REVIEW OF LITERATURE
Quality and safety of fish and fishery products are of prime importance in the whole chain from primary production up to the storage and sale process. Thus, the need for rapid analytical techniques to measure the food quality and freshness is greater than ever. A comprehensive manual depicting the procedures for the objective measurement of physico-chemical quality of fish food was developed by Woyewoda et al. (1986) and Haaland and Njaa (1988). The microbial spoilage occurring in fish products is measured through procedures described in comprehensive manual developed by Huss (1995), Gram and Huss (2000) and Gram et al. (2002).

Tarr (1947) in his studies reported that dehydration occurring during cold storage conditions increases the rate of oxidation and hence storage under condition of low water loss by packaging glazing or freezing in water is suggested.

Khan (1948) performed studies on the oxidative rancidity occurring in salmon (spring, coho and pink) treated with compounds (1-ascorbic acid, reductinic acid, reductone, diammonium dihydroxymaleate, and dihydroxy maleic acids) and stored for a period of 5-6 months at -10°C and -20°C. The studies concluded that 1-ascorbic acid and reductinic acid afforded excellent protection against oxidative rancidity while reductone, diammonium dihydroxymaleate had comparatively poor protection.
To determine the acceptability of food product, David Peryam and Girardot (1952) developed the scale called Hedonic scale at the Quartermaster Food and Container Institute of the U.S. Armed Forces, for the purpose of measuring the food preferences which was quickly adopted by the food industry and now is used for measuring the acceptability of foods.

York and Vaughn (1954) reported the effectivity of 0.5% Potassium sorbate against vegetative cells and spores of Clostridium botulinum (Type-C, D and E).

While determining the various chemical indices in fish fillets, Lerke and Farber (1969) proposed that direct bacterial counts could be used to study the shelf life studies in food stuffs.

Gopakumar and Nair (1972) in their studies on frozen stored pink perch (Nemipterus japonicus) and oil sardine (Sardinella longicieps) reported a significant (p<0.05) increase in peroxide value (PV), thiobarbiturc acid (TBA) and free fatty acid (FFA). Greater rate of lipid oxidation with an adverse impact on protein solubility was observed in Sardine while hydrolysis of lipids to FFA was more pronounced in pink perch. Accumulation of lipid hydrolytic product i.e. FFA and development of rancidity due to oxidation of the lipids were found to be the major deteriorating processes during frozen storage of Sardine.

Suggesting the safe nature of potassium sorbate as preservative, Luck (1976) proposed that depending on dosage, the half life of Potassium sorbate is 40-110 minutes and is completely metabolized to CO₂ and H₂O, releasing energy in calories.

While performing the different storage practices on mackerel (Rastrelliger kanagurta) with medium (4%) and high (11%) lipid contents, Nair et al. (1976) proposed that block frozen mackerel had higher frozen storage shelf life than individually quick frozen samples and the samples stored at -23°C samples.

Robach and Ivey (1978) while examining the effect of potassium sorbate dip treatment on broiler proposed that 10% potassium sorbate reported lower Salmonella count as compared to untreated samples stored at 10°C for 7 days.
Broiler parts dipped in 5% or 10% Potassium sorbate reported no change in organoleptic quality as observed by Cunningham (1979).

The histological studies on fish muscle with reference to the role of psychrophiles by Shewan and Murray (1979) reported that chilling inhibits the invasion of bacteria into the fish muscle.

Siddique and Ali (1979) in his studies related the decrease in protein content of iced prawn to the leaching of the water soluble amino-acid with the melting of ice.

Studies on the microbial and biochemical parameters in Jack Mackerel as assessed by Ryder et al. (1984) reported the shelf life of 7 days when stored in ice and the aerobic plate counts never exceeded $10^6$ g flesh upto 11 days of iced storage. Further, the development of Trimethylamine, total volatile base, pH and Thiobarbituric acid does not indicate the good quality of fish as suggested by them.

Ampola and Keller (1985) during their studies on shelf life extension of drawn whole Atlantic Cod, Gadus morhua reported the 2.5 % and 5.0 % potassium sorbate dipping along with individual packaging in oxygen resistant poly- ethylenephthalate plastic film beneficial for extending the shelflife of fillets.

While working on fresh, frozen or pre cooked patties, Lee and Ahn (1985) proposed that antioxidant substances present in ginger rhizome are highly potent in controlling the formation of secondary oxidation products.

The studies of Al - Jalay et al. (1987) on a variety of food system confirmed the anti oxidative effect possessed by various spices including cloves, cinnamons, Black pepper turmeric ginger, garlic and onions.

Kanner et al. (1987) while explaining the role of heme iron as promoter of lipid oxidation reported that oxidation process is greatly accelerated if the muscle tissue has been frozen and thawed. The weak muscle cells fail to maintain components in the reduced state and hence myoglobin and hemoglobin (Fe$^{2+}$) are oxidised to metmyoglobin and methemoglobin (Fe$^{3+}$) which further react with hydrogen peroxide to produce (Fe$^{4+}$), thus initiating lipid oxidation.
Sikorski et al. (1990) while explaining the effect of oxidized lipids on proteins propounded that oxidized lipids affect the hydrogen bonds and hydrophobic interactions in the proteins of frozen fish. Also, the fatty acid character of lipid molecules exerts a surfactant effect on protein surfaces, leading to hydrophobic interaction and protein unfolding, thus exposing interior groups for reaction. Addedly, the carbonyl groups of oxidised lipids may participate in covalent bonding, leading to the formation of stable protein-lipid aggregates.

The effect of different storage temperatures viz. -10°C, -20°C and -30°C on quick frozen mackerel (Rastrelliger kanagurta) as observed by Chinnamma et al. (1995) revealed that shelf life was proportionally increased with decrease in storage temperature. They further added that rancidity development due to the formation of free fatty acid and thiobarbituric acid value acted as a limiting factor for acceptability.

While working on shrimps, Hanpongkittikun et al. (1995) reported a shelf life of eight days in shrimp samples stored in ice. Further they found no Coliform colonies in shrimp samples during ice storage and a steady increase in the pH of shrimp from 6.40 to 7.15 was observed throughout the storage period.

Lazos (1996) observed significant changes in chemical composition and textural profile of fish balls prepared from minced fillets and trimmings of freshwater bream (Abramis brama). He attributed this change to the pretreatment, processing time and high temperature which affects the final composition.

Tejada et al. (1996) reported an increase in number and size of protein aggregates formed during frozen storage of minced cod muscle stored for up to 62 weeks at 20 ºC.

Rhee et al. (1997) in his studies proposed that ascorbic acid and sodium ascorbate treatment to meat products inhibits the lipid oxidation rate and preserved desirable meat flavours.

Increase in pH ,TBA, FFA% and decrease in sensory attributes (odor, taste, texture) was observed by Simeonidou et al. (1997) in frozen whole fish and fillets of Horse mackerel (Trachurus trachurus) and Mediterranean hake (Merluccius
They related the increased pH with the formation of basic compounds; and increased TBA & FFA% with the lipid deterioration during the frozen storage at -18°C for 12 months.

Studies on primary and secondary lipid oxidation products, interaction compounds and lipid hydrolysis products along with correlation of different lipid damage indices with storage time of frozen Blue whiting fillets stored at -40°C, -30°C and -10°C up to 1 year were conducted by Aubourg (1998).

The effect of partial freezing and refrigerated storage in quality of Sea bass as observed by Chang et al. (1998) reported the rapid increase in microbes at 5°C and 10°C. Also, a maximum microbial population upto 3×10^7 cfu/g in fish muscle indicates a good shelf life as suggested by him.

A significant increase in total viable count and pH of air packed sole (Solea solea) fillets stored at refrigerator at 2 °C was observed by Lopez-Galvez et al. (1998).

Slattery (1998) reported a small increase in pH and psychrotrophs with increase in storage period of 14 days, thus maintaining the good quality in iced Spanish mackerel (Scomberomorous commerson).

Cowan (1999) in his studies suggested the use of plant polyphenols, flavonoids, alkaloids as potent inhibitors of viruses, bacteria, protozoa and fungi.

While observing the chemical changes in microbial flora of aerobically stored Mediterranean boque (Boops boops) at 0, 3, 7, and 10°C, Koutsoumanis and Nychas (1999) reported that total viable counts reached 9 log_{10} cfu/g by the end of the storage period, regardless of the storage temperature used. Further, the pH increase in muscle was associated with the decrease in L-lactic acid during storage.

Shelf life studies on the warm water Nile perch, Lates niloticus and the cold water ocean Sebastes marinus stored at 0°C by Masette (1999) reported their shelf life of 2-3 weeks and 1 week respectively.
While studying the lipid-protein interaction in fish, Saeed et al. (1999) propounded the use of synthetic (Butyl hydroxytoulene, BHT and Butyl hydroxyanisole, BHA) and natural antioxidants (ascorbic acid, α-tocopherol) for inhibiting the transfer of free radical from oxidized lipids to amino acids and proteins and thus reducing the protein degradation.

Mazorra-Manzano et al. (2000) while working on iced Black skipjack muscle observed the fluctuation in muscle pH between 5.7 to 6.0 while lipid deterioration assessed as TBA reported a value of 5mg/100g at 18th day of storage.

Benjakul and Bauer (2001) while studying the influence of different freeze-thaw cycles on biochemical and physico-chemical changes in catfish (Silurus glanis Linne) muscle, reported a significant increase in TBA value during storage.

Aubourg et al. (2004) while studying the rancidity development in frozen Horse mackerel found an increase in oxidative rancidity parameters viz. PV, TBA and FR with increase in storage time and salt content in fish muscle. Further, a decreasing effect of muscle salt content on lipid hydrolysis was also observed.

Badii and Howell (2002) while investigating the relation between lipid oxidation, ice crystals and protein denaturation reported that antioxidants (vitamin C and E) and cryoprotectants (sorbitol and sucrose) are effective in controlling the lipid oxidation and ice crystal formation and hence the protein denaturation and toughening in lean cod (Gadus morhua).

An increase in Psychrophillic bacteria count upto 5 log cfu/g was observed for thawed minced fish Atlantic pallock (Pallachius vireos) by Gashti (2002).

Osborn-barnes and Akoh (2003) in their studies proposed that the effective way to retard lipid oxidation in fatty foods is the addition of antioxidants. Further, they added that the Primary antioxidants (α-tocopherol) are capable of accepting free radicals so as to delay the initiation step of autoxidation while Secondary antioxidants (citric acid) can retard lipid oxidation through a variety of mechanisms, including chelating metals,
replenishing hydrogen to primary antioxidants, scavenging oxygen, and deactivating reactive species.

Investigatory studies on the effect of citric acid (CA) and ascorbic acid (AA) on the lipid stability of Horse mackerel (*Trachurus trachurus*) by **Aubourg et al. (2004)** propounded that the use of Citric acid and ascorbic acid rendered the fish muscle less prone to oxidation than their untreated counterparts and hence lower (P<0.05) peroxide, Thiobarbituric acid and fluorescent compound formation values were obtained from CA treated fish fillets than from untreated ones.

**Chytiri et al. (2004)** in Trout fillets reported an increase in the secondary oxidation product i.e.TBA from 10.4 to 19.4 µmol/kg after 18 days of ice storage.

**Jeyasekaran et al. (2004)**, while investigating bacteria quality of vacuum packed tuna (*Euthynnus affinis*) chunks stored under abused refrigerated temperature (10±7°C), reported the total bacterial load in fresh chunks was $10^5$ CFU/lg.

**Ola and Oladipo (2004)** reported *Pseudomonas sps.* and *Alteromonas putrefaciens* to be the principal spoilage organisms during iced storage while *Bacillus sps.*, *Pseudomonas sps.*, *Alteromonas putrefaciens* and *Proteus* dominated the spoilage flora at ambient temperature.

**Arannilewa et al. (2005)** in his studies on the effect of frozen period on Tilapia fish (*Sarotherodon galiaenus*) observed that protein and lipid content decreased along with no change in ash and moisture with the increasing storage period. Also the coliform count too increased with the increased storage period, thus decreasing the quality of fish.

**Benjakul et al. (2005)** stated that the frozen storage resulted in increase in moisture content, protein denaturation along with the decline of gel forming ability in Threadfin bream, Big eye snapper, Lizardfish and Croaker stored at - 18 °C for 6 months.

**Mokhtar et al. (2005)** in his studies on freshwater Patin (*Pangasius sutchi*) stored for a period of 28 days at different temperature viz. 0°C, 3°C, 5°C and10°C developed a correlation between the consumers acceptability, storage time and temperatures via the acidity (pH) test.
Ozden (2005) observed the lipid, protein, moisture, ash and fatty acid composition of marinated fish – anchovies and rainbow trout and concluded that the free fatty acid composition increased with the increasing cold storage period.

Niki et al. (2005) while studying the mechanisms and effect of lipid peroxidation mechanisms suggested three different mechanisms for lipid oxidation viz. enzyme oxidation, non- enzymatic free radical oxidation and non- enzymatic non-radical oxidation.

Greater damage in whole jack mackerel frozen stored for 120 days was due to hydrolysis of lipid as reported by Aranda et al. (2006).

While studying the effect of frozen storage at -18˚C on Trout fillets with vegetable toppings, Tokur et al. (2006) observed a slow increase in TBA values in both TFVT and TF. Also, in terms of sensory evaluation, TFVT (Trout fillets with vegetable topping) did not show any significant change but the scores decreased for the control samples without topping (TF).

Bao et al. (2007) studied the effects of dry ice and super chilling on quality and shelf life of Arctic charr (Salvelinus alpines) fillets. They reported that water holding capacity, water content, total viable count, TBA and pH increased during storage.

Studies on the storage properties of three types of fried whiting balls made with different types of mince at refrigerated temperature by Boran and Kose (2007) revealed an increasing values of TBA and TMA (Trimethylamine) along with decreasing sensory values during 15 days of storage period. Also, the shelf life was found to be longest for product with pre-cooked mince.

Chomnawang et al. (2007) while studying chemical and biochemical changes of hybrid catfish fillet stored at 4ºC, reported a significant decrease in the total protein content and increase in pH with storage time (p<0.05).

While studying the changes in physico-chemical and sensory characteristics of smoke dried fish species stored at ambient temperature, Daramola et al. (2007) proposed that the keeping quality of smoked fish decreases as the storage time increases.
While conducting a survey between fishes brought from open market and department shop, Jannat et al. (2007) reported that Hilsha (*Tenualosa ilisha*) from department shop had more microbial contamination which might be due to the fact that the unsold fishes were kept longer times in the department shops.

Inhibition of histamine producing bacteria using natural preservatives (NaCl, garlic, turmeric and ginger) was observed by Paramasivam et al. (2007). They further added that NaCl (10%), garlic (5%), turmeric and ginger (more than 5%) can be used to arrest the growth of histamine producing bacteria in fishes, thereby avoiding histamine fish poisoning.

Pawar et al. (2007) observed the effect of ginger rhizome extract along with ascorbic acid, STPP and 2% NaCl on physico-chemical characteristics of raw and cooked chevon at 4±1°C for 7 days storage period. He reported a slow decrease in moisture, WHC, pH and Total protein along with a good score in sensory evaluation for treated samples.

Sallam (2007) while evaluating the antimicrobial and anti-oxidant effects of sodium acetate, sodium lactate and sodium citrate in refrigerated sliced Salmon, reported their efficiency against proliferation of various categories of spoilage micro-organisms and concluded sodium citrate to be the best anti-oxidant.

The preservative effect of Marjoram and Thyme on semi-fried mullet fish fillets during cold storage was studied by Yasin and Abou-Taleb (2007) who reported a general enhancement in sensory attributes and a low increment pattern in bacterial counts and chemical parameters (TVB-N, TMA-N). They associated these effects to the anti-oxidant and antimicrobial effect of Marjoram and Thyme.

While reviewing the co-relationship fish freshness and pH during cold storage, Abbas et al. (2008) reported that pH is a simple and reliable freshness indicator as it has lower reading observed in initial stages of storage which go on increasing while fish is stored for long time.
While observing the extension of shelf life of frozen Nile Karmount 
(Clarias lazera) using different antioxidants viz., 0.5% STPP, 0.5% Ascorbic acid, 0.5% 
Citric acid and 0.1% Na$_2$EDTA at -18$^\circ$C, Hussein (2008) reported that ascorbic acid and 
Na$_2$EDTA were the most effective antioxidants in reducing the TBA and FFA levels.

While investigating the effect of different frozen storage time on Caspian Sea 
white fish (Rutilus frisi kutum), Keyvan et al. (2008) reported a decrease in protein, fat 
and moisture at the end of 12$^{th}$ month. However, ash content was highest at the end of 
storage period.

Jamilah et al. (2008) proposed an increased shelf life of fresh beef cuts treated 
with organic acids viz. citric, lactic, tartaric and acetic acid. He attributed it to the ability 
of organic acid in decreasing pH and therefore promoting anti bacterial effect.

Musaiger and D’Souza (2008) in his studies on proximate, mineral and heavy 
metal composition of fish and shrimps proposed that the traditional methods of cooking 
have an effect on their nutrient composition and heavy metal content and therefore 
advised to avoid excessive frying and use minimal salt. They also proposed the 
consumption of a wide variety of species of fish and alternating between the various 
modes of cooking is the best approach to achieve improved dietary habits, minimizing 
mercury exposure and increasing omega-3 fatty acid intake.

Ortiz et al. (2008) while analyzing lipid damage in farmed salmon 
(Onchorhynchus mykiss) after slaughtering and chilled storage reported a marked 
increase in percentage of free fatty acids in fish muscle.

Selmi and Sodok (2008) attributed the low TBARS level and unaffected fatty 
acid composition in flesh quality of Tuna (Thunnus thynnus, Linnaeus) to the anti-oxidant 
effects of Thymus vulgaris, Linnaeus treatment during chilled storage at 0$^\circ$C for 18 days.

While evaluating the influence of potassium sorbate combined with MAP on the 
shelf life extension of Seer fish (Scomberomorus commerson), Yesudhason et al. (2008) 
reported effectivity of potassium sorbate in reducing the microbial count of stored fish 
samples.
Relationship studies between water activity and fish spoilage during cold storage by Abbas et al. (2009) proposed that the water activity played an important factor in fish spoilage and further the growth of different microorganisms depends on its rate.

Chakrabarti and Verma (2009) reported the inhibition of fungi in dried salted fish preserved using sorbic acid and sorbate at ambient temperature (28± 5°C).

Chotimarkorn et al. (2009) evaluated the lipid damage of farmed spotted Babylon snail muscle stored in ice for 7 days and they observed that bacterial counts and lipid damage by hydrolysis & oxidation increased with increasing iced storage period in the snail muscle.

Ke et al. (2009) while studying the impact of citric acid on the beef muscle recommended that the citric acid marination is effective in increasing the water holding capacity and tenderness of meat. Further, the lipid deteriorating processes like lipid oxidation also reported a decline.

The general order for antibacterial activity of different organic salts was Na A > NaL > NaC as proposed by Kilinc et al. (2009) during his studies on microbiological, chemical, sensory, colour and textural changes of Rainbow Trout fillets treated with organic acid.

Studies on biochemical and textural properties of frozen stored (-22°C) gilthead seabream (Sparus aurata) fillets were done by Makri (2009). The results indicated that the length of time of storage at -22°C affected the integrity of muscles, reduced the water holding capacity, caused aggregation of myofibrillar proteins and denaturation of myosin (or ‘actomyosin’), degradation of lipids, and affected the texture of gilthead seabream fillets as measured by the texture analyzing system. Thus, gilthead seabream could be marketed in the form of frozen fillets. However, stored frozen gilthead seabream fillets may be more vulnerable to changes than whole gilthead seabreams with reference to texture and integrity of myosins.

The studies of Medina et al. (2009) reported an increased quality preservation in chilled and frozen fish products by employment of slurry ice and natural anti-oxidants.
While working on smoked Tilapia (*Oreochromis niloticus*), Omojowo *et al.* (2009a) reported the potassium sorbate treated Tilapia fillets to be negative for *E. coli* and *Streptococcus sps*. Moreover, the coliform, *Staphylococcus* and fungi also revealed a low counts during 8-week storage period.

Omojowo *et al.* (2009b) while observing the effect of citric acid and potassium sorbate as preservatives on the safety and shelf life of Smoked cat fish suggested that potassium sorbate is more efficient than citric acid in controlling microbial quality and extending shelf life during eight weeks of storage.

Patir *et al.* (2009) revealed a lower number of micro-organisms and increased shelf life in Mirror carp (*Cyprinus carpio*) fillets subjected to 15% salting and 5% potassium sorbate treatment. Also, sensory attributes of products containing potassium sorbate exhibited higher acceptability with now health risk.

Pourashouri *et al.* (2009) while investigating rancidity inhibition during frozen storage of Wels Catfish (*Silurus glanis*) fillets by previous ascorbic and citric acid treatment recommended that employment of both the acids alone or in combination with other protective strategies can lower the primary and secondary lipid oxidation compound formation.

Widjaja *et al.* (2009) while studying the lipid damage indices of catfish (*Mystus nemurus*) stored at different temperature for different intervals and proposed that lipid hydrolysis and lipid oxidation occurred after 12 h during ambient, at 8 days during chilled and at 16 days during iced storage.

Aberoumand (2010) concluded that minced fish due to its larger surface area is more prone to environmental factors and bacterial contamination. He further proposed that temperature of -30°C is the optimum temperature for longer shelf life of minced fish.

Asgharzadeh *et al.* (2010) while observing the chemical changes in the minced muscle of Silver carp (*Hypophthalmichthys molitrix*) suggested that previous washing has a positive effect on fish quality due to maintenance of various chemical parameters viz.
expressible moisture, volatile amines, free fatty acids and thiobarbituric acid reactive substances until the end of storage period.

While working on Nile Tilapia Fish (Oreochromis niloticus) fillets, Emire and Gebremarian (2009) found that the protein, moisture, ash, total bacterial count and Coliform count decreased and the pH increased during the frozen storage.

Ghaly et al. (2010) assessed that food spoilage is mainly because of enzymatic, chemical and microbial activities. They further suggested that low temperature storage along with EDTA/TBHQ combination, Sodium Chloride and Ascorbic acid can delay the rate of spoilage and are thus helpful in enhancing the shelf life of fish.

While evaluating the effect of different cooking methods on the physico-chemical and sensory properties of Silver carp, Hakimeh et al. (2010) reported that decrease in moisture loss and increase in fat content were the most prominent changes in the proximate composition in all cooking methods. However, the high protein content and sensory score was recorded for fried samples in comparison to grilled and steamed samples.

Results on the biochemical and sensory evaluation of Cyprinus carpio L. var. communis during refrigerated storage (4°C) by Indira et al. (2010) revealed that the fish remained suitable for refrigerated storage despite of some biochemical and sensory changes.

The findings of Liu et al. (2010) on the quality of tray packed tilapia fillets stored at 0°C revealed that maximum protein degradation occurs when microbiological load exceeded 6 log cfu/g. However, the TBA values remained low throughout the storage and thus, a shelf life of 10-12 days was suggested for the frozen Tilapia fillets.

Shamsan and Aansari (2010) in his studies on biochemical composition and caloric content in sand whiting (Silago sihama) reported an inverse relationship between moisture content and lipid content (r=-0.6, p<0.05).

Songsaeng et al. (2010) evaluated the changes in some chemical, microbiological and sensory qualities of White scar oyster (Crassostrea belcheri) during different storage
conditions and observed lower changes in chemical & microbiological qualities in chilled shell-on oysters when compared with those stored at ambient temperature. Also, an inverse relation was observed between sensory score of all attributes and total viable count in oyster packed in different salt concentrations.

Essential oils obtained from herbs and spices in the range of 0.05-0.1% have inhibitory effect against food borne pathogens such as Salmonella typhimurium, E. coli, Listeria monocytogenes, Bacillus cereus and Staphylococcus aureus as suggested by Tajkarimi et al. (2010).

Ashraf et al. (2011) while comparing the nutritional values of wild and cultivated Silver carp (Hypophthalmichthys molitrix) and Grass carp (Ctenopharyngodon idella) proposed that Grass carp showed significantly higher protein and lipid content along with low moisture content than Silver carp. Also the farmed fish is nutritionally better than wild irrespective of species studied.

Balev et al. (2011) during his studies on lipid changes in Russian Sturgeon kept at -18°C for 360 days storage period observed lower non polar and polar lipid content and higher FFA concentration in control air packaged samples as compared to experimental vacuum packaged samples. However cholesterol concentration and phospholipids classes of frozen stored sturgeon was not influenced by storage period as well as type of packaging.

The effect of lemon juice on sensory, biochemical and microbiological quality of sous vide (SV)-packaged bonito (Sarda sarda, Bloch, 1793) by Cosansu et al. (2011) reported that treatment with lemon juice increased the acceptability and shelf life of SV packaged bonito for 2 weeks (40%). Lemon juice-treated sous vide samples reported lower pH, mesophilic and Psychrophillic aerobic counts than SV samples (P < 0.05) and had better sensory quality. It was concluded that sous vide samples spoiled on the 35th day, while the Lemon juice-treated sous vide samples were acceptable until 49th day of storage.
Low temperature treatment along with the combination of chemical additives such as Tertiary Butyl Hydroxyl Quinine (TBHQ) and ascorbic acid are considered to be most effective for controlling enzymatic, oxidative and microbial spoilage in meat products as proposed by Dave and Ghaly (2011).

Gokaglu et al. (2011) while studying the effects of Tomato and Garlic extracts on oxidative stability in marinated Anchovy reported lower peroxide, para-anisidine, conjugated diene, UV absorbance and FFA values in Tomato treated samples as compared to Garlic treated samples.

Kocatepe et al. (2011) while studying the effect of cooking methods on the proximate composition of black sea anchovy (Engraulis encrasicolus, Linnaeus 1758) recommended grilling to be the best cooking method for healthy diet due the observance of highest protein, lowest fat and high energy contents in grilled fish.

An extended shelf life for hot-smoked Clarius gariepinus treated with different concentration of ginger. He attributed it to the antioxidant, antimicrobial and anti-fungal properties of Ginger was proposed by Kumolu-Johnson and Ndimele (2011).

While observing the microbial analysis of Tilapia guineensis, Obemeata et al. (2011) reported that bacteria and fungi counts decreased from $7.9 \times 10^3$ to $5.4 \times 10^3$ cfu/g for bacteria and $6.2 \times 10^3$ to $3.2 \times 10^2$ cfu/g for fungi in the samples stored at $-18^\circ$C, while for the samples stored at $4^\circ$C an increase was shown in counts from $7.9 \times 10^3$ to $7.6 \times 10^7$ cfu/g for bacteria and $6.2 \times 10^3$ to $6.8 \times 10^4$ cfu/g for fungi after 4 weeks. They further concluded that storage temperature and duration period have effects on the quality of stored fish.

While studying the combine effects of potassium sorbate and dry salting on shelf life of gutted and ungutted Sardine (Sardina pilchardus), Can (2011) reported higher deterioration of chemical and microbial deterioration in whole fish than in filleted fish.

An increase in TBA, PV, FFA and pH was reported by Ozogul et al. (2011) in Common Sole (Solea solea) from the Mediterranean Sea during 24 days of iced storage with a maximum shelf life of 16-18 days.
Rostamzad *et al.* (2011a) recommended the previous soaking of Persian sturgeon fillets in ascorbic acid and citric acid for delayed lipid oxidation because of their oxygen scavenging effect. Also, the combination of ascorbic and citric acid proved to be more effective than ascorbic acid and citric acid alone.

Zoldos *et al.* (2011) evaluated the effect of ice glaze on lipid oxidation and microbiological indicators during 6 months of freezing storage of Alaska pollack (*Theragra chalcogramma*) under stable (−18 °C) and unstable temperature (varying from −5 to −18 °C) conditions. They reported that the average counts of psychrotrophs in each group were at the same level, ranging from 9.1 ×10³ CFU·g⁻¹ to 1.1 × 10⁴ CFU·g⁻¹. According to the microbiological results fillets stored under unstable conditions were considered to be acceptable, but sensory evaluation showed that at the end of frozen storage they could not be consumed because of rancidity.

While conducting the studies on effect of different preservation on proximate composition of Tilipia (*Oreochromis niloticous*) and mackerel (*Scomber scombrus*) during refrigeration storage, Arekemase *et al.* (2012) concluded that potassium sorbate is more effective in preservation of fishes than sodium benzoate and sodium metabisulphate.

Attala (2012) in his studies on unpeeled shrimp treated with organic acid and sodium sulfite proposed that the samples treated with 6% vinegar and 3 % citric acid and stored at 0°C had better sensory quality and extended shelf life. Further, a reduction in bacterial counts especially (APC, coliforms and fecal coliforms) was also observed in these treated samples.

Studies by Chin *et al.* (2012) on surimi powder incorporated noodles reported significant increase (p<0.05) in the ash, protein, fat, lightness, redness, yellowness, stickiness and cooking yield with the increase in levels of surimi powder. However, carbohydrate content, pH, tensile strength, elasticity modulus and hardness reported an inverse relation with the increase in surimi concentration.

During his studies on the impact of different cooking methods on proximate and mineral composition of *Amblypharyngodon mola*, Devi and Sarojnalini (2012) related
the higher level of fat in fried fish than raw or other cooked fish to the oil absorption during cooking process can be due to the oil penetration into the food along with partial loss of water by evaporation.

While studying the effect of cooking on physical, biochemical, bacteriological characteristics and fatty acid profile of Tilapia (*Oreochromis mossambicus*) fish steaks, Dhanpal *et al.* (2012) proposed that cooking significantly (p<0.05) alters the pH, color and texture of meat and drastically reduced the bacterial load. Also, the TVBN and TBA contents are well below the acceptable limit in cooked fish.

Ehsani and Jasour (2012) while determining the effect of pre-storage α-tocopherol acetate dipping treatment on the lipid stability of refrigerated Rainbow trout (*Oncorhynchus mykiss*) at 4°C for 12 days proposed that the treatment had no effect on the fat hydrolysis (FFA), but, however the lipid oxidation was inhibited by the same.

The studies of Gandotra *et al.*(2012a) on the fish muscles of *Mystus seenghala* placed at different temperature viz. 4±1°C and -12±2°C for 21 days revealed lower proximate compositional decrease and lesser increase in microbial count in frozen (-12±2°C) temp. as compared to chilling temp. (4±1°C).

Gandotra *et al.* (2012b) reported a decrease in proximate composition along with increase in microbial count in the fish muscle of *Labeo rohita* (Hambuch) stored under frozen conditions for a period of 21 days. They further suggested that fish under frozen storage conditions retained the acceptable limits for consumption upto 14 days only.

As per the studies of Abu-Ghazaleh (2013) on food borne pathogens, lactic acid, ascorbic acid, citric acid and sodium chloride can inhibit or reduce the growth of the *S. aureus* and *E. coli*.

Differences in biochemical, proteolytic (TVBN, N-TMA) and lipolytic (FFA, PV, TBA) processes for freeze thawed and fresh fillets of Common carp and Silver carp were observed by Jezek and Buchtova (2012). He further proposed that fats containing more PUFAs are more susceptible to oxidation process.
Marimuthu et al. (2012) while investigating the effects of different cooking methods (boiling, baking, frying and grilling) on proximate and mineral composition of snakehead fish (Channa striatus, Bloch) proposed that the changes in the amount of protein and fat were found to be significantly higher in fried and grilled fish. The ash content increased significantly whereas that of the minerals (Na, K, Ca, Mg, Fe, Zn and Mn) was not affected in all cooking methods. Also, the grilling method of cooking is found to be the best for healthy eating.

Pawar et al. (2012) while preparing a standardised recipe for fish cutlet products made from Catla proposed that ratio of 5:100 (w/w) of green chilly, ginger and garlic to Catla meat was found to be superior in sensory evaluation as compared to 7:100, 6:100, 5:100 and 4:100(w/w).

A delayed bacterial and oxidative decay was observed by Pezeshk et al. (2012) for both live and gutted fish immersed in Shallot extract during refrigerated storage.

Pieretti et al. (2012) studied the effect of three concentrations (0.2%, 1% and 3%) of Rosemary oil (RO) in the minced Rainbow Trout (Oncorhynchus mykiss) at 4±1°C. He reported that RO treatment improves the pH, oxidative stability of the lipids and fatty acid profile which resulted in shelf life extension of the fillets.

Rahimabadi and Divband (2012) while observing the effects of coating and Zataria multiflora boiss essential oil on chemical attributes of Silver Carp fillets stored at 4°C concluded that the given treatments are effective in retarding the primary and secondary lipid oxidation and microbial activity.

Rakshit and Ramalingam (2013) demonstrated that natural preservatives like gum arabia along with garlic cinnamon extract act as potent antibacterial and antioxidant agents in comparison to turmeric.

Taheri and Motalaabi (2012) reported that Vacuum Packaging (VP) was effective in reducing lipid oxidation and increasing shelf life of Cobia frozen fillets. Quality assessment of Cobia stored in VP for up to 6 months at -18°C was done by the monitoring of sensory quality, free fatty acids (FFA), peroxide values (PV),
Thiobarbituric acid (TBA), pH and expressible moisture (EM). Results showed that free fatty acid, primary and secondary oxidation products, expressible moisture and pH value of vacuum packaging samples were significantly lower than those in control samples (p<0.05).

A loss of nutrient quality viz. protein, fat, ash and moisture was observed by Aberoumand (2013) in Lizadussimeiri, Sparidae, Sciaenidae and Platycephalidae during 60 days of frozen storage period.

Akhtar et al. (2013) while studying the effects of thawing on the physicochemical quality parameters of meat proposed that improper thawing technique will lead to activation and multiplication of already residing dormant micro flora on meat surface and therefore, proper precautionary measures including temperature below danger zone and reduced thawing time must be practiced so as to avoid microbial spoilage.

The studies on processing methods on the proximate composition of red fish stored under ambient room conditions by Ayinsa and Maalekuu (2013) reported that during processing, crude fat content increased in fried fish but reduced in the salted and smoked fish. Also, an inverse interaction between the crude protein and fat content was reported by them.

An acceptable shelf life upto 17 days and enhanced sensorial quality at 4°C was observed by Coban (2013) in Sarda sarda fish fingers with the addition of 1% ginger oil.

A reduction in moisture, protein and fat was observed during salting process where as an increase in protein and fat was observed during frying by Holma et al. (2013) during his studies on traditional fish processing methods in Red fish stored under ambient room conditions.

An increasing trend for TBA, PV, TVB-N and pH was observed for Red Tilapia at -18°C by Karami et al. (2013) during 150 days of frozen storage period.

Khidir et al. (2013) while assessing the qualitative status of imported frozen fish fillets in Sulaiman markets reported the lowest thawing and cooking loss in white fish fillets. Further, among the chemical indices, Flounder reported the highest PV and FFA.
The proximate, oxidative stability and microbial changes in Bighead Carp (Hypophthalmichthys nobilis) as evaluated by Latip et al. (2013) proposed that protein and ash content decreased while TBA content increased significantly on 7th day of iced storage. However, no significant changes were observed in fat, texture and aerobic plate count during the whole storage period.

Natasa et al. (2013) studied the effects of freezing on bacteriological status of cold smoked and vacuum packed trout fillets and they determined that the total number of bacteria was smaller in the samples produced from frozen fish. Also, the average content of water and salt in the water phase in the samples made from frozen fish was statistically larger than those in the samples made from fresh fish.

Sharaf (2013) reported a decrease in protein, fat, ash, moisture along with minerals at the end of 8 weeks under -18°C storage in the fish muscles of Tilapia.

Vanitha et al. (2013) while observing the biochemical and sensory parameters of value added minced based products stored at -20°C reported that Fish cutlets and fish burgers remained acceptable upto 180 and 176 days of storage.

A great antioxidant activity for potassium sorbate (0.05g/kg) and nisin (0.2g/kg) in comparison to sodium diacetate was reported by Zhao et al., (2013) during his studies on preservation of pre-cooking shredded meat.

While examining the antioxidant potency of Moringa oleifera (MO) marinade, salt and butylated hydroxyl anisole (BHA) on oxidative stability of smoke dried Catfish, Adeyemi et al. (2014) proposed that MO is more potent in suppressing lipid peroxidation in comparison to BHA and salt.

During quality analysis of barred Spanish mackerel (Scomberomorous commerson), Al-Jasser and Al-Jasass (2014) reported that freezing storage allowed the retention of freshness qualities and thereby extending the shelf life either at -10°C and -18°C by increasing the acceptability tolerance for about 180 days.

While studying the effects of organic acids, Al-Haii et al. (2014) proposed the organic acids to be beneficial in increasing the shelf life and meat quality of fish by
eliminating L. monocytogenes, E. coli, Standard plate count (SPC) during storage at 5°C for 7 days.

Frank et al. (2014) during his studies on the effect of garlic and ginger on physicochemical and microbial attributes of liquid smoked Silver carp wrapped in aluminium foil during chilled storage suggested that the combined antioxidant and antimicrobial properties of both garlic and ginger is useful in preserving the fish meat at 4±1°C.

The studies on the effects of different concentrations of Garlic (Allium sativum) extracts (5, 10, and 15 g) on the quality of Sardinella longiceps by Guinares (2014) revealed a lower peroxide, free fatty acid and aerobic plate count values than the control samples during 30 days of frozen storage (-18 °C) period. Further, sensory analysis revealed that only color, intensity of smoky odor, and overall acceptability were significantly affected (p<0.05) by garlic extracts.

Organic acids (cinnamic acid, citric acid and levulinic acid) act as a natural antimicrobials to control various foodborne pathogens viz. E. coli, S.enterica, and L. monocytogenes as proposed by Hawkins (2014).

The studies on the effect of different cooking methods on Labeo calbasu by Memon et al. (2014) revealed that cooking had considerable effect on proximate composition and fatty acid composition of fish. Also, the deep fried fish showed a significant increase in n-6 fatty acids due to uptake of linolenic acid from the frying oil.

The combination of Propyl gallate and Sodium ascorbate was considered to be effective in delaying lipid oxidation of salted dried Snake headed fish (Channa channa) as reported by Nitipong et al. (2014).

Oladapo et al. (2014) in his studies on food spoilage suggested the inhibitory effect of chemical preservatives viz. potassium metabisulphite (0.5 mg/ml), sodium benzoate (1.5 mg/ml), citric acid (1.5 mg/ml), ascorbic acid (1.5 mg/ml) and potassium sorbate (1.5 mg/ml) against various foodborne pathogenic bacteria.

Studies on microbial profile of Trachurus trachurus, Scomber scombrus, Urophycis tenuis, Clupea harengus and poultry meat- chicken, turkey and gizzard by
Oranusi et al. (2014) reported the presence of *S. aureus*, *E. coli* and *spp of Bacillus, Klebsiella, Salmonella, Flavobacterium, Listeria* and *Pseudomonas*, with a significant high count on head and skin. Further, investigation revealed that the freezing retards pathogen multiplication, but during thawing these microbes can multiply and lead to foodborne illness.

Ready to serve fish cutlets from the filleting waste of Reef Cod (*Epinephelus chlorostigma*) could be an effective way of alleviating pollution and legal problems associated with the discard of processing waste as suggested by Reddy and Bhandary (2014). Also, no significant changes in biochemical and sensory evaluation were reported in fish cutlets during the whole storage period.

The studies of Skowyra et al. (2014) on the effects of *Perilla frutescens* extract on oxidative stability of model food emulsions revealed that *Perilla frutescens* has good antioxidant properties making it suitable for use in food matrix to achieve potential health benefits.

The findings of Verma et al. (2014) on quality characteristics of Value added chicken noodles reported higher proximate composition (ash, protein, lipid and moisture) along with an increase in sensory attributes of colour and appearance, flavour, texture, mouth coating, saltiness and overall acceptability with 30% chicken mince incorporation.

Chellaram (2015) during his studies on chemical composition and shelf-life of *Pleuroloca trapezium* meat pickle proposed that control pickle had a shelf life of 4 months under room temperature whereas the shelf life was extended to 5 months and 6 months in pickles with acetic acid and lactic, citric acid respectively.

While studying the impact of assorted spices on lipid quality alteration of refrigerated fish muscle, De and Chatterjee (2015) reported cinnamon to have antioxidant effects for longer duration as compared to pepper and fennel.

The studies on chemical profile, antibacterial and antioxidant activity of Algerian Citrus essential oils in *Sardina pilchardus* by Djenane (2015) revealed their use as potent inhibitors of lipid oxidation along with reduction of *S. aureus*.
Erkan et al. (2015) in his studies based on the shelf life extension of sea food proposed the use of natural preservatives and natural/edible film coating applications in delaying lipid oxidation, inhibiting microbial growth and enhancing sensorial properties.

Lower values of TBA, FFA and microbial count in frozen Wallago attu fish cutlets as compared to raw control samples were observed by Gupta et al. (2015) which they attributed to the addition of various spices having antioxidant and antimicrobial properties. They further added that raw muscles had the shelf life of 10 days while fish cutlets were acceptable till the end of 30 days of frozen storage period.

Incorporation of 15% Pink perch mince (Nemipterus japonicus) in 85% refined wheat flour for the production of noodles by Kamalkanth (2015) reported significant increase in physical and sensory properties of the extruded noodles. He further added that extrusion process is thermodynamically most efficient as high temperature enables destruction of bacteria and anti-nutritional factors and destruction of fat hydrolyzing enzymes during extrusion reduces rancidity.

Liu et al. (2015) reported the protective effect of tea catechins, vitamin- E, grape seed and carnosine against lipid oxidation in raw beef patties during refrigerated (4°C) storage conditions.

Studies on the effects of freezing storage on the biochemical composition of Saurida undosquamis muscles by Mazrouh (2015) proposed that the frozen muscles should be stored, for a short period so as to retain the taste, and keep both the protein and fat at optimal levels. Hurdle technology involving the use of salting and smoking technique particularly in has a significant role in enhancing the proximate composition and lowering the microbial count of L. calcarifer as suggested by Panchakshari et al. (2015).

While assessing the antimicrobial activity of onion (Allium cepa) and garlic (Allium sativum), Shakurfow et al. (2015) reported that the extracts of onion and garlic in cold water and organic solvent solution have the inhibitory effect on the growth of Listeria monocytogenes.
Subbaiah et al. (2015) during his studies on Nile Tilapia (Oreochromis niloticus) reported that protein denaturation has profound effect on texture quality of meat. They further added that long term frozen storage of fish increases toughness due to the decreased solubility of protein as a result of aggregation. Toughening of myotomal tissue is the major textural changes among fish and fishery products and is associated with denaturation of myofibrillar proteins and low density of Z lines, which occur during postmortem glycolysis.

Quality changes studies in fish burger from Common carp (Cyprinus carpio) by Bavitha et al. (2016a) revealed that fish burgers with 0.5% and 1% level Ginger incorporation had better sensory scores and shelf life over normal burger during 19 days of refrigerated storage.

A shelf life of 12 days with a progressive increase in PV, TBA, FFA, TPC and psychrotrophic count was observed by Bavitha et al. (2016 b) in fish cake made from common carp (Cyprinus carpio) during refrigerated storage. They further reported a negative correlation between overall acceptability of fish cake and the storage period.

The desirability and flavour of meat and meat products is based on the lipid content as suggested by Cheng (2016). Further, he added that autoxidation occurring in meat product due to enzymatic and non enzymatic reactions could be controlled to a great extent by the use of antioxidants.

Lower values of TBA, FFA, Mesophilic aerobic bacteria and psychrotrophs were observed by Duman and Peksezer (2016) in Alburnus mossulensis fish balls prepared using onion, parsley and black pepper.

Linear increase in (P < 0.01) crude protein, total lipids, ash, carbohydrate, and caloric values with increasing amounts of tilapia protein concentrate in the pasta was observed by Goes et al. (2016). They further added that including up to 30% of tilapia protein concentrate in pasta yields an increased nutritional value, but the sensory analysis reported 20% of tilapia protein concentrate in pasta had the highest acceptability.
Macwan et al. (2016) in his studies on 14 Essential Oils (clove, oregano, rosemary, pepper, nutmeg, liquorice, turmeric, aniseed, cassia bark, fennel, prickly ash, round cardamom, dahuian angelica root and angelica) proposed that these essential oils destroy bacteria by degrading their cell wall, damaging the cytoplasmic membrane and their proteins, cytoplasm coagulation, increased permeability leading to leakage of the cell contents, reducing the proton motive forcen and reducing the intracellular ATP pool via decreased ATP synthesis.

Organoleptic evaluation of Dhoma (Otolithus sp.) fish cutlets by Pilankar et al. (2016) reported a shelf life of 165 days. Loss of acceptability after 165 days was attributed to the formation of some volatile low molecular weight compounds, lipid oxidation and protein degradation during chilled and frozen storage.

Shelf life extension of seafood using plant antioxidants by Rayeni (2016) reported the presence enzymatic and non-enzymatic antioxidants. Further, he added that the enzymatic antioxidants have two defence mechanisms; primary and secondary. The primary defence is formed by glutathione peroxidase, catalase, superoxide dismutase while secondary enzymatic defence includes glutathione reductase and glucose-6-phosphate dehydrogenase.

A shelf life extension of 6 days in chicken meat treated with combination of rosemary and clove extract in comparison to control was reported by Zhang et al. (2016). Further, they suggested higher radical scavenging activity of cloves in comparison to rosemary was due to the higher polyphenol and flavonoid contents that are significantly different from rosemary extract.

Diler et al. (2017) while studying the effect of different killing methods on Crayfish (Astacus leptodactylus) proposed that sensory results were highly correlated with the microbiological counts ($r = -0.92$ for TMAB and odour; $r = -0.95$ for TPAB and odour; and $r = -0.96$ for Enterobacteriaceae and odour).