A perusal of literature reveals the scenario of research on the storage characteristics of various fishes, vegetables, fruits and meat products.

2.1 Storage of Fishes

The freezing and storage characteristics of many fishes *viz.* common murrel (*Channa striatus*), rohu (*Labeo rohita*), silver pomfret (*Pampus argenteus*), kalawa (*Epinephelus* spp.) have been studied by Perigreen et al. (1987), Sankar and Nair (1988), Joseph *et al.* (1988) and Joseph *et al.* (1989). Perigreen *et al.* (1987) studied the characteristics of common murrel (*Channa striatus*) stored in ice and noticed that moisture content (MC), peroxide value (PV), and free fatty acids (FFA) were increased during storage and a declining trend was observed in the values of non protein nitrogen (NPN) and alpha amino nitrogen (AAN). It was suggested that the rate of total volatile base nitrogen (TVBN) at the end of storage on ice was not high even though the fish became unacceptable during the period. Sankar and Nair (1988) compared the biochemical changes of silver pomfret (*Pampus argenteus*) under freshly frozen condition as well as after keeping in ice for one, two and four days. They observed an increase in PV, FFA and phospholipid (PL) while the MC was decreased in freshly frozen samples. According to them, the rate of formation of peroxide in the iced and frozen samples was higher than that in freshly frozen sample. Fishes were frozen after keeping in ice for two days and four days had lower levels of FFA than that held in ice for one day. TVBN and water soluble nitrogen (WSN) remained steady up to seven days in ice and showed slight decrease on further storage. An increase in MC, salt soluble nitrogen (SSN) and a decrease in NPN were also
noticed. A comparative study was made by Joseph et al. (1989) in kalawa (Epinephelus spp.) under freshly frozen and delayed frozen (after keeping five hours and ten hours at ambient temperature) conditions. NPN values of delayed frozen samples were higher than that of freshly frozen samples, but SSN values of freshly frozen sample were higher than that of delayed frozen samples. No significant difference in MC among the samples and a slight decrease in all cases during storage were also observed.

Srikar et al. (1989) reported the changes in lipids and proteins of marine catfish (Tachysurus dussumeri), which was stored over a period of 300 days at −20 °C. They determined the decrease in water soluble protein (WSP) and salt soluble protein (SSP) indicating the denaturation of proteins on prolonged frozen storage. A linear relationship between the decrease in PL and increase in FFA was also observed. Similarly, Reddy et al. (1995) showed that preprocess storage of pink perch (Nemipterus japonicus) in ice prior to mincing and freezing, resulted in significant decrease in WSP and SSP as well as NPN. A decrease in the proportion of soluble fractions of protein in whale shark (Rhiniodon typhus) meat during storage in ice was reported by Kumar et al. (2000). French et al. (1988) kept coho (Oncorhynchus kisutch) and sockye salmon (Oncorhynchus nerka) under 0, −1 °C, −2 °C, −3 °C and −25 °C for 25 days and analysed hydrolysis of individual soluble proteins by SDS-PAGE and noticed that the highest rates of hydrolysis in fish were at −2 °C and −3 °C.

In their work on effects of frozen storage of pink perch mince, Verma and Srikar (1994) found a non significant decrease in crude protein (CP), total lipid (TL) and WSP during initial storage, whereas, SSP decreased significantly (p<0.05).
throughout the storage. However, PV, FFA, trimethyl amine nitrogen (TMAN) and TVBN were found to increase significantly throughout the storage period of 180 days. Thus an inverse correlation was observed between SSP and PV, FFA and TMAN as well as TVBN. Similar results were reported by Sarma et al. (1998) in pink perch (*Nemipterus japonicus*) and oil sardine (*Sardinella longiceps*) by observing a significant increase (p<0.05) in PV, thiobarbituric acid reactive substances (TBARS) and FFA in both species during storage. They suggested that SSP, in both species, show significant correlations with PV, TBA (thiobarbituric acid) and FFA.

Degradation of myosin heavy chain (MHC) and actin was noticed during post-harvest storage at low temperatures (0-5 °C) in Pacific whitefish (*Merluccius productus*) by Lin and Park (1996). Lian et al. (2000) reported the denaturation of protein in red hake (*Urophycis chuss*) mince could be effectively controlled during frozen storage by the addition of 0.4% alginate, 4% sorbitol and 0.3% sodium tripolyphosphate (STPP). Similarly, the antioxidants namely ascorbic acid, α and β tocopherols, glutathione and volatile aldehydes were declined both in the frozen minced and intact fillets of channel catfish (*Ictalurus punctatus*) stored for six months (Brannen and Erickson, 1996).

Nair (1993) studied the levels of peroxide in pomfret muscle during storage at zero and 10 °C. The maximum peroxide value obtained at 10 °C was much less than that obtained at 0 °C. Similar observations were made earlier by Ke et al. (1977) in frozen mackerel stored at -15 °C, -30 °C and -40 °C indicating the increase in the rate of formation of peroxides when the temperature increased. Reduced lipid deterioration was reported in black-skipjack (*Euthynmus lineatus*) when stored in ice.
for 24 days and also noticed that the acceptability of fish was up to 18 days of storage (Mazorra-Manzano et al., 2000). Lilabati and Vishwanath (1999) studied the biochemical and microbiological qualities of ice-stored *Labeo gonius* over a period of three months. It was found that the fish were nutritionally rich, and the TVBN and TBA values were within the permissible limit and also recorded that the total plate count (TPC) were highest in gills than in muscles. But reduced TMA and TVBN delayed changes in protein functionality were noted in hake (*Merluccius merluccius*) stored in ice state (2±1 °C) under modified atmosphere packaging conditions (MAP) for 21 days by Pastoriza et al. (1996).

Baixas-Nogueras et al. (2001) studied the changes of the volatile and nonvolatile amines in Mediterranean hake (*Merluccius merluccius*) stored at 20 °C. It was reported that TMA and biogenic amines were higher in fresh samples than in frozen samples. They also suggested that the levels of volatile and non volatile amines were strongly dependent on temperature.

Simeonidou et al. (1998) found that the TBA and formaldehyde (FA) were significantly increased during storage on ice of seven Mediterranean fish species viz. bogue (*Boops boops*), chub mackerel (*Scomber japonicus collias*), horse mackerel (*Trachurus trachurus*), Atlantic mackerel (*Scomber scombrus*), Mediterranean hake (*Merluccius mediterraneus*), sardine (*Sardine mediterraneus*) and striped mullet (*Mullus barbatus*) for seven days.

Reddy et al. (1992) observed that frozen storage of mechanically deboned pink perch for 180 days resulted in a decrease in emulsifying capacity, protein solubility and relative viscosity, but an increase in water binding capacity in terms of absorbed
moisture and drip loss. There was little change in lipid oxidation products (PV and TBARS) but a very large increase in FFA.

Han and Liston (1987) investigated the interaction between lipid peroxidation and phospholipase A2 in fish muscle microsomes and frozen fish muscle. According to them, the levels of lipid peroxidation in fish muscle were higher when fishes were stored at higher frozen storage temperature and so were the levels of LPC.

Changes in muscle lipid composition of white pomfret (Stromateus cinereus) during ice temperature (0-2 °C) storage were reported by Rao and Bandhyopadhyay (1986). A decrease in glyceride content with an increase in FFA without any effective change in fatty acid composition was observed during the storage of fish fillets up to five days at 0-2 °C.

Tomas and Anon (1990) reported that salmon muscle was frozen either slowly or rapidly at −25 °C and then stored at −5 °C for up to 47 days. TBA values for rapidly frozen salmon showed some tendency to be higher than that frozen slowly. Hoke et al. (2000) examined the effect of washing and antioxidant addition on the overall quality of catfish (Ictalurus punctatus) frame mince during frozen storage. It was found that lipids, TBARS and FFA during frozen storage were declined in the washed mince compared to unwashed mince.

Enzymatic activities pertaining to proteolytic enzymes and lipases during frozen storage were reported by Warrier et al. (1988) and Vel et al. (1992). Warrier et al. (1988) reported the occurrence of proteolytic enzymes, aminopeptidase (Arg-Nnap hydrolase) and cathepsin B in muscle extracts of seven marine fish species such as dogma (Johnius dissimiert), seer (Scromberomorous guttatus), mackerel (Rastrelliger
kanagurta), pomfret (*Stromateus cinereus*), Indian salmon (*Eleutheronesma tetradaactylum*), shark (*Caracharhinus* spp.) and sardine (*Sardinella longiceps*). The enzymes showed a progressive decline in activity during storage at 0 °C, serving as an index of the freshness of fish. A significant decrease in the activities of proteases and lipases in various tissues of oil sardine and ribbon fish during frozen storage was reported by Vel et al. (1992).

Hsu et al. (1994) recorded the protein denaturation in Pacific whiting (*Merluccius productus*) fillets stored at -8 °C, -20 °C, -34 °C and -50 °C over a period of ten months by SSPE and Ca++ ATPase activity. No significant change in denaturation of proteins by SSPE and Ca++ ATPase activity was observed when the fillets were stored at -34 °C and -50 °C than those stored at -20 °C. But, a decrease in soluble protein, Ca’ ATPase and total and reactive –SH groups were reported in *Tilapia nilotica* during frozen storage (Ramirez et al., 2000).

The influence of the gonadal stage of hake (*Merluccius hubbsi*) on the biochemical properties of myofibrils stored at 2 °C to 4 °C was studied by (Pagano et al. 2001). It was found that Mg2+-Ca2+-ATPase activity and Ca2+ sensitivity of myofibrils from post-spawned hake were significantly higher than that of pre-spawned fish at zero time and during storage and the actin-myosin ratio of stored myofibrils were unchanged. However, a decrease in the reduced viscosity and Mg2+- (EGTA)-ATPase activity of natural actomyosin from both pre- and post-spawned hake (*Merluccius hubbsi*) stored on ice was reported by Roura et al. (1990).

The effect of prolonged cold storage on muscle ATPase and LDH activities was reported in a variety of fresh water and brackish water fishes. Decrease in enzyme
activity was observed in all samples stored frozen (−20 °C) over a period of 180 days (Nambudiri and Gopakumar, 1992).

The peroxidase enzyme activity in frozen fishes was reported by different investigators (Nakano et al., 1992; Eun et al., 1994; Watanabe et al., 1996; Jia et al., 1996). Nakano et al. (1992) detected GSH-Px activity in the muscle and skin tissue from several fish species viz. coho salmon (Oncorhynchus kisutch), carp (Cyprinus carpio), rainbow trout (Oncorhynchus mykiss), Japanese eel (Anguilla japonica), scallop (Patinopecon yessoensis) and sardine (Sardinops melanostictus). The activity of GSH-Px increased gradually when salmon fillets were stored at −50 °C. An NADH dependent lipid peroxidation system was identified by Eun et al. (1994) in channel cat fish (Ictalurus punctatus) muscle microsomes. Further, the enzyme activity was higher in fish fillets stored at −40 °C than those at −10 °C.

Watanabe et al. (1996) reported the activity of fish muscle GSH-Px, which presumably protects muscle from oxidative deterioration during storage and processing, in Japanese jack mackerel and skipjack tuna. The activity of peroxidase and the level of reduced GSH, an enzyme substrate decreased during five days of storage at 4 °C in both fishes. Jia et al. (1996) compared the quality loss and changes in the GSH antioxidant system in mackerel and blue fish muscle at both −20 °C and 2°C temperature. It was found that the loss of glutathione was more rapid in mackerel fillets than in blue fish fillets and GSH/ GSH-Px were an effective antioxidant system against lipid oxidation induced by an exogenous free radical generating system.
2.2 Storage of Fruits and Vegetables

The reports on the changes associated with refrigeration of fruits and vegetables are mentioned as follows.

The effects of frozen storage on vegetables and fruits were investigated by Rutherford and Whittle (1982), Scriven and Wills (1984), Aparicio-Cuesta and Garcia-Moreno (1988), Wu et al. (1993), Kumar and Nath (1993), Whitaker (1993), Mahajan (1994), Bal et al. (1995) and Simandjuntak et al. (1996). Rutherford and Whittle (1982) found that the onion cv robusta on cold storage at 4 °C showed the hydrolysis of oligosaccharides to reducing sugars. Scriven and Wills (1984) in their analysis of fruits and seed samples of Jonathan apple after a period of three to sixteen weeks of storage showed that the abscisic acid level in the flesh was maximal early in storage and declining after 16 weeks at −1 °C.

Aparicio-Cuesta and Garcia-Moreno (1988) studied the changes occurring in Vitamin C content in frozen cauliflower stored under different conditions. During storage at −22°C, 25% vitamin C was lost after 13 months and 62.2% after 30 minutes. Wu et al. (1992) reported that ascorbic acid in green beans and broccoli decreased and increased respectively during refrigerated storage significantly for up to seven days, while β-carotene content of both green beans and broccoli did not change during frozen storage. Shelf life of aonla (amla) fruits in a zero-energy cool chamber and at room temperature was compared by Kumar and Nath (1993). Physiological loss in weight, decay and loss of vitamin C were found less in fruits stored in the cool temperature compared to that of room temperature.
Whitaker (1993) investigated the changes during the storage of mature green tomato fruits (*Lycopersicon esculentum*) for 4–12 days at chilling. After 12 days, the ratio of phospholipid to protein in microsomes declined and a concomitant increase was noticed in the ratios of total membrane sterols (TMS) and cerebrosides (CB) to PL. The unsaturation index of fatty acids in PL and galactolipids increased slightly during storage at 2°C. In plastids the ratio of mono to digalactosyl diacyl glycerols declined substantially at 2°C.

Mahajan (1994) reported the biochemical and enzymatic changes in apple during cold storage. Total soluble solids (TSS), total sugars (TS), soluble protein contents, polygalacturonase (PGU) and cellulase increased up to 150 days of storage and thereafter declined. On the contrary, titrable acidity, total phenols and pectin contents followed a linear declining trend throughout the storage period of seven months. A decrease in the diffusion of reducing sugars in raw and previously frozen carrot cortex at 10°C for one month were reported by Oliveira and Silva (1992). Total, soluble and bound peroxidase activities were studied on frozen green beans stored under proper condition (−18°C, −22°C and in display freezer) and under adverse conditions (with temperature fluctuations) by Aparicio-Cuesta *et al.* (1992).

Bal *et al.* (1995) studied the effects of pre harvest spray of growth regulators on the pectin methyl esterase (PME) activity of *Ber* fruit during cold storage. The authors reported that the shelf life of the treated fruit can be extended up to 30 days in paper and polyethylene bags.

Simandjuntak *et al.* (1996) made a comparative study on the changes in composition, drip loss and colour of cantaloupe and honey dew melons were
determined in fresh and frozen conditions stored at -23 °C for five and ten months. During frozen storage, there were significant decreases (p<0.05) in total cell wall polysaccharide (CWP) sugars corresponding to increased storage time. Drip loss was negatively correlated with total neutral sugar content when storage time increased.

The quality of vegetables during cold storage were reported by Chourat et al. (2001) and Chourasia and Goswami (2001). Chourat et al. (2001) compared the quality of green beans during freezing in air blast and immersion freezing, and characterized the effect of immersion freezing before and after storage of green beans. It was found that the drip loss of green beans were higher in air blast freezer when compared to immersion freezing. Chourasia and Goswami (2001) reported the loss of quality of potato during cold storage by freezing and chilling injury due to low temperature.

The impact of blanching and freezing on the firmness retention and ultrastructural changes in the cell wall and middle lamella of carrot tissues were studied by Roy et al. (2001). Severe structural damage, loss of pectic materials and softening of tissues were found at slower freezing rates.

2.3 Storage of Fishery Products

In recent years, processing of clams and mussels has undergone extensive development because of their increasing demand in overseas countries for such delicacy foods. However, studies on shelf life of clam meat and mussels under frozen storage are scarce. Some of the reports on the changes in chemical, microbial and
organoleptic characteristics of mussels and shrimps under frozen storage are as follows.

Mishra and Srikar (1989) reported the shelf life of clam (*Meretrix casta*) meat during frozen storage for 200 days. They observed a decrease in moisture, total nitrogen, glycogen, NPN and AAN while an increase in TVBN, PV and TBA number. Prafulla *et al.* (2000) compared the quality changes in squid (*Loligo duvauceli*) and cuttlefish (*Sepia pharaonis*) stored at various conditions viz. direct icing, indirect icing and in a mixture of ice and salt. TVBN and TMAN showed a faster and steady rise in indirectly iced samples and also noted that indirect icing preserved the nutrients in squid and cuttlefish with shorter shelf life, while chilling in a mixture of ice and salt gave a better quality product.

Biochemical properties of actomyosin of striated adductor muscles of molina (*Aulacomya ater ater*) during cold storage were reported by Paredi *et al.* (1990). After two days of storage, relative percentage of myosin decreased and actin increased.

An effect of blanching on the physicochemical and functional properties of proteins from prawn (*Metapenaeus dobsoni*) during frozen storage was studied by Shamasunder and Prakash (1994a). Rate of drip loss was increased for every 30 days of storage at -18°C up to 300 days and a four fold decrease in solubility of protein was noted. Shamasunder and Prakash (1994b) studied the nature of proteins in drip exudates from frozen prawn (*Metapenaeus dobsoni*). It was reported that the total solids and proteins in the drip were 4.25 ± 0.20% and 4.8 ± 0.25% respectively and as a result of frozen storage a change in the protein present in the drip was noticed.
Bhobe and Pai (1986) made a comparative study on the changes in pH, TMA, soluble protein of shrimps under chilled (0 °C) and frozen conditions (−18 °C). They reported an increase in pH and TMA under both conditions while, a decrease was noticed in the case of soluble protein and also found that chilled samples spoiled within few days. However, the frozen samples did not spoil even after six months of storage. Similarly, Basavakumar et al. (1998) noticed an increase in MC, TVBN and TMA and a decrease of total protein on the 15th day storage of tiger shrimp (Penaeus monodon) in ice. They also found that the acceptability of shrimps were upto 11 days in their cooked form, but were unacceptable in their raw condition on the 9th day of storage in ice. An increase in TMA and TVBN were reported earlier by Shamshad et al. (1990) in shrimp (Peneaus merguiensis) stored at 0 °C.

A steady diminution of sensory acceptability and an increase in the oxidative rancidity were noticed in frozen oysters treated with antioxidants held at −18 °C (Abraham et al., 1994).

2.4 Storage of Meat Samples

The effects of frozen storage of various meat samples were investigated in the past. In this connection, Pikul et al. (1984) investigated the oxidative rancidity in fresh and processed chicken meat by measuring the malondialdehyde (MDA) content. It was reported that frozen storage for three and six months before cooking and refrigerated storage after microwave cooking showed an increase in MDA concentration.
The effect of frozen storage on myofibrillar ATPase activity and thermal transition in bovine muscles was analysed by Wagner and Anon (1986). It was noticed that myofibrillar ATPase activity and total enthalpy of denaturation (ΔH) decreased with time of storage. The rate of decrease was lower at -20 °C than at -5 °C or -10 °C. An increase in protein solubility, viscosity, gel strength and water holding capacity when stored at 4 °C were showed by Xiong and Brekke (1989) in chicken hen breast and leg myofibrils.

Strange et al. (1985) examined the effects of freezing and thawing, and refrigerated storage of pork liver. Significant (p<0.05) differences were noted in the number of isolated intact cells and in tissue protein content between freezing and thawing and refrigerated storage and fresh liver. It was also reported that repeated freezing and thawing appears to break down the liver structure differently than that of the refrigerated storage. Sen and Sharma (1999) studied the effect of repeated freezing and thawing of meat and liver of buffalo under storage at -18 °C for five days. It was reported that there was an increase in TBA, tyrosine values (TV) and drip loss in meat and liver due to repeated freezing and thawing.

Akamittath et al. (1990) made a comparative study on the role of salt, salt with phosphates and antioxidants on lipid oxidation in beef, pork and turkey steaks during storage at -10 °C for four weeks and eight weeks respectively. It was observed that there was an increase in lipid oxidation when treated with salt alone. However, the combination of the salt with phosphates and antioxidants inhibited the lipid oxidation. An increase in TBA value, acid number and PV in adipose tissue of breast
and thigh muscles of chicken during frozen storage under −18 °C was reported by Bystricky et al. (1993).

Biochemical variation in proteins for broiler rabbit muscles (longissimus dorsi and biceps femoris) held at chill (2 to 4 °C) and frozen temperature (−10 °C to −12 °C) through SDS-PAGE was reported by Kumar et al. (1993). Keshri and Sharma (1989) reported the moisture gain during chilling and subsequent loss of moisture on frozen storage of pigeon carcasses.

Water, nitrogen content, TBA, peroxide number (PN), FFA, melting point (MP), iodine number (IN) and saponification number (SN) were studied by Unsal et al. (1995) in sheep tails, sheep tail fat, both in fresh and after storage at −18 ± 1 °C for upto 60 days. It was reported that MP, TBA, PN, FFA and total nitrogen increased while water content, IN and SN declined.

The effect of antifreeze proteins were assessed by Payne et al. (1994) in meat during freezing (20 °C) and chilling (−2 °C) for five and seven days. According to them the antifreeze proteins reduced the size of ice crystals, compared to the control in frozen samples. However, the antifreeze proteins had no effect on chilled sample.

Wilkinson et al. (2001) studied the antioxidant activity of tocopherols (TOC), erythorbate (ERY), TOC+ERY and tertiary butylhydroquinone (TBHQ) in fresh and freeze-dried beef and chicken were measured using the TBARS test and a fluorescence assay. The authors reported that in relation to controls, ERY, TOC, TOC+ERY and TBHQ showed a decline in lipid oxidation in fresh and freeze-dried meat (p<0.05).
Dushyanthan et al. (2000) studied the effect of vacuum packaging on chemical qualities, viz. extract release volume (ERV), TBA number, TV and total microbial load of beef in different packaging materials and stored at different periods under chilled temperature (5 ± 2 °C) and frozen conditions (−10 °C). They reported that ERV, TBA number, TV and microbial load of beef stored in the chiller and freezer temperature were better than that packed under ordinary method. A significant increase in TBA and decrease in TPC, colour, texture, flavour and overall acceptability scores were observed during frozen storage of meat patties of buffalo (Bawa and Sekhon, 2000). Lopez-Caballero et al. (2002) also analysed the microbial inactivation in meat products by the combined treatment of high pressure and different temperature such as 5 °C, 20 °C, 35 °C and 50 °C respectively.