey et al. 1968).

Connell (1962) suggested that cod flesh stored at \(-14^\circ C\) was becoming denatured that is undergoing a configurational change in structure that leads to loss of enzymic (ATP-ase) activity. Adenosine triphosphatase exerts its effect on the muscle energy mechanism by cleavage of the terminal phosphate from its substrate adenosine triphosphate. The liberated chemical energy is then utilised in other organic reactions, transformed into mechanical energy, or it can be dissipated as heat (Tonzetich, 1954). According to Buttkus (1966) denaturation measured by the loss of myosin ATP-ase activity proceeds with positive entropy changes and can be looked upon as an opening or unfolding of the secondary and tertiary structure of the myosin molecule. Takashi Taguchi & Shizunori Ikeda (1968) studied the effect of lecithin on ATP-ase activity of actomyosin of pre and post rigor cod muscle.

Akihiko Hashimoto & Ken-ichi Arai (1978) found that the rate of inactivation of ca-ATP-ase of sardine myofilaments at pH 5.8 and 5°C was found to be comparable with that of ca-ATP-ase at pH 7.6 and 26°C.
Buttkus (1966) found out that myosin had two enzymic activities, an adenosine triphosphatase and an acetyl choline esterase, the rate of inactivation of acetyl choline esterase activity at 45°C was approximately equal to the rate of inactivation of ATP-ase activity at 25°C.

2.7.4 Freezing as a method of food preservation comes closer to preserving the food in the natural state than other methods of preservation. Of the various factors that influence the course of changes in the quality of fish muscle during frozen storage, the condition of the fish at the time of freezing appears to be the most important (Love, 1962a,b); and the temperature of storage is the most important single factor affecting the storage life of frozen fish (Anon, 1965; Dyer et al., 1968); and the temperature and humidity of the cold storage room have long been known to be important factors in determining the storage life of frozen foods (John A. Peters, 1970).

The first change noticed during cold storage of fish is surface drying, second closely related change is the denaturation of labile soluble fish proteins; this results in a toughening of muscle texture and an increase in drip loss during thawing, a third change is the appearance of off flavours and odours resulting from lipid spoilage (Beaumariage et al., 1969).
The amount of drip formed on thawing of frozen fish varies with a large number of factors involving both freezing and storage conditions and pre-freezing condition of the fish (Dyer et al., 1968; Empey & Howard, 1954). Dyer & Fraser (1961) suggested that when pH or acidity of the muscle was changed by lactic acid formation, the moisture binding capacity of the protein was reduced and drip was formed.

Glycolysis proceeds in fish muscle at subzero temperature (Tomlinson et al., 1963 and Burt, 1971).

It has been stated by Shewan (1954) that bacteria when frozen some suffered immediate death, irrespective of the rate of freezing or its temperature. Radhakrishnan et al. (1973) observed a gradual decrease of total and pathogenic bacterial counts in Bombay duck as the frozen storage period increased.

2.7.5 Use of glazes, preservatives and packagings. Ice glaze is inexpensive, can be easily applied and adopted in a production line and provides a satisfactory covering for a variety of fishery products, inspite of its susceptibility to cracking, its brittleness and high vapour pressure. According to the literature, ice by itself does not prolong the shelflife but chemical and antibiotic ices appear to appreciably extend the storage life of prawns (Tarr et al.)
1950; Fieger et al. 1956). The effectiveness of various water soluble antioxidants for retarding the development of rancidity in frozen lake herring products was studied by Greig et al. (1967) and observed that ascorbic acid was found to be more effective than propylgallate, monosodium glutamate or sodium tripolyphosphate. The effectiveness of ascorbic acid or ascorbic citric acid mixture for controlling yellow discolouration in frozen pomfrets, black spots in shrimps, inhibition of growth of the natural mixture of flora at temperatures between -18 and 28°C, for protecting the meat colour and for preventing discolouration in tuna meat and for improving the general quality of frozen stored pomfrets, surmai and mackerel were reported (Jadav & Magar, 1970; Bailey & Fieger, 1954; Shaikhmahamud & Magar, 1965; Fieger et al. (1956); Tressler (1957); Tanikawa, 1971 and Sawant & Magar, 1961).

Several varieties of fishes and shellfishes had better keeping qualities when coated with sodium alginate (Pillai, 1964). Glazing with a salt sugar (1%) solution was found to be superior to ordinary water glaze for frozen prawns (Mathen et al. 1970) and protective coatings such as agar-agar and dipping in hydroquinone solutions enhance the storage life of frozen oil sardines (Mathen et al., 1966). Shaikhmahamud & Magar (1965) tried boric acid, dipotassium hydrogen phosphate, sodium bisulphite, ascorbic acid,
citric—ascorbic acids, acronise®d, ferrimycin and penicillin for room temperature preservation of prawns. Tanikawa (1971) suggested the use of sodium nitrite, citric acid, ascorbic acid, butylated hydroxy anisole or butylated hydroxy toluene with ascorbic acid for preventing discoloration in frozen tuna meat and black spots in prawns. Sawant & Magar (1961) attempted to study the effect of chemical glazes such as sodium chloride, citric acid and sodium nitrite in frozen pomfrets, surmai and mackerel and found that the deleterious changes during frozen storage were slowed by these glazes. A dip in butylated hydroxy anisole (0.005%) for 15 minutes and subsequent storage in polythene lined gunny bag at -15 to -18°C was recommended to enhance the keeping quality and to prevent dehydration and discoloration in frozen pomfrets (Kamasastri et al. 1967). The polyphosphate and sodium citrate treatments reduced thaw drip and oxidative rancidity in frozen fish (Anon, 1963-64).

2.7.6 Changes during canning

Canning is that method of preservation of food where spoilage is averted by killing the microorganisms present by application of heat. Therefore canning can be called the process of heat sterilization of foods in hermetically sealed containers. Since sterilization implies complete destruction of all living organisms and since this condition
may not be attained in some processed foods, the term 'commercial sterilization' has been introduced in the canning industry. Commercially sterile cans may be defined as cans which have been so processed that the food under ordinary storage conditions, will neither spoil nor endanger the health of the consumer. This definition requires that the temperature applied should have been adequate for the destruction of clostridium botulinum spores (Herson & Hulland, 1969). Exclusion of air after sterilization prevents any further contamination by organisms.

The important factors controlling the drained weight of canned prawn are concentration of brine used for blanching and blanching time. Other factors such as acidity of brine used for filling the can, volume of brine used, time of sterilization and time of cooling the blanched meat are also to some extent found responsible for fluctuations in drained weight (Varma et al. 1969).

Probable sources of contamination of raw blanched and processed meat at various stages of handling of prawns and methods for their rectification have been described by Choudhury et al. (1970) and Choudhury & Bose (1971) gave an account of the bacteriological spoilage of canned prawn and its methods of prevention. The prime factor of spoilage was post process contamination which accounted for 92.3%
of the defective cans, while under processing accounted for only 7.7% of the cans. Importance of bacteriological quality of water, ice and other materials with which prawn comes in direct or indirect contact has been emphasized (Choudhury & Bose, 1971).

According to Tarr & Bisset (1954) the brown discolouration which frequently occurs during the canning of certain white fleshed fish is due largely to maillard (Sugar-protein) types of reaction. The browning reaction is liable to occur whenever foods containing proteins or amino acids and reducing sugars are heated and are stored for long periods without refrigeration. The production of stale and otherwise unpleasant tastes, the varying degrees of brown discolouration, the loss of protein solubility leading to a deterioration in texture and the failure of foods to reconstitute properly are deleterious. The nutritional value of proteins has been seriously impaired by reaction with carbohydrates. Evidence is presented by Tarr (1954), which indicates that only the free and not the combined ribose in fish muscle takes part in maillard reactions. About 5 times as much glucose as ribose is required to cause the same degree of browning in fish flesh.

Fresh silver and black pomfrets and hilsa were canned at fresh and iced conditions and the qualities of the canned products were studied by Venkataraman et al. (1970).
Under identical conditions a maximum quantity of cook drip and nitrogen contents were found to be lost in black pom-frets and minimum in hilsa.

The effect of canning and storage in the presence and absence of antioxidants such as nordihydro guaiaretic acid and ascorbic acid on the nutrients in black and white pom-frets and prawns was studied by Sawant & Magar (1961). Canning denatures the proteins; the amino acids contents are not adversely affected. On the other hand they observed significant loss in vitamins. On storage there is marked loss of nutrients and the extent of losses increases with rise in storage temperature. The antioxidants prevent discolouration of the canned product.

2.7.7 Changes in dried products

Sun drying of fish has been a traditional process of fish preservation in most of the countries of the world. The process, however, is inordinarily slow and gives a product lower in nutritional value and high percentage of moisture which decreases its storage life. Dehydrated foods are subjected to deteriorative reactions during storage resulting in discolouration, off flavours and changes in texture. It is generally agreed that these reactions are kept to a minimum if residual moisture is low and storage is in an inert atmosphere, preferably at a low temperature.
Nazir & Magar (1965) observed that dried Bombay ducks stored in tin containers kept better and longer than those stored in polythene bags. Hunt & Matheson (1958) studied the effect of dehydration on actomyosin in cod muscle. Actomyosin became insoluble in salt solution; the muscle fibres may or may not lose their power to contract, although about half the adenosine triphosphatase activity was not destroyed. Tarr & Gadd (1965) observed discolouration in freeze dried ling cod and sole muscle and stated that it was due to Maillard-sugar amino reactions. Toyomizu et al. (1963) suggested that oxidation of the oil was largely responsible for the brown discolouration of freeze dried dark muscle of horse mackerel.

2.8 Aim and scope of the present work

The above literature survey clearly indicated that the literature with regard to the processing parameters and consequent loss in quality of shellfishes like crab, mussel and clam are scanty and inadequate for application to processing establishments.

In this thesis all these aspects are taken into consideration. Extensive studies were conducted on all aspects of processing of crabs, mussels and clams. The species taken for studies are commercially used ones namely, Scylla serrata, Perna viridis and Villorita cyprinoides.
In Chapter 4.1 with regard to crab, the following aspects on their handling and processing are reported: seasonal variation of chemical constituents, changes taking place during ice storage, freezing, canning etc.

In Chapter 4.2 with regard to mussel, the relation between age (size) and chemical constituents, changes taking place during ice storage, freezing, canning etc. are reported and in Chapter 4.3 the changes taking place in clam muscle during icing and freezing are reported and the ameability of ice stored clams for canning purpose is reported.

The interference of high concentration of glycogen in mussel and clam muscles during the colour development of ribose (Mejbaum’s method) is observed and remedial steps are taken to minimise the interference.

Industrial processing of crabs, mussels and clams although taken widely in India, has not shown rapid strides as expected in terms of quantity inspite of heavy demands from overseas markets.

The results of the investigation prove that a number of parameters have to be considered and evaluated both at harvesting and subsequent post harvesting and processing of these valuable food commodity if it is to be an economically viable proposition industrially.