DEVELOPMENT OF SURIMI AND SURIMI-BASED PRODUCT FROM SILVER CARP

A Thesis
Submitted to the
West Bengal University of Animal and Fishery Sciences,
in partial fulfillment of the requirements for the degree of

MASTER OF FISHERY SCIENCE

in

FISH PROCESSING TECHNOLOGY

By

SUPRATIM CHOWDHURY, B.F.Sc.

Department of Fish Processing Technology
Faculty of Fishery Sciences
W.B.U.A.F.S.,
Mohanpur Campus, Nadia (W.B.)

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DEDICATED
TO
MY MOTHER

WEST BENGAL UNIVERSITY OF ANIMAL AND FISHERY SCIENCES
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CERTIFICATE

This is to certify that the work recorded in the thesis entitled **"DEVELOPMENT OF SURIMI AND SURIMI-BASED PRODUCT FROM SILVER CARP"** submitted by **Mr. Supratim Chowdhury** in partial fulfillment of requirement for the Degree of **Master of Fishery Science (Fish Processing Technology)** in the Faculty of Fishery Sciences, West Bengal University of Animal and Fishery Sciences, is the faithful and bonafide research work carried out under my supervision and guidance. The results of the investigation reported in this thesis have not so far been submitted for any other Degree or Diploma. The assistance and help received during the course of investigation have been duly acknowledged.

Chairman
Advisory Committee

APPROVAL SHEET

APPROVAL OF EXAMINERS FOR THE AWARD OF THE DEGREE OF MASTER OF FISHERY SCIENCE (FISH PROCESSING TECHNOLOGY)

We, the undersigned, having been satisfied with the performance of **Mr. Supratim Chowdhury** in the viva-voce examination, conducted today, the 7th Nov 2002, recommend that the thesis be accepted for the award of the degree.

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Mohanpur *Supratim Chowdhury*

September, 2002

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LIST OF ABBREVIATIONS

ANOVA	Analysis of variance
AOAC	Association of analytical chemist
DMA	Dimethylamine
DWM	Dewatered minced meat
EIC	Export inspection council
EMG	Enzymatically modified gelatin
EU	European Union
FA	Formaldehyde
FDA	Food and drug administration
FFA	Free fatty acid
HACCP	Hazard analysis critical control point
HHP	High hydrostatic press
ICMSF	International commission on microbiological specification for food
LDPE	Low density polyethylene
NPN	Non-protein nitrogen
PV	Peroxide value
RDU	Refrigerated display unit
SSN	Salt soluble nitrogen
TMAO	Trimethylamine oxide
TPC	Total plate count
TVB-N	Total volatile base nitrogen
UNFAO	United Nation Food and Agricultural Organisation
USDA	United States Drug Administration
USDC	United States Department of Commerce
WHC	Water holding capacity

CHAPTER. I

INTRODUCTION

I. INTRODUCTION

The food processing industry is termed as a "sun-rise industry" and has an important role in improving agricultural productivity, reducing wastage, providing better nutrition and improving the availability of quality food for the domestic market. Present market trends reflect a rapidly growing demand for ready-to-serve and ready-to- cook convenience products. The sophisticated consumer abroad as well as the urban consumer at home demand new types of value added, hygienically prepared, highly nutritious and attractively packed products. Nearly 350 million people in India live in urban areas and processed foods will become their first choice sooner or later. Global processed food business is around Rs.16,000 billion while India's contribution is Rs.1,400 billion (Rasul, 2001). India provides great opportunities for investment and growth in food-processing sector. A massive thrust to food processing and other agro-based industries will add value to the product thereby increasing the income of the farmers, create employment opportunities, diversify the rural economy and foster rural industrialization.

India has vast marine and inland resources for fishing and mostly local fishermen have tapped this wealth to meet domestic demand. It is only in the last two to three decades that the organized corporate sector has ventured into the processing and export of marine products. Now export of marine products constitutes the target segment of all Indian processed food exports (Rasul, 2001).

The fish processing industry requires an improvement for better utilization of the existing catch especially the fish by-catch and underutilized species. It has been estimated that the discard of fish as by-catches is in the range of 17 to 39 million tons/year with an average of 27 million tons/year (Basu, 2001). This huge amount of

underutilized by-catch can be put into better use by adopting suitable methods such as minced fish technology. In fact, over the last four decades minced fish technology has made a major contribution to the increased exploitation of the by-catches and underutilized species.

Minced meat is the flesh separated in a comminuted form from the skin, bones, scales and fins of the fish. The process of meat separation when applied to low cost fishes, results in significant improvement of the quality of the product and it's acceptance. Minced fish is used as a base material for the preparation of number of products of good demand such as fish sausage, cakes, cutlets, patties, balls, pastes, texturised products, etc. However, the most important use of minced fish is the production of surimi. The minced fish technology offers a number of benefits, a few of them include minimizing wastes, more efficient use of existing resources, production of new versatile and nutritious foods and economic advantage to both the producer and consumer.

Throughout the world fish mince has attracted considerable attention from food manufacturers. Its unique texture forming ability made it an excellent base for manufacture of a wide variety of seafood products. The quality and functional characteristics of minced fish can further be improved by water washing. Repeated washing of minced meat followed by addition of cryoprotectant results in, most of odor imparting compounds, pigments, water-soluble proteins and undesirable materials being removed and a translucent, bland material called "Surimi" is obtained. Surimi provides greater opportunities for product diversification and has better storage stability than unwashed mince (Flick *et al.*, 1990).

The production of surimi-based products in Japan has ranged between 7,25,000 and 8,54,000 metric tons over the last 10 years (Zenkama, 1998). The product can be divided into six categories. They

are Satsuma-age, Chikuwa, Kamaboko, Flavored Kamaboko, Hanpen /Naruto and other imitated surimi based products such as Crab leg (Park, 2000). In United States, basically four typical types of surimi seafood dominate the market, viz., crabmeat sticks, flakes, chunks and combo (Park, 2000). Surimi seafood in U.S. is legally called as "Imitation Crabmeat". In Korea, the largest surimi-based product is "Ah-mook". Among the European Union (EU) countries, France is the largest consumer with a total consumption of 20,000 metric tons in 1997. This is followed by Spain with a consumption of 17,000 metric tons and Italy with a consumption of 6000 metric tons (Anon., 1998). The consumption of surimi seafood in Russia, South America and China has also grown recently. The consumption in South-East Asia traditionally consists of fish balls.

During the middle of 90's, a decrease in Alaska pollock harvest was observed due to stricter fisheries management (Morrissey and Tan, 2000). This resulted in a dramatic change in the surimi industry with a possible downtrend. Hence, there was a need to open the door for use of new species in the surimi industry. South East Asia initiated the expansion by using threadfin bream to make surimi. New technologies such as use of protease inhibitors have made it possible to use fish such as Pacific whiting for surimi production. New washing techniques have also improved the quality and recovery of myofibrillar proteins from fatty fish, such as mackerel.

In the present study, freshwater fish species silver carp (*Hypophthalmichthys molitrix*) has been taken for manufacturing of surimi. Silver carp is an exotic carp, which is characterized by high growth rate. It forms a very important and potential fishery of the main river systems in China, Russia, Japan, Formosa, Thailand, Malaysia, Israel, India, etc. By domestication through extensive culture and large-scale seed production by induced breeding

technique, silver carp has now become an important fishery in many countries including India. In Indian environment, the growth of silver carp is remarkably faster and attains highest growth rate in length in the second year of life and maximum growth rate in weight in third year. The UNFAO fisheries statistics of 1998 shows that among different carp species silver carp recorded the highest aquaculture production of about 3308 thousand tons in 1998. However, in India, consumer's acceptance of silver carp is poor as compared to Indian major carps. Hence, production of acceptable surimi from silver carp will certainly put this underutilized fish species into suitable and profitable use.

The present investigation aims at (**1**) standardizing the processing steps for producing an acceptable surimi from silver carp, (**2**) to compare the changes in quality with or without cryoprotectants during storage, (**3**) to test the acceptability of surimi when incorporated in a product, (**4**) to test shelf-life of surimi-based value added product under frozen storage, (**5**) to study the shelf-life of the value added product in refrigerated condition, (**6**) standardization of frying procedure and (**7**) to identify the critical control point in surimi production.

CHAPTER. II

REVIEW OF LITERATURE

II. REVIEW OF LITERATURE

Surimi is primarily stabilized fish proteins. In itself it is not a foodstuff; rather it is an intermediate raw material from which traditional Japanese kneaded foods called "Kamaboko" are manufactured. Over the past 20 years, surimi and surimi-based seafood have become Americanized and currently includes a wide range of surimi-based seafood products. These new generation products resulted from two revolutionary developments: 1) the discovery of the function of cryoprotectants in surimi manufacture in 1960 and 2) the creation of crabmeat style surimi-based seafood (Park, 2000). Surimi and surimi-based seafoods have already established a solid base for production as well as markets in North America, Europe, Russia and in many Asian countries. In this section, research works carried out on the different aspects of surimi are reviewed.

2.1 MANUFACTURING PROCESS

2.1.1 Raw materials for surimi production

The selection of the right quality raw material for preparation of surimi is an important factor. The fish selected should have about 70% myofibrillar proteins. If the water-soluble proteins are high, the relative yield of the protein will be less. Alaska pollock has a very high content of myofibrillar protein and has good gel forming ability. That is the reason why more than 95% of the world's surimi is made from pollock.

The quality of surimi prepared from each species of fish depends on all those factors, which affect the composition of the fish. These factors include seasonal variation, feeding habit, pH of the habitat water, adaptation, temperature, lipid content, sex and spawning. Among the different species of fish white-fleshed lean

TABLE: I

WORLD SURIMI PRODUCTION (UNIT: 1000 metric tons)

YEAR	ALASKA POLLOCK	THREADFIN BREAM	SOUTHERN BLUE WHITING	PACIFIC WHITING	OTHERS	TOTAL
1989	436.8	30.0	8.3	14.5	94.3	583.9
1990	389.5	40.0	5.8	20.0	87.1	542.4
1991	329.7	50.0	10.7	39.8	85.4	515.6
1992	357.0	50.0	19.8	46.9	82.8	556.5
1993	258.0	49.0	19.8	30.0	67.0	423.8
1994	302.8	60.0	29.0	45.0	72.7	509.5
1995	324.3	66.5	24.0	36.6	87.0	538.4
1996	274.7	69.0	30.0	39.0	86.2	498.9
1997	250.0	74.0	31.0	43.0	83.0	481.0

(Source: McReynolds, 1999)

TABLE: II

GRADING OF FISH FOR SURIMI PRODUCTION

	VERY GOOD	GOOD	POOR
Teleost	Croakers, Lizard Fish, Alaska Pollock, Perches, Pacific Hake, Ocean Perch, Lung Cod, Threadfin Bream, Shads, Puffers, Horse Mackerel, Flying Fish, Black Marlin.	Perk Fish, Barracuda, Pacific Cod, Eel, Soles, Ribbon Fish, Sciaenids, Carrangids, Seer, Pomfret, Yellow Fin Tuna.	Angle Fish, Halibut, Oil sardines, Mackerel, Lantern Fish, Silver Grey, Rock Fish, Flounders, Trouts, Silver bellies, Anchovies, Albacore, Bigeye Tuna, Mackerel Tuna.
Elasmobranch	Hammer Head Shark, Dog Fish.	Bonito, Mackerel Shark, Man-eater Shark, Rays.	Spiny Dog Fish, Threshes Shark.
Fresh Water		Carps, Tilapia, Mullet, Milk Fish.	Snake Heads, Ophiocephalus, *Wallago attu*
Crustacean	-	Cuttle Fish, Squids.	Prawns, Krill.

(Source: Gopakumar, 1997)

fish like Alaska pollock is best suited for surimi production (Morrissey and Tan, 2000). Cod, hake, capelin, herring, sprat, mackerel, sardine, anchovy and menhaden are also commercially used for surimi production. Among the tropical species, croaker, sciaenid and threadfin bream are used for surimi. Table: II represents the gradation of different species of fish for surimi production.

In U.S., nearly 75% of the surimi production comes from Alaska pollock. Pacific whiting is a gadoid fish, which has been tried for surimi production (Groninger *et al.,* 1985). Currently Pacific-whiting represents approximately 20-25% of surimi production in U.S. Arrow tooth flounder has been successfully used for preparation of surimi (Babbitt *et al.,* 1992). Several research groups have investigated hoki as a surimi source and they have found it to be of excellent quality (Macdonald *et al.,* 1990,1994). Apart from these fish species, several other fishes including certain pelagic fatty fish varieties have also been studied. Some of them include red hake (Lee, 1986), shark (Chen, 1995), Pacific pomfret (Numakura *et al.,* 1983), menhaden (Bimbo *et al.,* 1988; Leinot, 1992), sardine (Tsukamasa and Simizu 1990; Saeki; *et al.,* 1991; Sarkar, 1997), mackerel (Spencer *et al.,* 1988; Kotah *et al.,* 1989), capelin (Langmyhr *et al.,* 1988; Spencer *et al.,* 1988), lizard fish (Nazaki *et al.,* 1978; Yasui and Lim, 1987) and red cod (Vlieg, 1982). Very less work is done on the quality of surimi from freshwater fish species. Common carp and tilapia was studied and found suitable for product development (Hassan and Mathew, 1999). Common carp mince have been produced in U.S.A. from both cultured and natural resources (Dassow, 1980). Siddaiah *et al.* (1999) has investigated the suitability of silver carp in producing acceptable products. Recently some more works have also been

done on the quality of surimi manufactured from freshwater fishes (Ismond and Tonogai, 1994; Lin and Morrissey, 1994; Onibala *et al.*, 1997).

2.1.2 Mechanical separation of fish meat

The quality of the surimi depends on the raw material and also on the meat separation process. The fish meat separation process can be done either manually or mechanically. However, it is the development of mechanical deboners, which has set a milestone in the commercial production of surimi, and the Japanese processors are credited for the advent of mechanically separated fish mince (Miyauchi *et al.*, 1973).

Flesh separators or deboners can be employed in the processing of fishery products for two major purposes. First, the process can be utilized to insure maximum recovery of fish flesh from fillets. A second use involves the potential utilization of fish species that do not fit the traditional market and/or cannot be processed with conventional equipment because of shape or size (Nickelson II, *et al.*, 1980).

Most separation techniques use a perforated filter to screen the fish from non-flesh components. The use of mechanical deboners substantially increases the yield of meat from fillets (Martine, 1972). Higher meat yield and lower bone content are the prerequisite for efficient deboning (Lanier and Lee, 1992).

The belt-and-drum type system is most widely accepted because it offers the benefit of adjusting the pressure readily and it is easy to clean. In belt-and-drum type, the perforation sizes of 1 to 7 mm are available commercially but 3 mm perforation size of drum generally offers the most reasonable compromise (Flick *et al.*, 1990).

Different researchers reported the use of different models of bone separators for preparation of fish mince. Verma and Srikar (1994) reported the use of pounding type meat-picking machine (Model S-3, Toyo Seikon Kaisha Ltd., Japan). Baader 694 separator was successfully used for deboning mullets (Tseo *et al.,* 1983). Reciprocatory type meat separator was used to separate flesh from pink perch (Dora and Chandrasekhar, 1998). The frequently used quality test for picked meat is the presence of the viable bones and calcium contents, which normally should be less than 0.5% (Yamoto and Wong, 1974; USDA, 1975).

2.1.3 Leaching and washing

One of the most critical steps in surimi manufacturing is the washing of minced fish flesh. Water leaching facilitates the concentration of myofibrillar proteins by removal of water-soluble proteins and other nitrogenous components from minced fish flesh (Rasekh *et al.*, 1980; Tseo *et al.*, 1983). Washing helps in minimizing the problems associated with color, taste and odor. About two-thirds of the minced fish meat is myofibrillar protein, which is the major component in the formation of three-dimensional gel sturucture. The remaining one-third consists of blood, myoglobin, fat and sarcoplasmic proteins that impede the final quality of the surimi gel (Park and Morrissey, 2000). Washing effectively removes the undesirable component in minced fish flesh.

The washing process involves mixing minced meat with cold water (5^{0}C) and removing water by screening and dehydrators or centrifuging to about 5-10% solids (Park and Morrissey, 2000). The process is repeated as per the requirement. The conventional leaching/washing process requires copious amounts of water in a lateral flow direction with minced fish (Watanabe *et al.*, 1982;

Green *et al.*, 1984; Swafford *et al.*, 1985). However, due to rising utility costs, limited water sources and pollution problems, minimization of water usage for leaching and reduction of wastewater disposal have recently become a major consideration for surimi manufacturers (Lin and Park, 1997).

The number of washing cycles and the volume of water vary with fish species, freshness of fish, type of washing unit and the desired quality of the surimi (Lee, 1984). A water / meat ratio ranging from 4:1 to 8:1 is often employed by on-shore processors and the process is repeated 3 to 4 times to ensure sufficient removal of sarcoplasmic proteins. At-sea processors use a lower water/meat ratio (1:1 to 3:1) with only one or two washing cycles due to their limited access to freshwater. Increased water usage for washing usually resulted in more protein loss and wastewater disposal (Lin and Park, 1996). It was estimated that 50% of total proteins were lost during washing (Adu *et al.*, 1983; Aguilar *et al.*, 1989; Yang and Froning, 1992), and 30 liters of wastewater per one kg of surimi produced, were generated from on-shore processing plants (Lin *et al.*, 1995).

Gopakumar *et al.*, (1992) have shown that washing time, mince: water ratio and number of washing cycles required have to be varied depending upon the species of fish and its freshness. Adu *et al.* (1983) obtained 77% protein recovery for rock fish, using two exchanges at 4:1 (v/w) water: flesh ratio. Babbit (1986) recovered 75% protein from Alaska Wally pollock. A single washing at water: flesh ratio of 3:1 under acidic conditions (pH 5-5.3) was reported to be most efficient (Aguilar *et al.*, 1989). For most tropical fish, two washing operations, each of 2 minutes duration, using a mince: water ratio of 1: 2 (w/v) is optimal (Gopakumar, 1997). Most pelagic fishes contain high amount of lipids; hence, production of surimi

becomes difficult. Addition of sodium bicarbonate (0.5%) and sodium chloride (0.15%) to wash water is found very effective in producing good surimi from sardine (Suzuki, 1981; Roussel and Cheftel, 1988).

2.1.4 Straining and dewatering / refining

The minced, washed and leached fish meat is wet slurry, which contains fragments of bones, ligaments, scales and water. Dewatering and straining are thus, followed to prevent the presence of extraneous matters in the final product. During the washing process intermediate dewatering is done after each washing cycle. The process is repeated two or three times, which helps in eliminating any problem during final dewatering (Lee, 1986). The quality and yield of surimi also appears to increase by intermediate dewatering (Swafford *et al.*, 1985).

Before the final dewatering under a screw press, undesirable particles, such as fine bones, scales and connective tissues, are removed by refiner. The screw press, which commonly has 0.5-1.2 mm perforations, draws water out with compression to a level of 82-85% moisture, which is similar to a fish fillet (Park and Morrissey, 2000). It is also common to use 0.1-0.3% salt mixtures of NaCl and $CaCl_2$ to facilitate the removal of water from the screw press (Park and Morrissey, 2000).

Green and Lanier (1999) accomplished the dewatering of leached mince between stages by draining through four layers of cheesecloth followed by hand pressing. Subsequent dewatering of leached mince was accomplished by first draining in a nylon mesh bag followed by basket centrifugation (Bark Model 10XC) using a nylon mesh liner. Lin and Park (1997) used centrifugation (2,600 x g, 5 min) as a means for dewatering between washings. During the

final washing step, a higher centrifugal force (6,800 x g, 10 min) was applied to reduce moisture content of washed mince.

2.1.5 Use of additives in surimi

2.1.5.1 Cryoprotectant in surimi

During frozen storage, quality deterioration of surimi due to microbiological and autolytic changes is significantly decreased. However, several undesirable changes still occur in frozen surimi as a function of altered water/solid interactions. Most of the studies indicate that denaturation of muscle proteins plays the dominant role in the quality change of frozen stored meats (Park, 1994).

In raw surimi, certain compounds are added to stabilize the myofibrillar proteins. These compounds prevent changes in surimi by freezing, frozen storage or thawing and are referred to as cryoprotectants. A wide variety of compounds will cryoprotect labile proteins during freeze thawing (MacDonald and Lanier, 1994). These include sugars, amino acids, polyls, methylamines, carbohydrate polymers, synthetic polymers (e.g., polyethylene glycol) and other proteins (e.g., bovine serum albumin), and even inorganic salts (e.g., potassium phosphate and ammonium sulphate). Antioxidants and metal chelators, such as phosphate compounds, may also act to extend the shelf life of surimi and other food proteins, serving as cryoprotective adjuncts.

Sucrose and sorbitol have become the most common cryoprotectants in surimi processing. Sucrose addition is known to stabilize proteins against heat denaturation (Lee and Timasheff, 1981; Arakawa and Timasheff, 1982; Park and Lanier, 1990) and against freeze denaturation (Matsumoto, 1980; Park and Lanier, 1987; Park *et al.*, 1988). Sucrose has also been shown to inhibit the

destabilization of myofibrillar proteins by NaCl (Park and Lanier, 1990).

It is well known that the native conformation of many proteins and enzymes can be stabilized by carbohydrates or polyalcohols (Akahane, 1982). The protective effect of carboxylic acids and carbohydrates on protein molecules may be closely related to their effects on the hydration of proteins. According to the study of Noguchi (1974), a marked reduction in freezing damage of proteins was obtained with addition of glucose, mannose, galactose, fructose, sucrose, lactose, glycerol, sorbitol, gluconic acid, glyceric acid and fructose – 6- phosphate.

Noguchi (1974) proposed a list of chemical attributes that seem to be characteristic of cryoprotective substances for proteins. They are: **1)** The molecule should possess one essential group, –COOH, - OH, or $-OPO_3H_2$ and more than one supplementary group-COOH, - NH_2, -SH, $-SO_3H$ and/or-OPO_3H_2. **2)** The functional groups must be properly spaced and oriented with respect to each other. **3)** The molecule must be comparatively small.

The most commonly used surimi formula is 92% washed minced meat, 4% sugar and 4% sorbitol and this product can be stored upto a year without loss of gelling properties (Regenstein and Regenstein, 1991). A mixture of sucrose (4%), sorbitol (4%) and polyphosphates (0.3%) was fairly found to be effective in surimi (Lee, 1984). Extended frozen storage of surimi is made possible by the addition of 4% sucrose, 4% sorbitol and 0.2% polyphosphate, which inhibit the freeze denaturation of myofibrillar proteins (Noguchi, 1974; Akahane, 1982). Uijttenboogaart *et al.* (1993) reported that sodium ascorbate (0.2%) sodium tripolyphosphate (0.2%) and propylgallate (0.02%) protect mackerel surimi.

In 1992, with commercial surimi processing of Pacific

whiting, enzyme inhibitors like beef plasma protein, egg white, whey protein and potato extract have been used in conjunction with 8 to 12% cryoprotective ingredients and gel enhancers which are formulated with sucrose, sorbitol, tetrasodium pyrophosphate or sodium tripolyphosphate, calcium carriers (calcium lactate, calcium sulfate, calcium caseinate) and sodium bicarbonate (Park and Morrissey, 1994). Arai *et al.* (1984), Sase *et al.* (1987), and Watanabe *et al.* (1985) introduced anti freezing properties of an enzymatically modified gelatin (EMG). The current market trend for non-sweet, natural, preferably proteinaceous cryoprotectants may make the EMG a desirable cryoprotectant ingredient.

Sugar and calories have also become a consumer issue. Lanier and Akahane (1986) discovered and patented the use of polydextrose, a non-sweet and low caloric agent for the cryoprotection of muscle proteins. Park *et al.* (1987 a,b; 1988; 1993) and Park and Lanier (1987) continued studies of polydextrose as a non-sweet cryoprotective ingredient in beef, mullet myofibrils and Alaska Pollock surimi. The effectiveness of 10-DE (dextrose equivalent) maltodextrin (without sweetness) was compared to that of polydextrose, sugar and sorbitol in maintaining salt-soluble protein extractability and gel forming ability of Alaska pollock (Lanier and Akahane, 1986; Park *et al.*, 1988).

Cryoprotectants were originally incorporated into the dewatered meat by a kneader. At present, silent cutters are used because it uniformly distributes cryoprotectants faster and temperature increases during chopping are less. Commercial practices for mixing cryoprotectants using a kneader and a silent cutter are 6 minutes and 2.5 minutes, respectively (Park and Morrissey, 2000). The temperature of the mix must not exceed 10^{o}C because higher temperatures damage protein functionality.

2.1.5.2 Mode of action of cryoprotectants

A number of scientists have proposed different theories about probable mechanism behind the action of the cryoprotectants. Noguchi (1974) and Matsumoto (1979) assumed that each cryoprotective compound function as a coating material by associating with the protein through ionic or hydrogen bonding. It was thought that the compounds associated through their ionic groups with the oppositely charged sites of proteins, increases electrostatic repulsion and hinders aggregation of protein molecules during frozen storage. Such increased net charge might also augments protein hydration. The compounds such as carbohydrates and/or polyalcohols when added, they presumably covered the protein molecules by hydrogen bonding with OH groups of the protein. The extra OH groups of the additive molecules would hydrogen bond with water, thereby increasing hydration of the molecules and hindering their aggregation (Park, 1994).

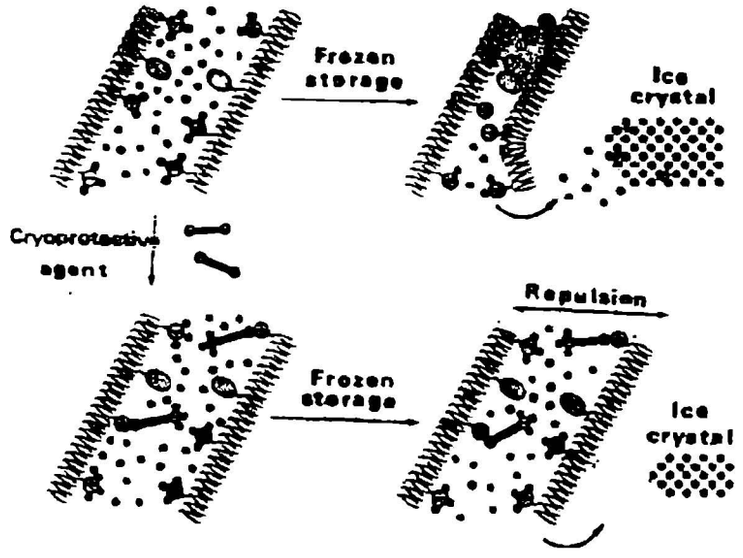
Matsumoto (1980) proposed that globular proteins denature through unfolding during frozen storage. Largely the intermolecular nonpolar bond maintains the native conformation of globular molecules. In the folded protein-water system, the nonpolar groups on the polypeptide backbone are oriented inward so as to avoid contact with the water phase. In the unfolded protein-water system, some nonpolar groups are projected to the interface with water, forming oriented structures. In the presence of cryoprotectant molecules, some of them may be associated with or bound to the protein molecules. This results in an increased hydration of the protein molecules and an increased resistance against displacement of water even under frozen condition. This in turn hinder unfolding of the protein molecules, which otherwise would

cause aggregation.

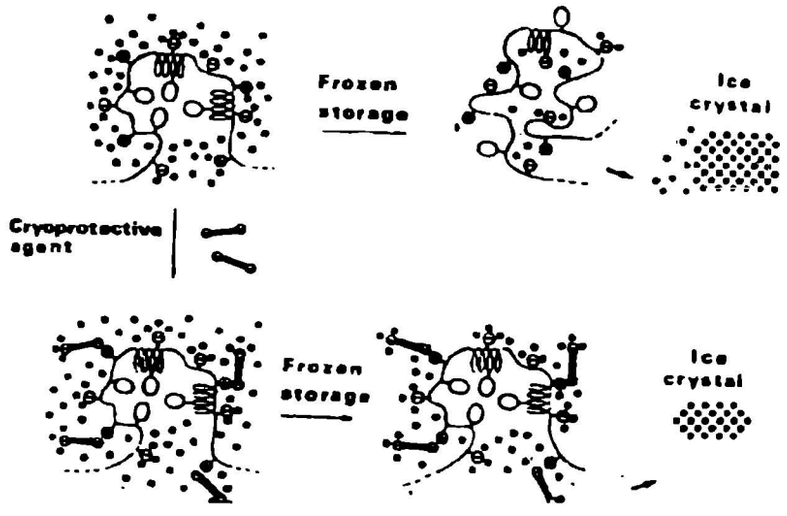
An alternate mechanism involving the thermodynamics of interaction between proteins and solvent components have been investigated for sucrose/water/protein systems (Lee and Timasheff, 1981). Measurement of protein-solvent interactions showed that the protein was preferentially hydrated in aqueous sucrose solution. The association of sugar or polyol molecules in a soluble protein system disrupts some hydrogen bonds between water molecules. The displaced water molecules then reorient or rearrange themselves to form maximum number of new hydrogen bonds with each other. Water molecules around the sugar and the polyols become ordered as a result.

Gekko and Morikawa (1981) concluded that the preferential hydration of protein in sucrose-water or polyalcohol water mixtures may be due to a combination of the following three factors; first, there may be a repulsion between hydrophilic sucrose or polyalcohol and the non-polar residues on protein surface which induces stronger intermolecular hydrophobic protein associations. Second, there may be an attraction between hydrophilic materials and polar residues on the protein surface. Third is the stearic exclusion principle.

Cryoprotectants also protect muscle proteins during frozen storage by depressing the freezing point. Matsumiya and Otake (1983) observed that the freezing point of prepared raw surimi blended with sorbitol was depressed from 0.17 to 1.79°C when the sorbitol concentration was increased from 1 to 10%. Caple *et al.* (1986) explained that the antifreeze glycoproteins alone or with polyalcohols are thought to be specifically absorbed at the ice-water interface in such a way, that inhibits the ability of water molecules to join the ice lattice.



A schematic model of denaturation (aggregation) of alpha-helical proteins during frozen storage and its prevention by cryoprotectants --(+) , Cationic side chain :--(–) Anionic side chain: -- , Nonpolar side chain ● ;Water Molecule(–)--(–), Dianionic cryoprotectant molecule



A schematic model of denaturation (unfolding) of non-helical proteins during frozen storage and its prevention by cryoprotectants --(+) , Cationic side chain :--(–) Anionic side chain: -- , Nonpolar side chain:● ;Water Molecule:(–)-(–) , Dianionic cryoprotectant molecule

FIG : I. MODE OF ACTION OF CRYOPROTECTANTS.

2.2 QUALITY CHARACTERISTICS OF FISH SURIMI

2.2.1 Composition

The composition of surimi varies from that of the raw material as well as the mince. The washing step of the minced meat is primarily responsible for this. The sarcoplasmic protein and lipid are removed during the washing step. Riley (1985) reported that solid losses are as high as 30% of the original weight of the minced fish meat taken and in terms of the proteins; the loss of water-soluble proteins and myofibrillar proteins is 1.7% and 1%, respectively (Lee, 1985).

The protein content of surimi lies between 12 to 15% but the quality of the surimi protein is very high. Many authors have reported the decrease in protein content during washing (Bligh and Regier, 1976; Grantham, 1981; Roussel and Cheftel, 1988). Pigott and Tucker (1990) and Suzuki (1981) reported that in the raw pollock surimi, fat content is less than 1%. Nettleton (1985) pointed out that loss of water-soluble Vitamin-B complex is quite expected during washing. Commercial surimi can contain 75% to 85% water and 5% to 10% carbohydrate depending on its intended use (Miyauchi *et al.*, 1973; Lee, 1986 and Sonu, 1986). The moisture content and pH were considered as the prime criteria to judge the quality of surimi (Suzuki, 1981). According to Regenstein and Regenstein (1991), a good quality of surimi should contain about 79 to 81% of moisture and a pH value of 6.8 to 6.9. Surimi also contains certain additives such as salts, sugars, starches and phosphates. Generally, salted surimi contains 2.5% NaCl, 5% sorbitol, and 5% sucrose while non-salted surimi contains 0.2 to 0.3% polyphosphates, 4% sorbitol and 4% sucrose (Gopakumar, 1997).

2.2.2 Functional properties of surimi

Functional properties can be defined as an effect induced by an ingredient on either the organoleptic properties of a food such as flavor, odor, texture, and appearance or the mincing properties of the food during its processing like extrudability, resistance to tear or breakage, etc. Fish protein is one of the most important classes of functional ingredients as it shows versatile functional properties particularly during processing. Rhee (1985) reported that the physical and chemical properties like gel-forming ability, emulsifying capacity, foaming capacity, etc., are the important functional properties of surimi.

2.2.2.1 Gelling properties

Gelation is a process of protein aggregation, resulting in well-balanced tertiary network structure, which trap within a large quantity of water (Schmidt, 1981). In surimi, the formation of myofibrillar protein network structure is responsible for the functional properties of surimi. It is the gel structure of protein that brings about the elasticity and the textural strength of the products.

Since myofibrillar protein is salt soluble, the grinding of fish without salt does not disrupt the myofibrillar structure, the M-line and the Z-bands are still intact (Sato *et al.*, 1987). When fish meat is minced with salt, disintegration of the myofibrillar structure and formation of actomyosin network are observed (Sato *et al.*, 1987). The first process of formation of gel is turning the myofibrillar protein into a sol state by addition of salt. Sol formation is due to loss of microstructure of myofibrillar protein in water with help of

salt (Niwa, 1992). It was found that 2.5% to 3% NaCl produces an optimum gelling effect in terms of gel strength (Lanier *et al.*, 1985).

Setting of mince at below ambient temperature enhances the unfolding of protein helices and the interaction between the thicker networks. Gel based product is influenced by cooking temperature and length of time, during processing (Mantejano *et al.*, 1984; Lee, 1984; Douglas-Schwarz and Lee, 1988). Excessive heating result in tough rubbery analog (Lee, 1986). Myosin is the most important protein affecting the gel forming ability of fish during low temperature setting (Niwa *et al.*, 1980; Numakura *et al.*, 1987). The CaATPase enzyme association with the myosin molecule further enforces the gel strength of low temperature set surimi (Numakura *et al.*, 1989; Funatsu and Arai, 1992). Transglutaminase enzyme has also been reported to take part in the setting process (Kimura *et al.* 1991; Tsukamase *et al.*, 1993; Kumazawa *et al.*, 1995).

Gelation in surimi is influenced by protein concentration, ionic strength, pH, type of meat and heating condition. The total concentration of myofibrillar protein is very important for gelation. If the water content is too high, gels will be weak (Lanier, 2000). Hence, proper dewatering of surimi is important to the gelling properties of surimi. For surimi to gel well, salt must be added to break the ionic linkages and assist in the dispersion of the proteins because an even dispersion of the proteins is necessary for the development of an elastic structure in the heat-set gel (Niwa, 1992). pH plays an important role in the gelation of surimi. The drop in pH can dramatically affect the heat gelation properties of surimi by leading to accelerated denaturation of protein (Lanier, 2000). Setting proceeds best at higher pH (Torley and Lanier, 1992; Matukawa *et al.*, 1996) and requires prior solubilization of the protein by salt or with NaCl favoring subsequent cross-linking

compared with KCl (Wan and Seki, 1992).

The optimum setting temperature varies according to species mainly because the myosin or actomyosin, which is the substrate for the reaction, has a different thermal stability depending on fish species (Arai and Seki, 1993; Niwa *et al.*, 1993; Joseph *et al.*, 1994). Generally, fish that inhabit colder waters have the least stable proteins compared with fish living in warmer waters. Yet, fish from cold but very deep waters may have more stable protein than fish in the same waters nearer the surface as a response to the higher pressure of their habitat. Kamath *et al.* (1992) have shown that Alaska pollock surimi exhibits maximum gel strength when pre-incubated at 25°C for 2-3hours. Similar gel strength enhancement could be achieved at lower temperature (5°C) with a much longer setting time. Lee and Park (1998) found that pollock gels achieved highest gel strengths when set at 5°C, whereas setting of Pacific whiting gels was most effective at 25°C. Kim (1987) found that the strongest pollock gels were obtained with 4°C setting, whereas a 40°C setting was best for Atlantic croaker.

The feasibility of ohmic heating to maximize the gel functionality of Pacific whiting surimi without enzyme inhibitors was investigated by Yangsawatdigul *et al.* (1995). Chung *et al.* (1994) investigated the effects of high hydrostatic press (HHP) on the gel strength of Pacific whiting and Alaska Pollock. A threefold increases in strain and stress were found for HHP treated whiting gels made without an enzyme inhibitor compared with gels heated in a 90°C water bath.

2.2.2.2 Protein solubility

The protein solubility profile is an excellent index of protein functionality, which influences the textural properties of fish

indicating the potential application. Myofibrillar protein, the major component of surimi is generally classified as salt-soluble protein. However, studies had revealed that a considerable amount of myofibrillar protein were lost in surimi waste streams (Lin *et al.*, 1995). The loss of myofibrillar protein during surimi processing could be due to the nature of their water solubilily (Park and Morrissey, 2000). Stefansson and Hultin (1994) and Wu *et al.*, (1991) reported that myofibrillar protein solubilize in water and low ionic strength solution. Hennigar *et al.* (1988) reported that gels could be prepared using fish muscle without NaCl. He also suggested that myofibrillar protein from fish muscle could be soluble in water or very low ionic strength solutions.

2.2.2.3 Water holding capacity

Water holding capacity (WHC) of protein depends on protein sources, composition and presence of carbohydrates, lipids, pH and salt (Harmensson *et al.*, 1972). According to Gerald *et al.* (1983), WHC changes due to a change in volume of myofibrillar protein. The temperature of the wash water has direct influence on the water holding capacity of the mince (Gopakumar, 1997). Water having a pH close to fish muscle pH, facilitates the retention of its natural water holding capacity. Gopakumar, (1997) also reported that washed and dewatered mince when mixed with cryoprotectant resulted in enhanced water holding capacity. The water retention properties of protein affect the juiciness, texture and flavor of meat (Gerald *et al.*, 1983; Regenstein and Regenstein, 1984).

2.2.3 Factors affecting surimi quality

2.2.3.1 Biological (intrinsic) factor

2.2.3.1.1 Effects of species

In addition to Alaska pollock, a number of species are used as raw material for commercial surimi processing. The functional and compositional properties of the surimi vary based on the species used (Park and Morrissey, 2000). It is, therefore, important for processors to understand the relationships between the physiochemical function of fish and the functional and compositional properties of surimi.

Certain species of fishes such as Pacific whiting, arrow tooth flounders, threadfin bream, Atlantic menhaden and white croaker are reported to contain enzyme cathepsin (Toyohara and Shimizu, 1988; Boye and Lanier, 1988; Toyohara *et al.*, 1990; Greene and Babbitt, 1990; An *et al.*, 1994). This enzyme is responsible for causing textural deterioration when surimi paste is heated slowly. Enzyme inhibitors, therefore, are required unless the surimi is cooked rapidly using an ohmic heater (Yangsawatdigul *et al.*,1995) or is thinly extruded and cooked rapidly, like in crab stick processing.

To make surimi from oily/dark or red-fleshed fish, such as mackerel, sardine and salmon, certain steps must be applied to negate the effects of the oil and heme proteins. Heme proteins, promote fat oxidation in the dark muscle, which causes an offensive, rancid odor (Tokunaga and Nishioka, 1988). Use of 0.1-0.5% $NaHCO_3$ in the first washing solution and decantation can be helpful to remove the extra oil. The addition of 0.5-0.1% sodium pyrophosphate and the use of vacuum during washing are also recommended to remove heme proteins (Park and Morrissey, 2000).

2.2.3.1.2 Effects of seasonality / sexual maturity

Compositional properties of fish vary as the fishing season changes. Generally, fish harvested during the feeding period produce the high quality surimi. During this period, fish muscle has the lowest moisture content and pH, as well as the highest total protein (Anon., 1984). Fish harvesting during and after spawning season produce the lowest quality surimi as they have a relatively higher pH and tend to retain more water.

2.2.3.1.3 Effect of freshness or rigor

Freshness of fish primarily depend on time /temperature (Park and Morrissey, 2000). The biochemical and biophysical changes during the development of rigor mortis induce significant changes in the functional properties of muscle protein. Fish should be processed as soon as possible after going through rigor. Before passing through this stage it is difficult to remove the "fishy" odor, various membranes and other contaminants that affect product quality (Pigott, 1986). Park *et al.* (1990) reported that significantly high protein content and yield, reduced cooking loss and enhanced gel forming ability were associated with surimi processed from manually filleted pre-rigor tilapia fish.

Peters and Morrissey (1994) investigated time-temperature effects on the compositional and functional quality of Pacific whiting surimi. Their study suggested that if the fish are kept refrigerated, Pacific whiting should be processed within 24hr of capture, otherwise the quality begins to decline.

2.2.3.2 Processing (extrinsic) factors

2.2.3.2.1 Harvesting

Surimi quality is affected by the harvesting conditions and methods used for capture, as well as the onboard handling methods and vessel storage conditions. The geographic location of the fishing grounds may affect quality and determine factors such as the size of fish or the amount of time required to deliver the fish to the processing plant (Park and Morrissey, 2000). Several factors such as weather condition at sea, capture methods, size of tow, length of tow salt uptake and temperatures of the fish after capture also affect final product quality.

2.2.3.2.2 Onboard handling

Time and temperature of the fish between capture and processing can be considered two of the most important factors in final surimi quality. In the whiting fishery, it is recommended that fish be cooled down rapidly and landed for processing within 24 hr after harvest (Morrissey *et al.*, 1994). Proteolysis is time and temperature dependent, and faster chilling of fish as well as low temperature storage, would help to offset longer storage time effects (Morrissey *et al.*, 1997).

2.2.3.2.3 Water

The important quality factors associated with water are temperature, hardness or mineral content, pH and salinity. The level of chlorination in the water should be considered because of its bleaching and deodorizing effect (Lee, 1986). Warm water fish can tolerate a higher water temperature than cold-water fish without reducing protein functionality (Arai *et al.*, 1973). Considering the change in air temperature during processing, the

recommended water temperature for obtaining maximum quality is 5°C or less.

Theoretically, soft water with minimum levels of minerals, such as Ca^{++}, Mg^{++}, Fe^{++} and Mn^{++}, is recommended for washing. Hard water causes deterioration of texture and color quality during frozen storage (FAO, 1997). In addition, Ca^{++} and Mg^{++}, are responsible for the color change (Lee, 1990). The pH of the water must be maintained at approximately that of pre-rigor fish muscle tissue (6.8 – 7.0) to obtain higher water retention gels.

Before, washing the salinity of fish mince is approximately 0.7%. Moisture removal gradually increases when the percent salt concentration of the wash water is increased (Lee, 1990, Lin *et al.*, 1995). It is common to use a mixture of NaCl and/ or $CaCl_2$ at 0.1-0.3% in the final wash water (Park and Morrissey, 2000).

2.2.3.2.4 Time / temperature of processing

Prolonged holding time and elevated temperatures can cause severe proteolysis of myofibrillar protein causing more of it to be dissolved as water-soluble waste (Suzuki, 1981; Patashnik *et al*, 1982, Xiong and Brekke, 1989). With prolonged storage time, however, severe degradation occurred, although the storage temperature had been maintained at 0°C (Lin and Park, 1996). According to An *et al.* (1994), in the temperature range of 0-5°C, cathepsins B and H might contribute to the degradation occurring at low-temperature storage. Consequently, to minimize proteolysis, fish should be processed promptly on landing or kept at 0^0C if holding is necessary. The solubility of protein during washing increased as well when fish were held for a long period and / or at higher temperature (Park and Morrissey, 2000).

2.2.3.2.5 Washing cycle and wash water ratio

A water: meat ratio ranging from 4:1 to 8:1 is often used by onshore processors (Park and Morrissey, 2000). This washing process is often repeated three to four times to ensure sufficient removal of sarcoplasmic protein. On the other hand, at sea processors use a lower water / meat ratio (1:1 to 3:1) with only one or two washing cycles because of their limited access to freshwater. Increased water use for washing usually results in more protein loss and increased waste disposal (Lin and Park, 1996). It was estimated that ~ 50% of total protein were lost during washing (Adu *et al.*, 1983;Crawford *et al.*, 1989; Yang and Froning, 1992).

According to Nishioka (1984) the gel strength of surimi continued to increase as the number of washing cycles increased. A recent report by Lin and Park (1996), indicated that most sarcoplasmic proteins are fairly soluble and removed during the initial washing steps, subsequent washing removes the residual sarcoplasmic proteins along with small amount of myofibrillar proteins. Lin and Park (1997) investigated to minimize water use for leaching by reducing the water/ meat ratio and increasing the wash cycles (WC) and wash time (WT).

2.2.3.2.6 pH and salinity

Lin and Park (1996) evaluated the effects of salt concentrations and washing cycles on the extraction of proteins. Sarcoplasmic proteins are readily soluble in water (0% NaCl) and easily removed in the initial washing steps. Myofibrillar proteins become relatively soluble and are lost during extensive washing. Hence, control of water / meat ratio, washing time and washing cycles is critical in reducing the loss of myofibrillar proteins. Another factor that affects myofibrillar protein solubility is pH

(Crawford *et al*; 1989; Yang and Froning, 1990; Turgeon *et al.*, 1992; Monahan *et al.*, 1995). Proteins have reduced solubility at the isoelectric point because protein - water interactions are replaced by protein - protein interactions. At pH above or below the isoelectric point, the protein acquires an increasing net negative or positive charge. These net charges provide more binding sites for water and cause repulsion among protein, thus increasing protein solubility (Hamm., 1960).

2.3 SURIMI AND SURIMI BASED PRODUCTS

Surimi is the intermediate raw material from which the end products called "Neriseihin" (surimi-based products) are manufactured (Flick *et al.*, 1990). About 90 percent of surimi-based products are various types of fish cakes called Kamaboko. Less than 10 % of surimi-based products are represented by fish sausage, fish ham and fish burgers. Imitation crab and other surimi-based shellfish analogs may be included under Kamaboko.

2.3.1 Kamaboko and related products

According to Park (2000), Kamaboko often refers to all surimi-based products in Japan. Kamaboko products are divided among three major categories: steamed, broiled and fried (Flick *et al.*, 1990). Typical steamed kamaboko is called "Itatsuki" (board-mounted) kamaboko. The broiled kamaboko is called "Chikuwa", which has the shape of a hallow bamboo stem. Typical fried kamaboko (age-kamaboko) products are "Satsuma-age" and "Tempura". According to N. Kata (1997), the typical fried kamaboko is called "Satsuma-age" in Tokyo, "Tempura" in Osaka and "Twighin ahmook" in Korea. Three types of pre-cooking are often used to

differentiate Satsuma-age (Park, 2000). They are "Yude-age" (boiled-fried), "Mushi" (steamed-fried) and "Ki" (fried).

Kamaboko is also given various names depending on product shapes, such as "Sasa" (bamboo-leaf shaped), "Soba" (noodle-shaped), "Date-maki" (whirled or rolled) and so on (Flick *et al.*, 1990).

2.3.2 Surimi seafood analog products

Surimi-based seafood analog products are developed in several styles, but particularly as crabmeat (Park, 2000). The product may be divided into four major categories according to their fabrication and structural features: molded, fiberized, composition-molded and emulsified (Flick *et al.*, 1990).

2.3.2.1 Molded

Molded products are made by molding the chopped surimi into the desired shape and allowing it to set and form an elastic gel (Flick *et al.*, 1990). Molding may be accomplished by either single extrusion or a co-extrusion. Restructured shrimp flavored surimi based products are in this category.

2.3.2.2 Fiberized

Fiberized products are made by extruding the paste into a thin sheet through a rectangular nozzle having a narrow opening 1/25 to 1/8 inch (Flick *et al.*, 1990). The extruded sheet is then partially heat set and cut into strips of desired width by a cutter. Surimi used in this process should be of good quality. Fine strips are preferred for fibrous crab leg products, whereas wider strips are more suitable for simulated shellfish in the form of sea flake and chunk.

2.3.2.3 Composite molded

In this type of product the strings of desired length are mixed with or without surimi and extruded into a desired shape (Flick *et al.*, 1990). This type of product gives a better bite than the strictly molded variety, which tends to be rubbery and uniform in texture. Composite molded products are found in chunk form and sold mixed with fiberized products. According to Gopakumar (1997) fish ham is prepared by mixing the cured tuna cubes with pork fat and surimi batter containing spices. This is stuffed in casing, sealed and cooked in hot water.

2.3.2.4 Emulsified

In emulsified product animal fat or vegetable oil is added usually at 10% level (Flick *et al.*, 1990). The resulting pastes are stuffed into casings and steam or smoke cooked. Sausage type products fall into this category. According to Gopakumar (1997), mixing salt, spices, seasonings, starch and fat to the surimi produces fish sausages. It is then ground well and the paste is stuffed in natural or synthetic casings, sealed and cooked in steam (85-90^{0}C).

2.3.3 Battered and breaded products

Seafood that have been subjected to further processing by being coated with batter and breading, include finfish, crustacean, mollusk, as well as certain specialty items such as fish cakes, surimi and stuffed portions (Sasiela, 2000). The decision to process seafood further is often complex and requires a sound understanding of the interrelationship of the substrate, the equipments performing the transformation, the added ingredients

and regulatory considerations. Further, processing of seafood encompasses the transformation of a raw aquatic commodity into an item that is designed to meet a consumer need. According to the U.S. Department of Commerce (1995) the minimum flesh content requirements for USDC-inspected raw breaded fish portion and raw breaded fish sticks are 75% and 72%, respectively.

Seafood accounts for approximately 50% of all frozen battered and breaded products in US. Ingredients used in battered and breaded formulations fall into two groups. The first group includes flour, eggs, milk and the second include greens, spices, whey, leavening agents starch, salt and sugar. These ingredients, from a quantitative perspective, determine the physical differences in batters and breading (Flick *et al.*, 1990).

The type of coating, generally, used is a corn or wheat flour-based aqueous cohesive batter, along with either a cracker-meal or breadcrumb breading (Sasiela, 2000). The crumbs can also be toasted to impart the desired colors. The product thus formed may be subjected to precooking by frying it in frying oil at 375°F to 400°F for only about 30 seconds (Sasiela, 2000).

During the precooking step important changes take place within the coating, which includes starch gelatinization, protein coagulation, browning reactions, fat absorption, leavening release, moisture reduction and flavor development (Sasiela, 2000). The final cooking can be done by different cooking appliances among which deep-fat frying or convection baking are the primary choices, with rapid preparation time being an important criterion.

One of the controlling factors of coating texture is the granulation of the outermost coating. Breading can range from ½ inch cube to fine particles that will pass through a 80 mesh standard sieve (Flick *et al.*, 1990). If fine mesh is used, the batters

ability to absorb liquid is increased. A coarse coating can result in a loosely adhering product that will fall off during handling or transportation.

According to Flick *et al.* (1990), cold water (10°C) preferably should be used as it helps in increasing batter adhesion. The batter should be mixed with water past the point where no unwanted lumps remain. Johnson (1982) and Roessink (1989) reviewed the scope of battered and breaded fishery products. Torres *et al.* (1985) studied the effect of frying temperature, viscosity of the batter and the method of breading the fillets on colors and crispness scores, fat absorption, net weight loss, moisture loss and residue-to-fat ratio of the breaded fish fillets.

2.4 FRYING TEMPERATURE AND TIME FOR FISHERY PRODUCT

According to Dean (2000) the most satisfactory frying temperature for fish is 350°F to 374°F. Man and Atan (1984) reported the temperature of 190°C for 3 to 4 minutes in the preparation of deep fried seer fish. Similarly, Rasco *et al.* (1987) applied a frying temperature of 180°C for 3 minutes to prepare coated deep fried fish. Roessink (1989) suggested that for the frying of battered and breaded fishery products, frying temperature between 180°C and 250°C should be used because below 180°C it requires long cooking time and oil absorption becomes a serious problem. Chand *et al.* (2001) reported that during frying evaporation of moisture occurs which leads to the decrease of moisture content. According to Zaitsev *et al.* (1969), the evaporation of moisture is directly proportional to the frying time and temperature. Frying also results in weight loss of the product. According to Chand (1991), the traditional methods of frying may

fail to give superior product; hence standardization of frying procedure is important, which includes both frying temperature and time.

2.5 CHANGES IN SURIMI AND SURIMI BASED PRODUCTS DURING STORAGE

2.5.1 Changes in protein

One of the most prevalent chemical reactions to occur in fish muscle during freezing and frozen storage is the complex phenomenon of protein denaturation (Santos-Yap, 1996). Protein denaturation occurs due to the formation of ice crystals, surface dehydration and cell rupture (Mishra and Srikar, 1989). Wagner and Anon (1986) reported that the denaturation of protein occurs during freezing and frozen storage due to the unfolding of myosin head region by weakening of the actomyosin, which result in loss of protein functionality. Suzuki (1981) reported that fluctuating temperature during frozen storage reduces the gel forming ability of fish proteins. The solubility of myofibrillar protein depends on the freezing rate, frozen storage temperature and prefreezing conditions (Reddy and Srikar, 1991). High frozen storage temperature causes insolubilization of myofibrillar protein (Fukuda *et al.*, 1981). Park *et al.* (1988) and Sych and Carrier (1991) have reported a loss of salt soluble protein in cryoprotected surimi during frozen storage. The extent of myofibrillar protein denaturation can be analyzed by measuring the solubility in 0.6M NaCl or KCl and ATPase activity (Matsumoto, 1980; Wagner and Anon, 1986). Koning *et al.* (1985) reported that the formation of free fatty acids (FFA) and denaturation of protein are related phenomenon.

2.5.2 Changes in TMAO

All fish contain trimethylamine oxide (TMAO), a water-soluble nitrogenous compound used by fish for osmoregulation. TMAO dimethylase is an enzyme, which degrades TMAO to formaldehyde and dimethylamine during frozen storage (Lanier, 2000). Formaldehyde is a strong protein denaturant, and thus the gelling properties of surimi or minced fish can deteriorate rapidly if this enzyme system is active and present at a sufficient concentration.

Leaching process acts to remove most of the TMAO from the meat and seems to inactivate or remove the dimethylase enzyme as well (Holmquist, 1982). However the enzymatic degradation of TMAO to DMA and FA (formaldehyde) has been reported in Alaska pollock mince compared to its muscle (Babbitt *et al.*, 1984). Toughening of flesh due to protein denaturation has been suggested to be caused by cross-linking of protein produced by FA during the enzymatic degradation of TMAO to DMA and FA (Gill *et al.*, 1979). Babbitt *et al.* (1972) suggested that DMA should be used as quality index of frozen fish rather than TMA.

2.5.3 Changes in lipid

Tiwari (1995) has reported a reduction of 73.5% fat in minced meat after three washing cycles. The residual lipid is the main cause of quality deterioration of surimi during frozen storage. The lipid oxidation is influenced by the factors such as the amount of lipids, their susceptibility to auto oxidation (Ke *et al.*, 1982), the level of heme compounds (Fischer and Deng, 1977), the level of microsomal system, associated with lipid oxidation (Mc Donald *et al.*, 1979) and the presence of metal ions (Allen *et al.*, 1979). Non-enzymatic oxidation is predominant in frozen stored mince (Borderias *et al.*, 1978).

Polyphosphates have antioxidant properties, particularly in combination with other additives (Tableros, 1980). Lampila (1992) reported that polyphosphates have profound effect on the functional properties of freshwater and marine fish products. Martin *et al.* (2000) reported that Atlantic cod fillets dipped in tripolyphosphate or metaphosphate have decreased thaw and cooked drip loss and resulted in higher weight content of cooked and raw product.

2.6 MICROBIOLOGY OF SURIMI SEAFOOD DURING PRODUCTION AND STORAGE

The quality and safety of surimi-based seafood products depend largely on the contaminant load in the raw surimi and ingredients (Matches *et al.*, 1987). According to Yokoyama (1992), surimi crab leg processing equipment contained bacterial levels of 1.8×10^{6} /cm^2 for a belt conveyor, 2.5×10^{4}/ cm^2 for containers of mixed paste and 5.4×10^{2} / cm^2 for the inner wall of mixer. Himelbloom *et al.* (2000) reported that fish cleaning and washing removes some microorganism; however, about 90% are retained because of entrapment and bacterial adhesion during subsequent processing operations.

Mincing of fish disrupts cellular material and disperses the contaminating microorganisms. But, minced fish still provides an ideal medium for psychrotrophic bacterial growth because of the high water and protein content and neutral pH (Himelbloom *et al.*, 2000).

Total aerobic bacterial counts were $<10^{4}$/g for both frozen and refrigerated Spanish surimi (Castillo *et al.*, 1995). More than 80% of surimi imported to Italy contained $<10^{3}$ bacteria/g, whereas faecal coliforms and streptococci were $<10^{2}$/g and only 1 out of 150

samples contained *Staphylococcus aureus* (Ercolini *et al.*, 1995). For surimi made in Mexico from three different fish, seasonality was a significant factor, resulting in higher initial microbial loads during summer processing (Hernandez *et al.*, 1997). Studies have revealed that the microbial burden in frozen surimi declines on an average of 39% from the original aerobic plate counts for pre-frozen surimi (Eliot, 1987; Himelbloom *et al.*, 1991).

A survey of *Listeria sp.* in surimi seafood revealed that 29% of the sample was contaminated with *Listeria monocytogenes* (Weagant *et al.*, 1988). Psychrotrophic bacteria *Aeromonas hydrophila* and *Yersinia enterocolitica* are able to grow at 50°C during extended storage. The bacterial pathogen *Bacillus cereus* has been isolated from one sample of commercial surimi crabmeat after it received temperature abuse (Yoon *et al.*, 1988; Hollingworth *et al.*, 1991; Ingham, 1991).

Breaded surimi seafood products exported to Italy contained 10^3-10^6 bacteria/g; faecal coliforms and streptococci counts were $<10^3$/g, but several samples contained *S. aureus* and *E. coli* (Ercolini *et al.*, 1995).

2.7 QUALITY ASSURANCE OF SURIMI-BASED PRODUCTS

The quality and safety of surimi seafood products depends largely on the contaminant load in the raw surimi and ingredients (Matches *et al.*, 1987). Variability in bacteriological data exists for surimi seafood operations that involve different number of steps, degrees of handling and product specifications.

On December 18,1997, the U.S. Food and Drug Administration (FDA) mandated the application of Hazard Analysis Critical Control Point (HACCP) principles to the processing and

importing of fish and fishery products (Himelbloom *et al.*, 2000). HACCP is a preventive system of hazard control that can be used by processors to ensure the safety of their products to consumers.

The bacteriological standards for fish and products were established in 1986 and the values still remain acceptable. The objective in food processing is to reduce microbial levels below acceptable limits to ensure long, refrigerated shelf – life and safety to the consumer.

Safety and quality considerations will remain for surimi-based products, which is a value added ready-to-eat commodity. Close scrutiny of processing operations, from ingredients to final product, in association with HACCP can ensure a safer product. However, storage conditions (temperature and time) of surimi-based products will have the greatest impact on the development of spoilage or unsafe products regardless of packaging. Thus, retailers and consumers should be aware of the limited preservation capabilities in these quality-sensitive and safety-sensitive seafood products (Himelbloom *et al.*, 2000).

CHAPTER. III

MATERIALS AND METHODS

III. MATERIALS AND METHODS

3.1 MATERIALS

3.1.1 Raw material

Live silver carps (*Hypophthalmichthys molitrix*) were caught from the ponds of Fresh Water Fisheries Research Station, Kulia, Kalyani Nadia and used for the present study. The fishes were transferred to the laboratory within an hour of harvest and they were almost instantly processed.

3.1.2 Chemicals and glasswares used

The chemicals used in the analysis were either of 'Analytical' or 'Guaranteed' reagent grades. Total plate count was estimated by using nutrient agar obtained from 'Hi-media', Mumbai. The glassware used were all of 'Borosil' make.

3.1.3 Subsidiary materials for value added products

3.1.3.1 Ingredients

Commercially available good quality spices were used as per the requirement of the recipe for 'fish cake'. All the spices used were of "Sunrise" brand. Refined table salt of "Tata" brand was used to prepare the product. Double refined, mustard oil of a popular brand (Dhara) was used for frying. Potato, onion, ginger and garlic were procured from local market. Egg albumen was used as batter. Bread crumbles (toasted) were used for the purpose of breading.

3.1.3.2 Packaging materials

Low-density polyethylene (LDPE) bags up to 200 gauges were used for packing dewatered minced meat (DWM), surimi and "fish cakes".

3.1.3.4 Frying materials

Round bottom steel pan was used for frying of fish cakes. Perforated stainless steel ladle was used for transferring the fried fish cakes from hot oil. Gas oven was used for frying. A long stem thermometer with a range from 0°C to 250°C and a reading accuracy of 1°C was used to note the temperature of the frying oil. Stainless steel vessels and trays were used during the entire process.

3.1.4 Equipment

3.1.4.1 Processing equipment

a) Meat picking machine: The separation of the meat from the skin and bones of dressed fish was done using Roll type fish meat picking machine.

b) Fish meat mincer: The picked meat was minced by mincer.

c) Bowl chopper: The mixing of the minced meat with the cryoprotectants and ingredients was done in a bowl chopper or silent cutter.

d) Hydraulic screw press: The final dewatering was done by using a hydraulic screw press.

e) Deep freezer: Horizontal model deep freezer maintaining a temperature of -35° ± 1°C was used.

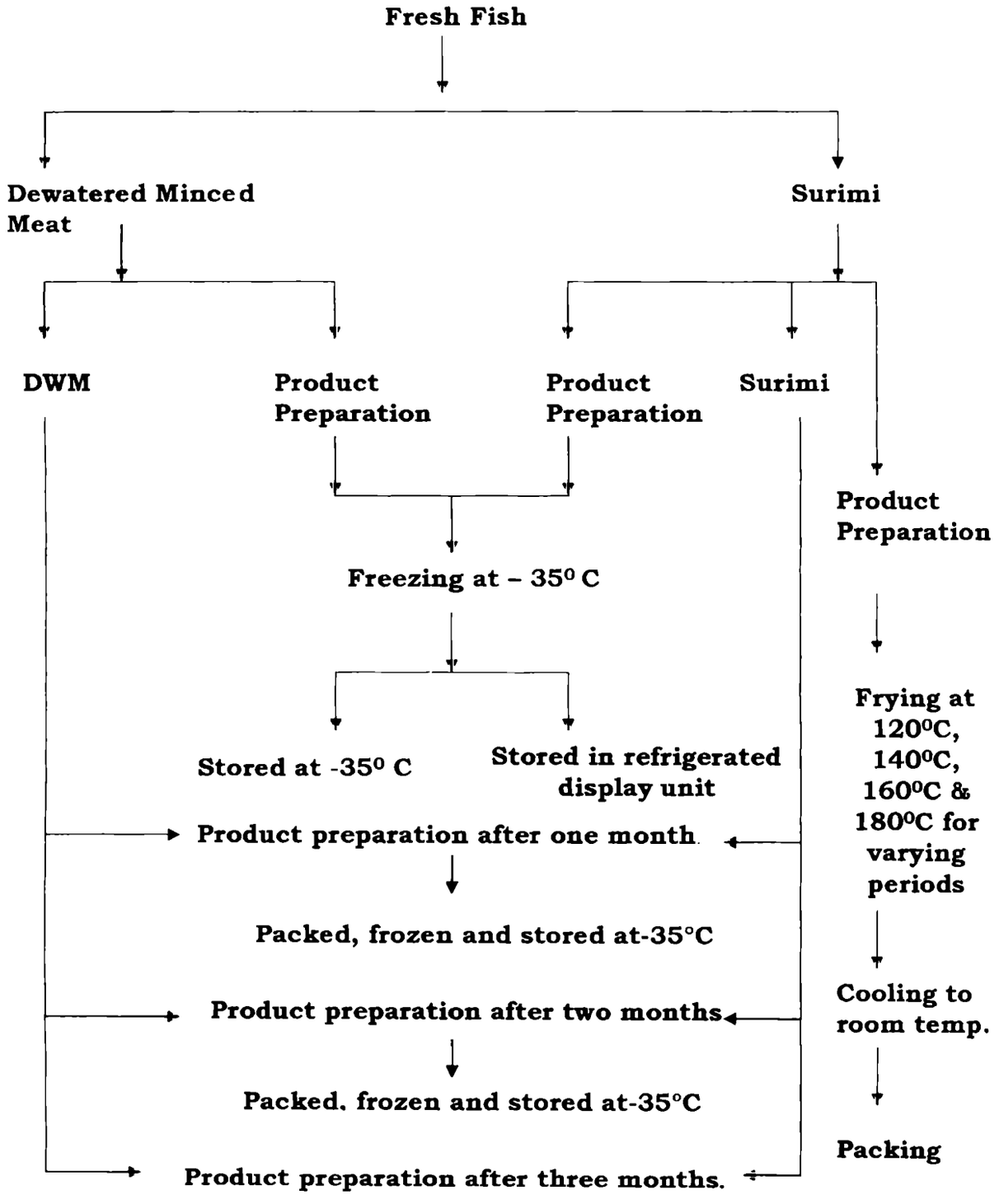


FIG: II (A) EXPERIMENTAL DESIGN

TABLE: III CODE USED FOR SAMPLES

STORAGE PERIOD	RAW MATERIAL		PRODUCTS				
	BATCHI		BATCH	WITHOUT TREATMENT (DWM)	SURIMI	BATCH VI	
	DWM	SURIMI				DWM	SURIMI
0	C	T	II	C1	T1	C5	T5
30			III	C2	T2		
60			IV	C3	T3		
90			V	C4	C4		

f) Vessels and utensils: All the vessels and utensils were made of stainless steel.

g) Processing tables: (stainless steel).

3.1.4.2 Analytical instruments

- Kjeldahl digestion system
- Kjeldahl distillation unit
- Muffle furnace
- Hot air oven
- IIC, Bacteriological incubator
- REMI, R8C laboratory centrifuge
- Sterilizer/Autoclave
- Electronic single pan balance
- Vacuum oven
- Distillation apparatus
- Laminar flow
- pH meter
- Laboratory blender
- Homogenizer

3.2 METHODS

3.2.1 Study of raw material characteristics

3.2.1.1 Physical characteristics

Total length, standard length and weight of the fish caught were measured. The yield of the picked meat was calculated based on the whole fish and dressed fish respectively.

3.2.1.2 Chemical characteristics

Methods used to assess the freshness of the fish are described in sections 3.2.5 and 3.2.6.

3.2.1.3 Sensory characteristics

The samples of silver carp caught were assessed organoleptically based on the general appearance, flavor, odor, eyes and texture on 10-point scale (CIFE, 2001). The overall acceptance of the fish was then assessed based on the mean score of the panelist. 8-point hedonic scale (Keeton, 1983) was used to assess the sensory quality of the value added products.

3.2.1.4 Microbiological characteristics

The microbiological characteristic of fresh fish was carried out according to the standard method recommended by APHA, (Speck, 1984). Appropriate dilution of the homogenate was made in a physiological saline (0.85%) and plated into duplicate on nutrient agar, by pour plate method. The plates were incubated at 37°C temperature for 48 hours.

3.2.2 Standardization of washing procedure

The minced meat was water washed by using chilled water (5°C) to remove blood, pigment, fat and other low molecular weight components. The mince: water ratio (w/v) of 1:2 was adopted for 2 minutes and the number of washing cycles were restricted to two as per the method described by Gopakumar *et al.* (1992). After each wash, the meat was gently squeezed in a muslin cloth to remove as much water as possible and then allowed to soak for 5 minutes. Finally, the meat was subjected to pressing and the

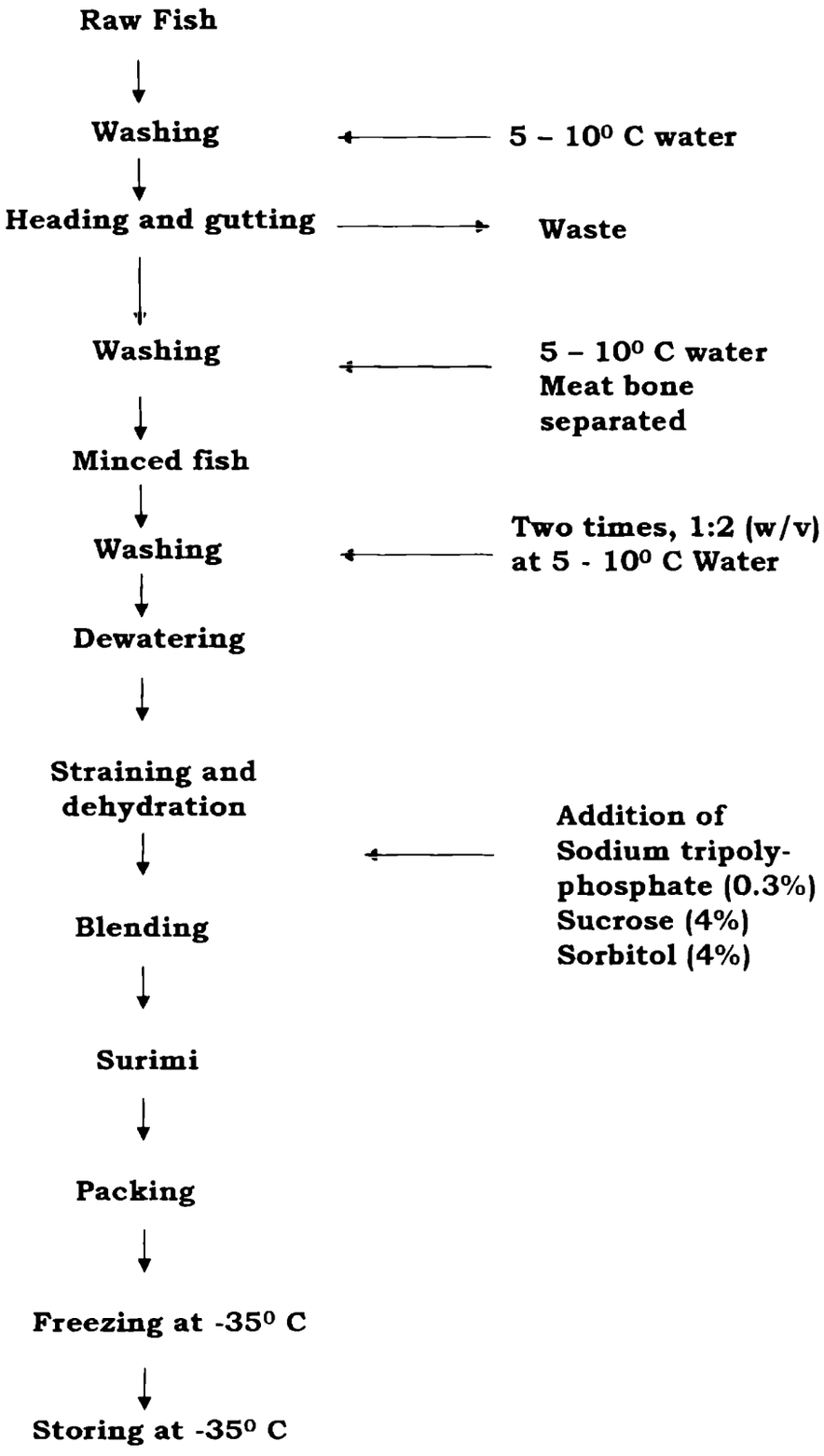


FIG: II (B) FLOW DIAGRAM OF SURIMI PROCESSING.

moisture content of the product was maintained at about 80% level.

3.2.3 Production of surimi and value added product

After final dewatering, the partially dehydrated meat was divided into 3 batches. The first batch, dewatered minced meat (DWM), was divided into two groups. One group was packed in LDPE bags and subjected to freezing and frozen storage at -35°C temperature. The other group was processed into fish cake, packed and subjected to freezing and stored at -35°C as well as in refrigerated display unit (RDU) with a temperature range of 2 to 4^0 C.

The second batch was mixed with 4% sorbitol, 4% sucrose and 0.3% sodium tripolyphosphate in a bowl chopper for two minutes. Surimi was then subdivided into two groups. One group was packed and subjected to freezing and stored at -35°C temperature. The other group was processed into fish cake, packed, frozen and stored at -35°C in the similar way as the DWM.

The third batch after water washing was processed into fish cake and was frozen. The frozen products were then kept separately in frozen storage (-35°C) and refrigerated display unit (2-4°C).

The effect of freezing and frozen storage on the DWM, surimi as well as on the products were studied. The shelf life of products in frozen storage and refrigerated display unit was assessed. The frying time and temperature for the products were also standardized.

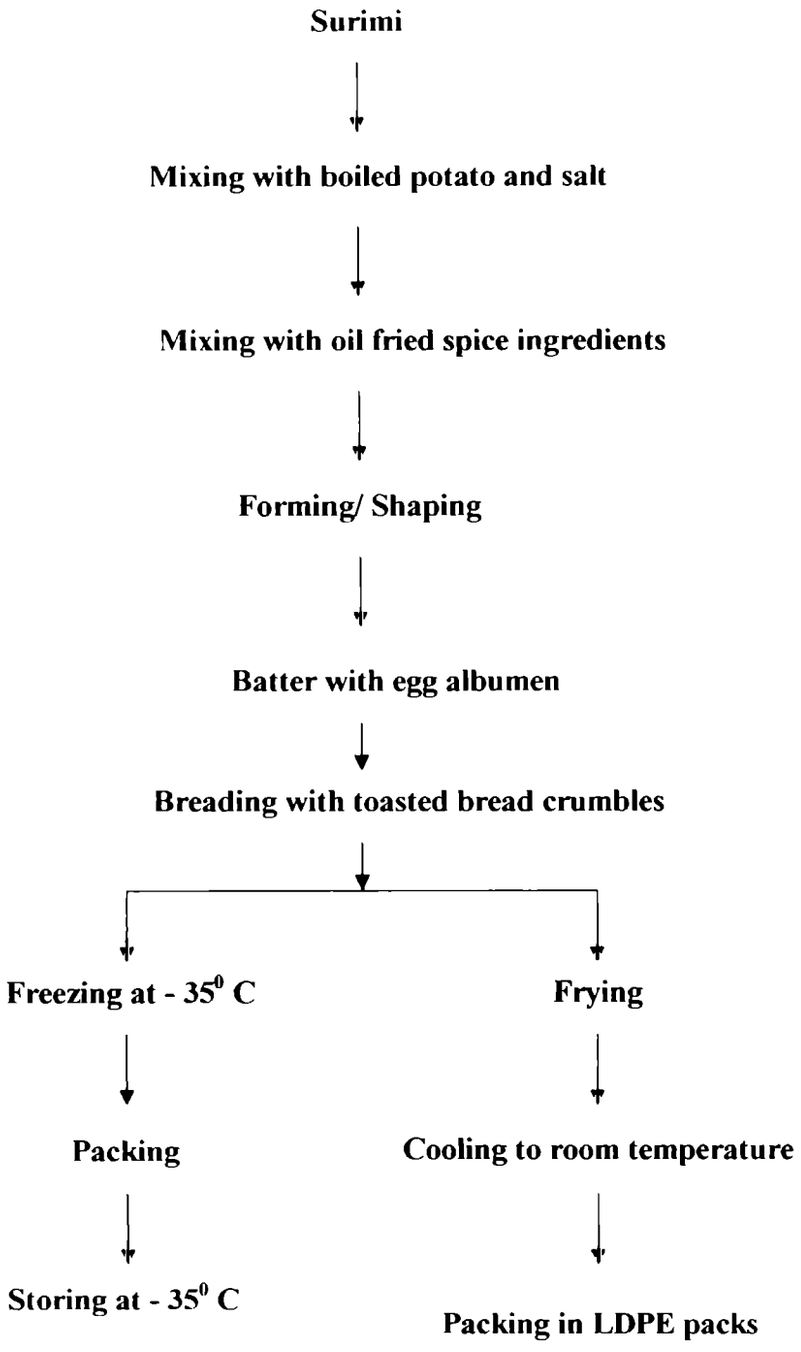


FIG: III FLOW DIAGRAM OF FISH CAKE PREPARATION

TABLE: IV RECIPE USED FOR FISH CAKE

A. PASTE

INGREDIENTS	PERCENTAGE
1. Surimi	60
2. Potato	25
3. Onion	10
4. Garlic	1.0
5. Ginger	1.0
6. Green Chilli	0.3
7. Cumin	0.3
8. White Pepper	0.3
9. Salt	1.5
10. Chilli Powder	0.3

B. BATTER: Egg Albumen

C. BREADING: Toasted Bread Crumbles

Plate-1

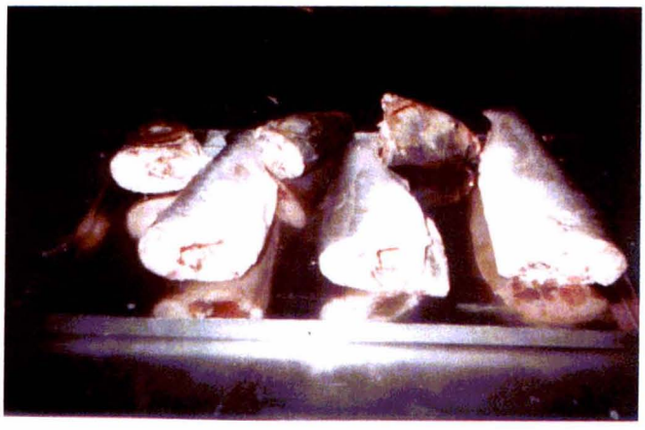


Plate- 2

Plate- 3

Plate-4

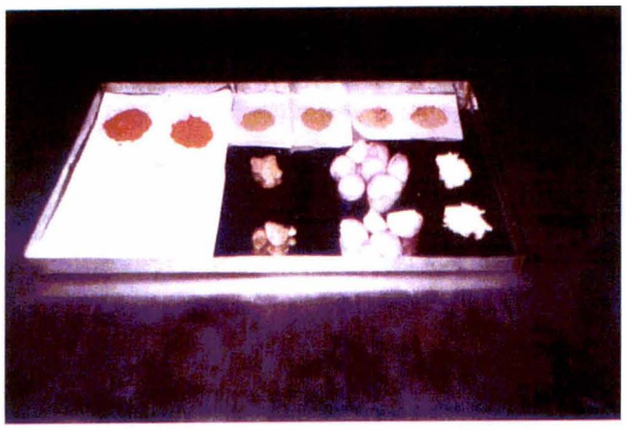


Plate- 5

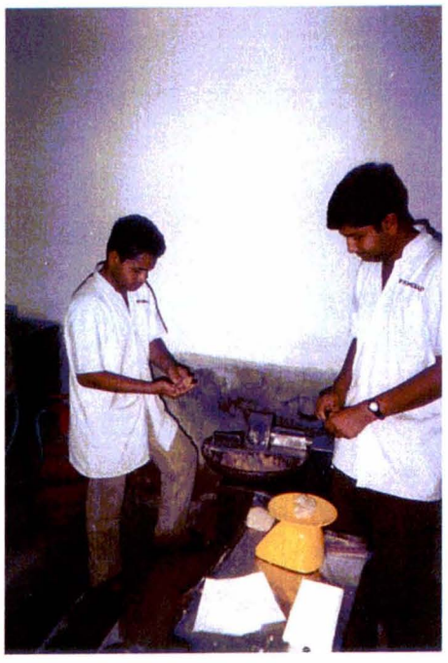


Plate- 6

Plate- 7

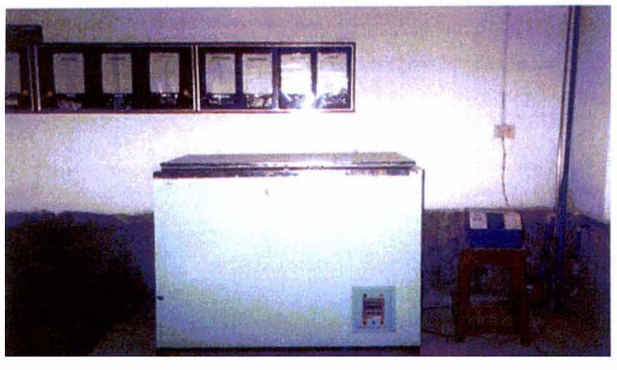


Plate- 8

3.2.4 Standardization of frying method

Deep fat frying method was adopted for frying the products as suggested by Chand (1991). Sufficient amount of oil was used to keep the fish cakes fully immersed in oil during frying. Temperature during frying was maintained by adjusting the flame of the gas oven. During frying, constant temperature was maintained for most of the time, except a maximum temperature variation of 5°C during the initial part of frying in each batch.

The standardization of the frying operation was carried out so as to give suitable product even after being frozen for several weeks. It includes the standardization of both frying temperature and time. The frying temperatures selected for study were 180°C, 160°C, 140°C and 120°C. Again, at each temperature, the products were fried for varying periods. The suitable temperature and time combinations were selected from the above frying treatments based on the organoleptic quality of the fried products. Frying loss and moisture content of the fried products at different frying treatments were also analyzed.

The moisture loss was computed as follows: -

$$\text{Moisture loss (as \% of initial weight)} = \frac{M_1 - M_2\,(100-F)}{100}$$

Where, M_1= Moisture content of raw product (%)

M_2= Moisture content of fried product (%)

F = Frying loss (%)

Here, the weight loss due to bread crumbles from the breaded products during frying was neglected.

Plate-9

Plate- 10

Plate- 11

3.2.5 Chemical composition of surimi, DWM and product

3.2.5.1 Proximate composition

Moisture content was determined by the standard hot air oven method (AOAC, 1995). The total nitrogen was estimated by Kjeldahl method (AOAC, 1995). Crude protein value was calculated by multiplying the total nitrogen value by a factor of 6.25. The total lipid was estimated by the method described by Bligh and Dyer (1959). The ash content was measured by the method of AOAC (1995). The results were expressed on wet weight basis.

3.2.6 Quality parameters studied during storage

3.2.6.1 Total Volatile Base Nitrogen (TVB-N)

The TVB-N was determined by the method recommended by EIC (1995). 100g of sample were blend with 300ml of 5% trichloroacetic acid (TCA) solution and filtered to obtain a clear extract. 5ml of extract was distilled with 5ml 2(N) NaOH. The distillate was collected in 15ml 0.001(N) HCl containing 0.1ml Rosolic acid indicator. After distillation excess acid was titrated by using 0.01N NaOH to a pale pink end point. A blank was also determined. The result is expressed as mg/100g of sample.

3.2.6.2 Salt soluble nitrogen (SSN)

The SSN was estimated by the method of Dyer *et al.* (1950). 5g of sample was homogenized at about 4°C in a tissue homogenizer for 3 minutes using chilled 5% NaCl solution, buffered with 0.02M $NaHCO_3$ and pH was adjusted between 7 and 7.5 using 0.1(N) HCl. The total volume of the homogenate was made up to 100ml. It was centrifuged at 4000 rpm for 10 minutes

and then nitrogen content of 2ml supernatant was determined by Kjeldahl method and expressed as % of total nitrogen.

3.2.6.3 Non- protein nitrogen (NPN)

The NPN was estimated by the method as recommended by Nambudiri (1985). 10g of sample were blended with 10% TCA, filtered and precipitate washed with TCA. The filtrate is made up to 50ml. 10ml of the extract was then taken for the estimation of nitrogen by microkjeldahl method. The result is expressed as mg/ 100g of sample.

3.2.6.4 Free Fatty Acid (FFA)

The FFA content in sample was determined by the method as recommended by Nambudiri (1985). A suitable quantity of the minced muscle was blended thoroughly with twice its weight of $NaSO_4$ in a mortar. The blend is shaken in distilled chloroform for 5 to 10 minutes and filtered. Fat content of 10 ml of the extract was determined by evaporating the chloroform. Another 10ml of the extract was evaporated and to it 10ml of neutral alcohol was added. It was titrated against 0.01 N NaOH using phenolphthalein as indicator. The result is expressed as % FFA as oleic acid.

3.2.6.5 Peroxide Value (PV)

The PV of the lipid was determined from the lipid extract according to Jacobs (1958) iodometrically. 10g of the sample was taken and ground well with 15g anhydrous NaSO4. It is then transferred to a 100ml stoppered flask and 30-50ml of chloroform was added and placed in a dark place for 15 to 20 minutes with occasional shaking. 10ml of chloroform extract and 25ml of solvent (2 volume of glacial acetic acid and 1 volume of

chloroform), 1ml of KI solution and 35ml of water were added. The liberated iodine was titrated against standard $Na_2S_2O_3$ and expressed as milliequivalent of O_2/ kg of fat.

3.2.7 Assessment of sensory quality

Sensory quality of surimi stored for three months were assessed for overall acceptability by incorporating it in fish cakes using the recipe as shown in table: IV. The ingredients were mixed and the paste was made into cuboidal blocks. They were battered, breaded and fried. The product was then evaluated for sensory attributes such as taste, flavor, texture, etc. Products from fresh surimi and frozen surimi were organoleptically compared on 8-point hedonic scale. For standardization of the frying operation, same scale was also used.

3.2.8 Statistical analyses

ANOVA (Snedecor and Cochran, 1967) was calculated to find out the significant difference in the sensory characteristics of samples between the batches and treatments. To find out the relationships between the various methods used to assess the quality changes during storage, correlation coefficient was calculated. ANOVA was also done to assess the significant difference in overall acceptability of fried fish cakes at different frying treatments. Regression equation of the relationship between the frying loss and moisture content, frying time with frying loss and moisture content, was assessed.

3.2.9 Development of HACCP concept in the production of value added products

The HACCP concept was applied to "Surimi" production line. The strategy as outlined in ICMSF (1986) was used for the identification of critical control point in surimi production.

CHAPTER. IV

EXPERIMENTAL RESULTS

IV. EXPERIMENTAL RESULTS

Fresh silver carp (*Hypophthalmichthys molitrix*) used in present study were analyzed for physical, chemical, microbiological and sensory characteristics. Quality of surimi prepared from fresh fish and those stored under frozen condition over a period of three months were analyzed to assess the changes in DWM and surimi. The fish cakes prepared from the fresh surimi and those stored under frozen condition were analyzed for chemical and sensory characteristics. Experimental trials were also conducted to standardize the frying operation of the products. The qualities of products stored in frozen and refrigerated display unit were also studied. The results of these analyses are given in following sub-sections.

4.1 CHARACTERISTICS OF RAW MATERIAL

4.1.1 Physical characteristics

The physical characteristics of fresh fish are presented in table V-A. The average total length and standard length of fish was 53.2cm and 47.8 cm respectively; with an average round weight of 1600g. The yield of dressed fish and yield of picked meat was found to be 68.31 % and 44.18% from whole fish, respectively. The weight of meat after water washing was 580g as compared to picked meat weight of 707g, resulting in 82.03% yield from picked meat after washing.

4.1.2 Chemical characteristics

4.1.2.1 Freshness evaluation

The fresh silver carps were assessed for quality using chemical, microbiological and sensory parameters. The chemical characteristics such as TVBN, SSN, PV and FFA values are

TABLE: V RAW MATERIAL CHARACTERISTICS		
A	**PHYSICAL CHARACTERISTICS**	
1	TOTAL LENGTH (cm)	53.2
2	STANDARD LENGTH (cm)	47.8
3	ROUND WEIGHT OF FISH (g)	1600
4	WEIGHT OF DRESSED FISH (g)	1093
5	YIELD OF DRESSED FISH (%)	68.31
6	WEIGHT OF PICKED MEAT (g)	707
7	YIELD OF PICKED MEAT (%)	44.18
8	WEIGHT OF PICKED MEAT AFTER WASHING (g)	580
B	**PROXIMATE COMPOSITION**	
1	MOISTURE (%)	78.4
2	PROTEIN (%)	16.75
3	ASH (%)	1.5
4	FAT (%)	2.86
C	**FRESHNESS PARAMETERS**	
1	TVB-N (mg %)	2.55
2	SSN (g %)	77.419
3	NPN (g/100g)	0.3
4	FFA (% of oleic acid)	2.03
5	PV (milliequivalent of O_2 /kg)	13.4
6	pH	6.91
D	**MICROBIOLOGICAL CHARACTERISTICS**	
1	TPC/gm of SAMPLE	$2.04X10^5$

TABLE VIA PROXIMATE COMPOSITION OF DWM SURIMI & PRODUCT			
	DWM	**SURIMI**	**PRODUCT**
MOISTURE (%)	80.84	78.06	72.91
PROTEIN (%)	15.43	15.90	12.87
LIPIDS (%)	0.80	0.82	2.18
ASH (%)	0.98	1.12	2.38
TABLE VIB MICROBIOLOGICAL CHARACTERISTIC			
TPC/g	$1.64x10^5$	$1.04x10^5$	$2.81x10^5$

TABLE VII SENSORY CHARACTERISTICS OF FISH		
CHARACTERISTICS	**DESCRIPTIVE TERMS**	**SCORE**
Appearance	No bruises, lustrous sheen	8
Eyes	Shiny cornea, black pupil, no blood spots, not sunken.	9
Gills	Less bright red gills, white mucous	8
Odor	Seaweedy	9
Texture	Firm, elastic and leaves no thumb impression when pressed	8 9
Color	Lustrous sheen with distinct varied colors	
Overall	Very good	51

presented in table: V-C. The microbiological and sensory characteristics are shown in table: V-D and VII respectively.

4.1.2.2 Proximate composition

The proximate composition of the fillet, DWM, surimi and the raw fish cakes prior to frying is presented in the table: V-B & VI-A. The protein content of fish fillet was 16.75%, moisture 78.4%, ash 1.5% and fat 2.86%. The DWM and surimi were found to have moisture content of 80.84% and 78.06% respectively and protein content of 16.43% and 15.9% respectively. In both DWM and surimi a drop in lipid content (0.8% in DWM and 0.82% in surimi) was observed. In the products, an increase in lipid (2.18%) and ash (2.38) content was evident accompanied by lowering of moisture content and protein, which was as low as 72.91% and 12.87% respectively.

4.2 Nitrogenous compounds

The various nitrogenous compounds analyzed during frozen storage are TVB-N, SSN and NPN. The results are presented in table: VIII, IX and X, respectively. The results of analysis for products in refrigerated display unit (RDU) are given in table: XVI.

4.2.1 TVB-N

The changes in TVB-N content in DWM, surimi and products of various batches showed increasing trends with the storage periods (Table: VIII and Fig: IV). For DWM and surimi, the TVB-N values ranged between 8.05 mg% to 17.03 mg% and 4.62 to 12.92 mg%, respectively, during frozen storage. The TVB-N content of products prepared from DWM and surimi at 0, 30, 60 and 90 days revealed that products from DWM (control) had higher TVB-N content than those from surimi. Among the four batches of

products, those prepared from frozen raw materials at 30, 60 and 90 days indicated marginally higher TBV-N content than the product prepared from fresh raw materials.

The changes in TVB-N content of products in RDU are presented in table: XVI. The values of TVB-N content for products from surimi reached 15.42 mg% within 7 days as compared to DWM based products, which was 17.69 mg%.

4.2.2 SSN

The SSN content of all the samples (Table: IX and Fig: V) showed decreasing trend during storage period. In surimi, the SSN content of total nitrogen decreased from 82.65% on 10^{th} day to 71.33% on 90^{th} day of storage. The SSN content of DWM also exhibited a decreasing trend ranging from 80.52% to 61.78% of total nitrogen during the same period. The SSN content of the products of 30, 60 and 90 days old raw material was markedly lower than the product from fresh raw material.

The SSN content of the products from both DWM and surimi showed very low values of 44.53% and 44.87% after 7 days of storage in RDU.

4.2.3 NPN

Like SSN, the NPN values also showed a decreasing trend in both surimi and DWM (Table: X, Fig: VI). However, the decrease was much lower in surimi (0.21 g/100g to 0.17g/100g) than in DWM (0.18g/100g to 0.11g/100g). The products also revealed a down trend though the initial NPN values for the products from surimi exhibited very minor difference ranging from 0.19g /100g sample to 0.15g/100g sample.

TABLE: VIII CHANGES IN TOTAL VOLATILE BASE NITROGEN (mg%) IN DWM, SURIMI AND VALUE ADDED PRODUCT UNDER FROZEN STORAGE

DAYS	BATCH I		PRODUCT							
			BATCH II		BATCH III		BATCH IV		BATCH V	
	C	T	C_1	T_1	C_2	T_2	C_3	T_3	C_4	T_4
0	5.01	4.52	5.02	4.97						
10	8.05	4.62	10.06	6.83						
20	9.06	5.58	14.24	9.34						
30	10.23	6.58	18.78	13.53	10.89	8.17				
40	11.31	7.63	20.86	15.08	17.56	13.42				
50	12.40	8.65	25.19	17.66	20.38	18.46				
60	13.48	9.56	28.14	20.64	23.02	20.46	17.22	12.43		
70	14.19	10.05	31.08	23.83	25.97	23.29	20.68	18.91		
80	15.76	11.67	35.91	25.98	30.18	28.70	25.63	23.01		
90	17.03	12.92	37.99	27.84	32.01	31.97	32.38	27.71	20.42	15.81

C: DWM C1, C2, C3, C4: DWM based products
T: Surimi T1, T2, T3, T4 : Surimi based products

TABLE: IX CHANGES IN SALT SOLUBLE NITROGEN (% of T.N.) IN DWM, SURIMI AND VALUE ADDED PRODUCT UNDER FROZEN STORAGE

DAYS	BATCH I		PRODUCT							
			BATCH II		BATCH III		BATCH IV		BATCH V	
	C	T	C_1	T_1	C_2	T_2	C_3	T_3	C_4	T_4
0	82.79	83.71	80.86	83.00						
10	80.52	82.65	78.07	81.20						
20	78.21	81.15	77.15	80.40						
30	76.22	80.22	77.48	78.50	75.98	79.53				
40	74.12	78.98	74.05	76.64	74.25	78.14				
50	73.01	76.32	73.32	75.98	72.17	76.75				
60	70.13	74.95	68.53	74.67	70.15	76.35	70.09	73.40		
70	76.93	74.02	66.38	73.34	67.67	73.67	67.61	71.19		
80	63.29	72.87	61.60	72.05	65.05	72.85	66.07	69.62		
90	61.78	71.33	59.60	70.81	64.56	72.10	64.22	69.25	60.58	70.52

C: DWM
T: Surimi

C1, C2, C3, C4: DWM based products
T1, T2, T3, T4 : Surimi based products

TABLE: X CHANGES IN NON-PROTEIN NITROGEN (g/100g of meat) IN DWM, SURIMI AND VALUE ADDED PRODUCT UNDER FROZEN STORAGE

DAYS	BATCH I		PRODUCT							
			BATCH II		BATCH III		BATCH IV		BATCH V	
	C	T	C_1	T_1	C_2	T_2	C_3	T_3	C_4	T_4
0	0.18	0.21	0.17	0.19						
10	0.17	0.21	0.16	0.18						
20	0.16	0.20	0.15	0.18						
30	0.16	0.20	0.15	0.17	0.16	0.18				
40	0.15	0.19	0.14	0.17	0.14	0.17				
50	0.14	0.19	0.13	0.16	0.13	0.18				
60	0.13	0.18	0.12	0.15	0.13	0.16	0.13	0.16		
70	0.12	0.18	0.11	0.15	0.12	0.15	0.13	0.15		
80	0.12	0.18	0.10	0.15	0.10	0.14	0.12	0.15		
90	0.11	0.17	0.10	0.14	0.10	0.14	0.11	0.14	0.10	0.15

C: DWM
T: Surimi

C1, C2, C3, C4: DWM based products
T1, T2, T3, T4 : Surimi based products

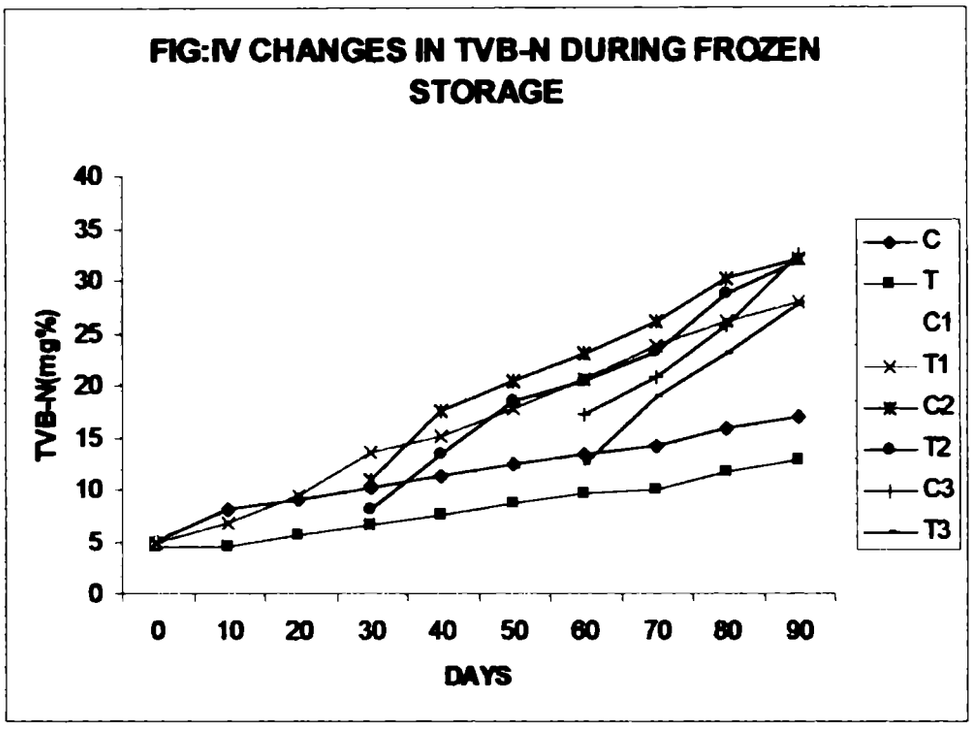


FIG:IV CHANGES IN TVB-N DURING FROZEN STORAGE
TVB-N(mg%)
40
35
30
25
20
15
10
5
0
0 10 20 30 40 50 60 70 80 90
DAYS
C
T
C1
T1
C2
T2
C3
T3

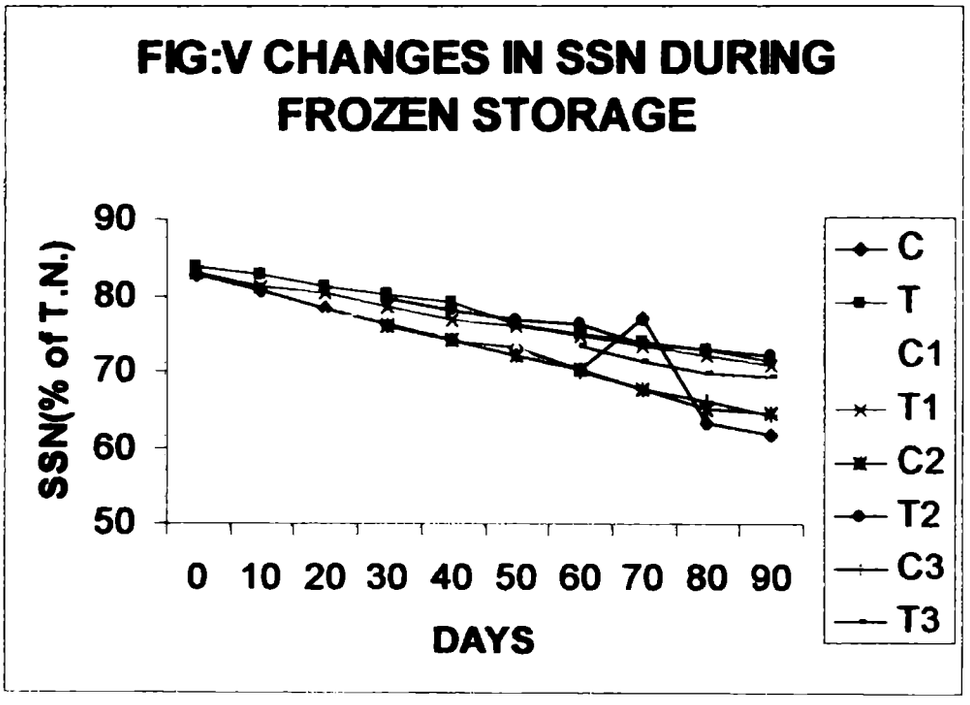


FIG:V CHANGES IN SSN DURING FROZEN STORAGE
SSN(% of T.N.)
90
80
70
60
50
0 10 20 30 40 50 60 70 80 90
DAYS
C
T
C1
T1
C2
T2
C3
T3

After 7 days of storage in RDU, the products from surimi and DWM had a NPN content of 0.09 g/100g and 0.08g /100g respectively.

4.3 LIPID CHARACTERISTICS

The lipid characteristics of DWM, surimi and the four batches of product were analyzed by estimating FFA and PV. The changes in FFA values are shown in table: XI and fig: VII. For surimi sample the FFA values ranged from 2.82% as oleic acid to 9.58% as oleic acid during 90 days of storage. The DWM showed a marginal increase from 2.49% to 11.76% as oleic acid during the same period. The change in FFA value was much higher in frozen stored products than raw materials. In RDU the change in FFA was 3.39 to 7.46% as oleic acid for DWM based products as compared to surimi based products (3.47 to 8.57% as oleic acid).

The PV for DWM, surimi and the products are presented in table: XII and fig: IX. The PV values ranged from 9.1 to 17.76-mill equivalent of oxygen per kg of fat in surimi over a period of three months. In the products the increase in PV was much higher ranging from 18.43 to 71.14 mill equivalents of oxygen per kg of fat as in case of products prepared from raw surimi.

There was a drastic increase in PV values for fish cakes stored in RDU (Table: XVI). For surimi-based products, it increased from 18.43 to 50.61 milliequivalent of O_2 per kg of fat whereas an increase from 20.97 to 54.53 milliequivalent of O_2 per kg of fat was observed in DWM based products.

4.4 SENSORY CHARACTERISTCS

Table: XIV presents the average mean score for the products formulated from fresh as well as frozen raw materials. The average mean score for overall acceptability of the products prepared from

TABLE: XI CHANGES IN FREE FATTY ACID (as % of oleic acid) IN DWM, SURIMI AND VALUE ADDED PRODUCT UNDER FROZEN STORAGE

DAYS	BATCH I		PRODUCT							
			BATCH II		BATCH III		BATCH IV		BATCH V	
	C	T	C_1	T_1	C_2	T_2	C_3	T_3	C_4	T_4
0	2.21	2.26	3.39	3.47						
10	2.49	2.82	4.08	4.64						
20	3.41	3.65	4.74	5.33						
30	4.43	4.48	6.65	6.58	5.20	5.26				
40	5.26	5.32	8.86	8.76	6.85	7.56				
50	6.18	6.15	9.73	9.29	7.59	9.47				
60	6.64	6.71	11.95	10.50	11.98	11.91	8.30	8.78		
70	8.03	7.72	13.02	11.87	14.87	15.43	10.53	10.04		
80	9.85	8.71	14.90	12.75	16.59	16.50	11.54	11.72		
90	11.76	9.58	16.57	13.59	20.06	18.54	14.89	14.25	12.82	11.54

C: DWM
T: Surimi

C1, C2, C3, C4: DWM based products
T1, T2, T3, T4 : Surimi based products

TABLE: XII CHANGES IN PEROXIDE VALUE (milliequivalents of O_2/kg of fat) IN DWM, SURIMI AND VALUE ADDED PRODUCT UNDER FROZEN STORAGE

DAYS	BATCH I		PRODUCT							
			BATCH II		BATCH III		BATCH IV		BATCH V	
	C	T	C_1	T_1	C_2	T_2	C_3	T_3	C_4	T_4
0	14.00	9.00	20.97	18.43						
10	14.65	9.10	28.72	25.08						
20	15.60	10.23	33.58	30.37						
30	16.54	11.66	43.08	38.38	34.51	25.56				
40	17.49	12.62	53.92	43.05	37.46	30.86				
50	18.40	13.83	59.60	51.68	43.32	37.04				
60	19.79	15.78	67.72	58.33	54.27	41.81	27.79	23.03		
70	21.16	16.14	78.61	62.56	65.68	44.84	29.32	26.94		
80	22.60	17.31	83.95	67.18	72.09	49.18	34.28	33.23		
90	23.50	17.76	89.36	71.14	81.16	55.80	40.34	36.93	30.91	24.56

C: DWM
T: Surimi

C1, C2, C3, C4: DWM based products
T1, T2, T3, T4 : Surimi based products

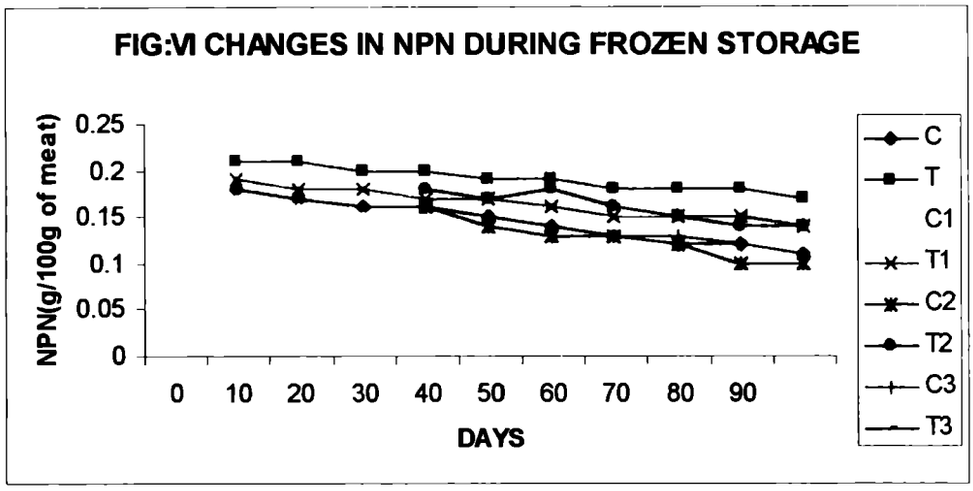


FIG:VI CHANGES IN NPN DURING FROZEN STORAGE
NPN(g/100g of meat)
0.25
0.2
0.15
0.1
0.05
0
0 10 20 30 40 50 60 70 80 90
DAYS
C
T
C1
T1
C2
T2
C3
T3

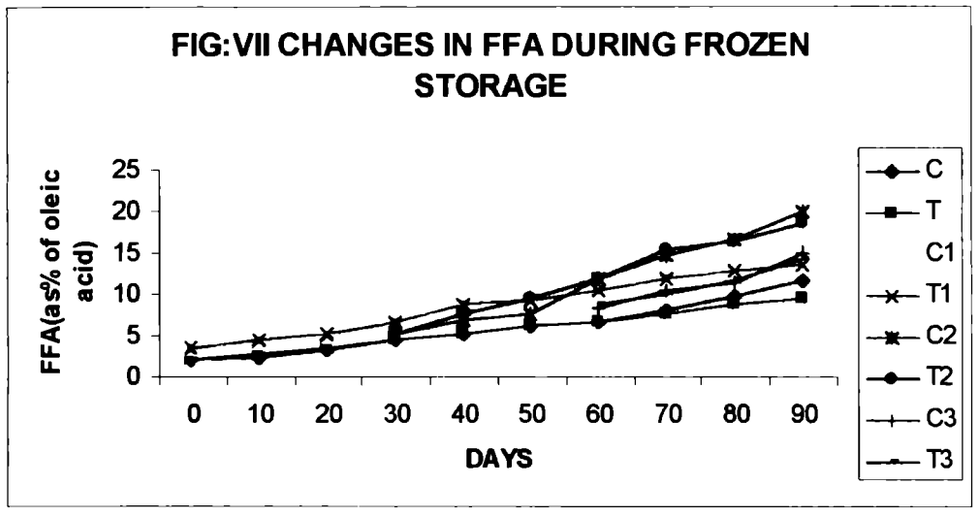


FIG:VII CHANGES IN FFA DURING FROZEN STORAGE
FFA(as% of oleic acid)
25
20
15
10
5
0
0 10 20 30 40 50 60 70 80 90
DAYS
C
T
C1
T1
C2
T2
C3
T3

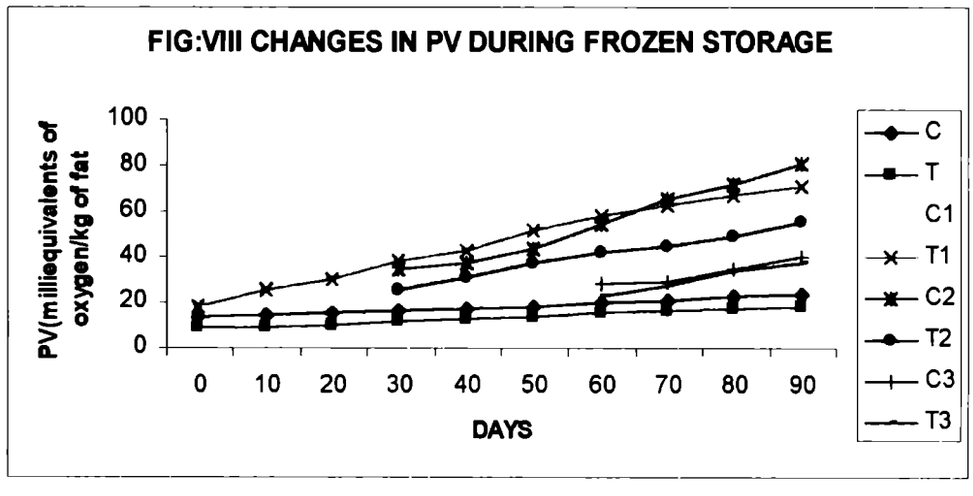


FIG:VIII CHANGES IN PV DURING FROZEN STORAGE
PV(milliequivalents of oxygen/kg of fat
100
80
60
40
20
0
0 10 20 30 40 50 60 70 80 90
DAYS
C
T
C1
T1
C2
T2
C3
T3

TABLE XIII
CORRELATION CO-EFFICIENT BETWEEN ANALYTICAL METHODS

SAMPLE	Correlation co-efficient between analytical methods									
	TVBN X SSN	TVBN X NPN	TVBN X PV	TVBN X FFA	SSN X NPN	SSN X PV	SSN X FFA	NPN X PV	NPN X FFA	PV X FFA
C_1	-0.959*	-0.989*	0.890*	0.985*	0.978*	-0.968*	-0.979*	-0.991*	-0.985*	0.995*
T_1	-0.996*	-0.980*	0.997*	0.994*	0.979*	-0.995*	-0.998*	-0.988*	-0.975*	0.994*

*Significant at 5% level

TABLE XIV
MEAN PANEL SCORES OF SENSORY ATTRIBUTES OF FRIED FISH CAKE PRODUCED FROM FRESH AND FROZEN RAW MATERIAL

SAMPLE		COLOR & APPEARANCE	FLAVOR	TEXTURE	FISH FLAVOR INTENSITY	OVERALL ACCEPTABILIT'
BATCH	TREATMENT					
II	C_1	6.0	6.6	6.6	5.8	6.6
	T_1	6.6	7.0	6.6	6.0	6.8
III	C_2	5.8	6.2	6.2	6.0	6.2
	T_2	6.4	6.4	6.6	6.0	6.0
IV	C_3	5.6	5.8	6.0	5.8	5.4
	T_3	6.2	6.2	6.4	5.4	6.0
V	C_4	5.6	5.8	5.4	5.8	5.0
	T_4	6.0	6.0	6.0	5.2	5.8

TABLE XV
ANOVA OF FLAVOR AND TEXTURE OF FRIED FISH CAKES PRODUCED FROM FRESH AND FROZEN RAW MATERIALS

i) Flavor

Source of Variation	Sum of squares	Degrees of freedom	Mean squares	F	F critical
Due to batches	1.215	3	0.405	81*	9.276619
Due to treatments	0.125	1	0.125	25*	10.12796
Error	0.015	3	0.005		
Total	1.355	7			

ii) Texture

Source of Variation	Sum of squares	Degrees of freedom	Mean squares	F	F critical
Due to batches	0.895	3	0.298333	9.421053*	9.276619
Due to treatments	0.245	1	0.245	7.736842	10.12796
Error	0.095	3	0.031667		
Total	1.235	7			

*Significant at 5% level

TABLE XVI
CHANGES IN QUALITY OF FISH CAKES IN REFRIGERATED DISPLY UNIT

DAYS	PV (Milliequivalent of O_2/kg of fat)		FFA (as % of oleic acid)		TVB-N (mg %)		NPN (g/100g)		SSN (% of total nitrogen)	
	C_5	T_5	C_5	T_5	C_5	T_5	C_5	T_5	C_5	T_5
0	20.97	18.43	3.39	3.47	5.02	4.97	0.17	0.19	80.86	83.0
3	25.67	24.15	4.67	4.53	8.43	8.45	0.15	0.16	70.75	70.29
5	36.75	33.93	5.33	6.37	13.46	11.96	0.11	0.13	59.46	58.75
7	54.23	50.61	7.46	8.57	17.69	15.42	0.08	0.09	44.53	44.87

C_5: DWM based product
T_5: Surimi based product

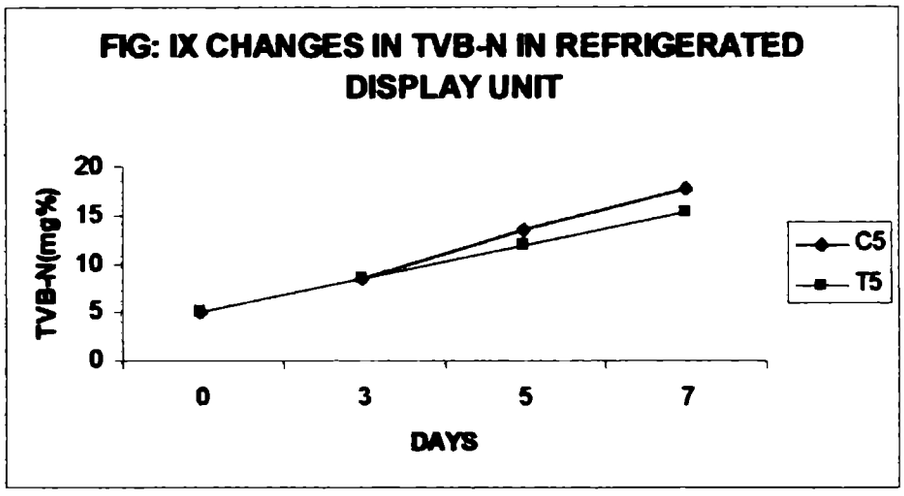


FIG: IX CHANGES IN TVB-N IN REFRIGERATED DISPLAY UNIT
TVB-N(mg%)
20
15
10
5
0
0
3
5
7
DAYS
C5
T5

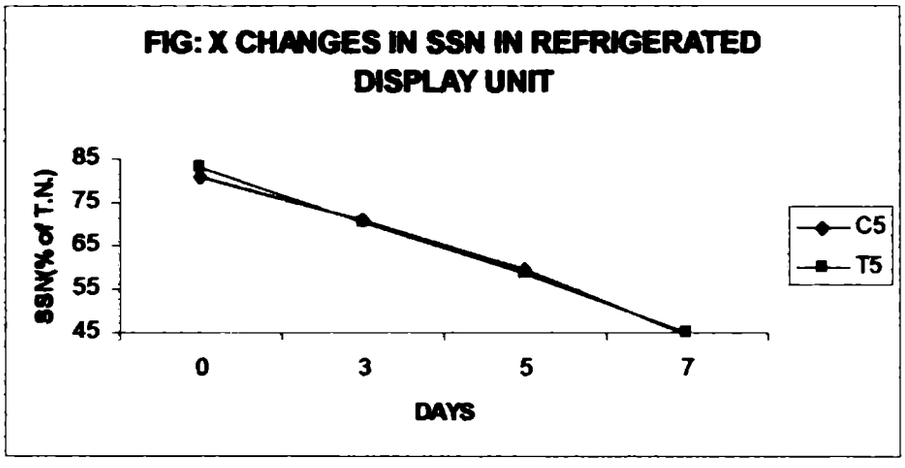


FIG: X CHANGES IN SSN IN REFRIGERATED DISPLAY UNIT
SSN(% of T.N.)
85
75
65
55
45
0
3
5
7
DAYS
C5
T5

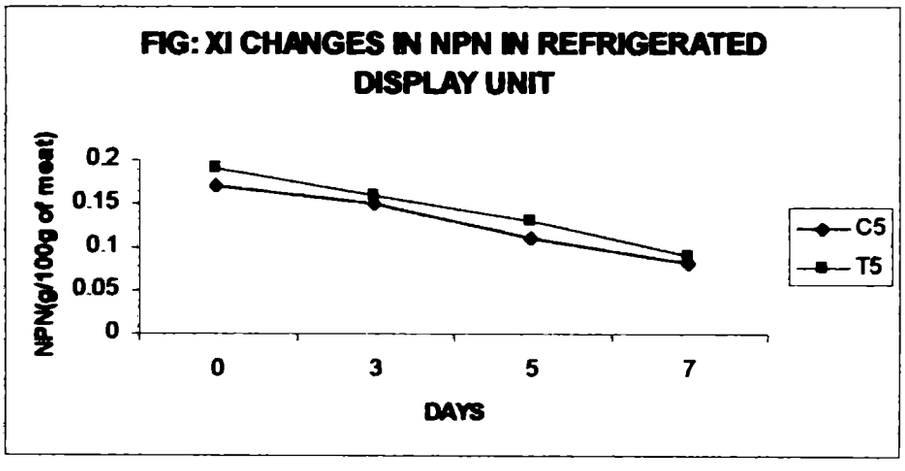


FIG: XI CHANGES IN NPN IN REFRIGERATED DISPLAY UNIT
NPN(g/100g of meat)
0.2
0.15
0.1
0.05
0
0
3
5
7
DAYS
C5
T5

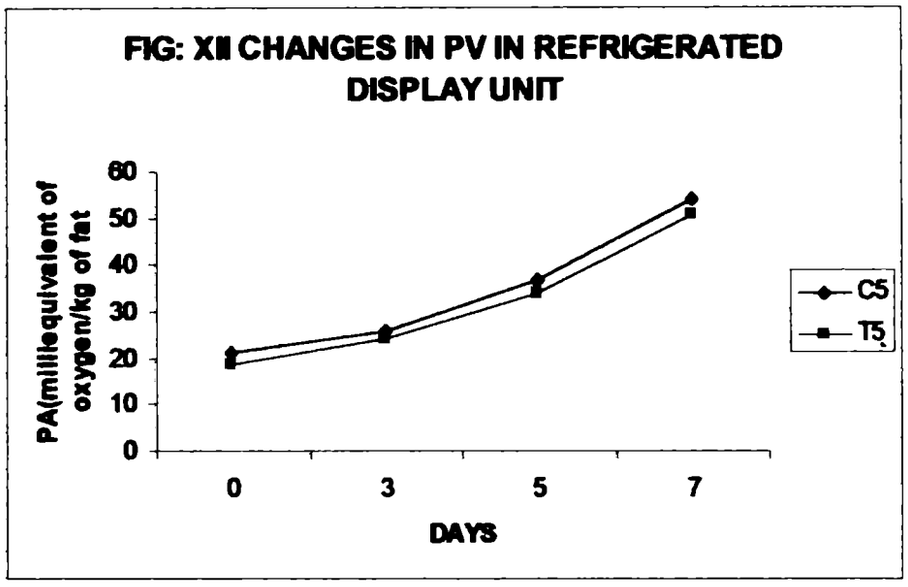


FIG: XII CHANGES IN PV IN REFRIGERATED DISPLAY UNIT
PA(milliequivalent of oxygen/kg of fat
60
50
40
30
20
10
0
0
3
5
7
DAYS
C5
T5

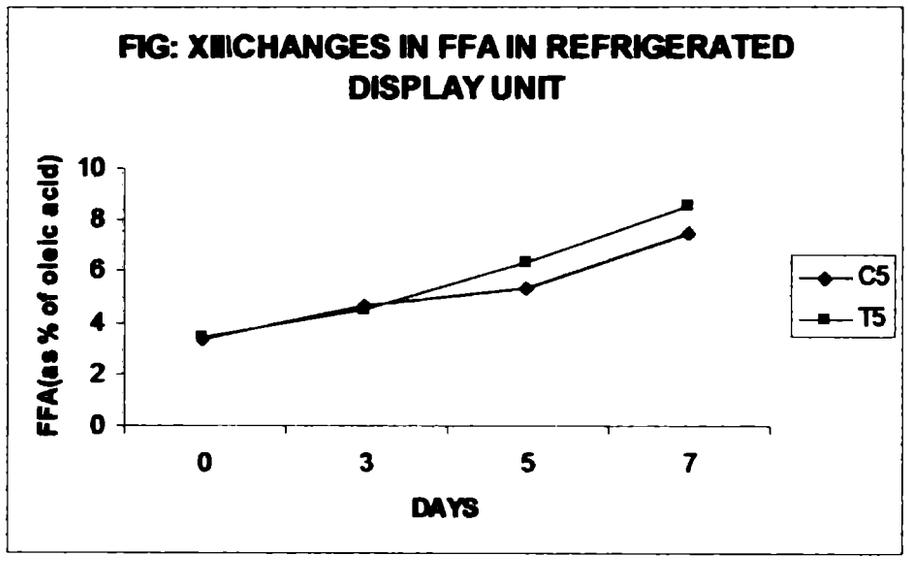


FIG: XIII CHANGES IN FFA IN REFRIGERATED DISPLAY UNIT
FFA(as % of oleic acid)
10
8
6
4
2
0
0
3
5
7
DAYS
C5
T5

DWM showed a sudden decline for the products prepared after 60 days. In case of products from surimi, the average mean score also exhibited gradual decline. The product from 90 days old surimi was found to be more acceptable than that prepared from DWM stored for the same period. Overall the scores showed a decreasing trend with increase in storage period of the raw materials.

4.5 STANDARDIZATION OF FRYING TREATMENT

In order to standardize the frying treatment suitable for the fish cakes, the effect of variation in frying temperature and time on frying loss (weight loss), moisture content, moisture loss of fried products and organoleptic characteristics were studied. The results of the changes in the physical characteristics are presented in table: XVII. The oil consumption rates during frying are given in table: XIX.

4.5.1 Effect of frying on weight loss

Weight loss during frying operation (frying loss) was expressed as the percentage of weight of raw fish. From the table: XVII (a) and fig: XIV it can be seen that frying loss at a particular temperature increased with increase in frying time. Again for the same frying time, frying loss was observed to be more at higher temperatures. The frying loss percentage was low at frying temperature of 120°C. It varied from 6.28% to 13.55% with the variation of frying time from 3 to 10 minutes. At 140°C frying loss percentages varied within a range of 12.28% to 24.26% for a frying time of 3 to 10 minutes. At 160°C temperature the corresponding frying loss for 3,4 and 6 minutes of frying were 18.81%, 18.78 % and 24.68 % respectively. Much higher frying loss percentage were

encountered at a temperature of 180°C, where the range varied from 19.15% to 28.61% for frying time of 2 to 6 minutes.

4.5.2 Effect of frying on moisture content of fried products

The effects of frying at different frying treatments were studied and the results are presented in table: XVII (b) and fig: XV. It was observed that, the moisture content decreased as the duration of frying increased at a particular temperature. Again for the same frying time, the moisture content showed a declining trend with a corresponding increase in temperature. The highest moisture content of 63.21% was recorded at a temperature of 120°C for 3 minutes and the lowest moisture content of 54.73% at 180°C for 6 minutes.

4.5.3 Effect of frying on moisture loss

The moisture loss in fried products during frying was expressed as percentage loss of initial weight of raw fish cakes. The initial moisture content of raw fish cakes was taken as 67.91%. The results are summarized in table: XVII(c) and fig: XVI. Moisture loss like frying loss exhibited an increasing trend with increase of frying time at a particular temperature and was more at higher temperature. The moisture loss range during the present study was 8.66% to 28.84%. It was also observed that the moisture loss was always higher than frying loss at each frying treatment.

4.5.4 Effect of frying on organoleptic quality of fried product

The detailed comparisons of the organoleptic quality of fried fish cakes at different frying treatments are summarized in *table:* XX. The frying treatments of 160°C for 3 to 4 minutes, 140°C for 4-

TABLE XVII
FRYING LOSS, MOISTURE CONTENT AND MOISTURE LOSS OF FRIED FISH CAKES AT DIFFERENT FRYING TREATMENTS.

FRYING TREATMENTS		FRYING LOSS (%) (a)	MOISTURE CONTENTS OF FRIED FISH CAKES (%) (b)	MOISTURE LOSS (%) (c)
TEMP (^{O}C)	TIME (min)			
120	3	6.28	63.21	8.66
	4	6.64	63.09	9.00
	6	8.32	59.81	13.07
	8	12.62	57.08	18.03
	10	13.55	56.64	18.93
140	3	12.28	58.91	18.22
	4	13.76	57.65	18.19
	6	15.83	57.51	19.50
	8	21.92	54.24	25.34
	10	24.26	53.02	27.75
160	3	18.81	57.03	21.60
	4	18.78	57.00	21.61
	6	24.68	56.67	25.22
180	2	19.15	57.48	21.43
	4	27.58	53.72	29.00
	6	28.61	50.37	31.95

FIG XIV. EFFECT OF FRYING TIME (min) ON FRYING LOSS (%) IN FRIED FISH CAKES AT DIFFERENT FRYING TEMPERATURES

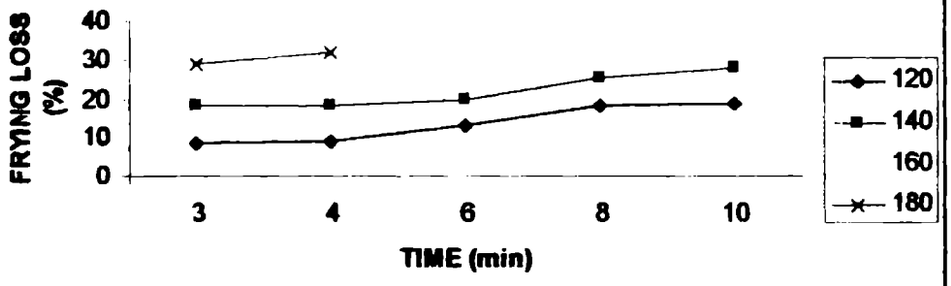


FIG. XV EFFECT OF FRYING TIME (min) ON MOISTURE CONTENT (%) IN FRIED FISH CAKES AT DIFFERENT FRYING TEMPERATURES

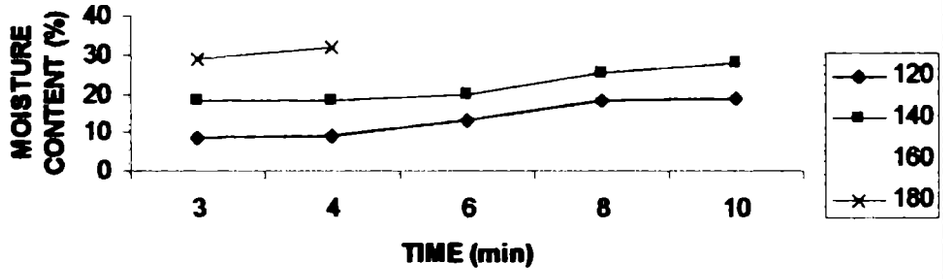


FIG XVI. EFFECT OF FRYING TIME (min) ON MOISTURE LOSS (% of initial fish cake weight) IN FRIED FISH CAKES AT DIFFERENT FRYING TEMPERATURE

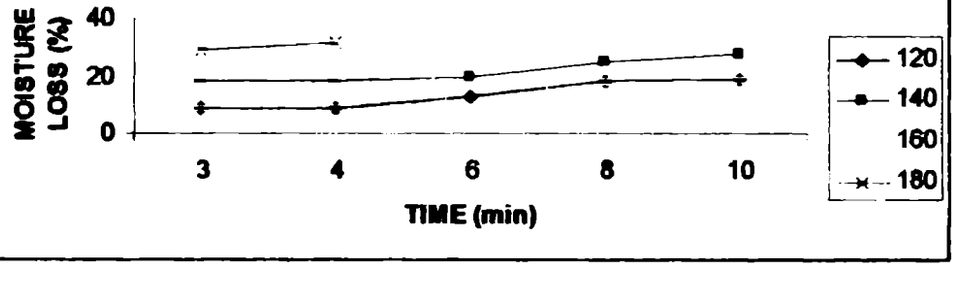


TABLE: XVIII
REGRESSION EQUATION FOR FRYING LOSS AND MOISTURE CONTENT ON FRYING TIME AND MOISTURE CONTENT ON FRYING LOSS AT DIFFERENT FRYING TEMPERATURES.

Combination		Frying Temp (°C)	Regression equation (Y= a + bx)	Correlations Coefficient (r)
X	Y			
Frying Time (min)	Frying Loss (%)	120	Y= 2.337 + 1.153x	0.973 *
		140	Y= 6.478 + 1.796x	0.984 *
		160	Y= 11.673 + 2.096x	0.943 **
		180	Y= 15.654 + 2.366x	0.911 **
Frying Time (min)	Moisture content (%)	120	Y= 66.595 – 1.069x	-0.971 *
		140	Y= 61.517 – 0.846x	-0.967 *
		160	Y= 57.451 – 0.126x	-0.967 *
		180	Y= 60.970 – 1.778x	-0.999 *
Frying Loss (%)	Moisture content (%)	120	Y= 68.552 – 0.905x	-0.974 *
		140	Y= 64.654 – 0.475x	-0.992 *
		160	Y= 58.117 – 0.058x	-0.997 *
		180	Y=69.767 – 0.633x	-0.924 **

* Significant at P≤ 0.01 ** Significant at P≤ 0.05.

TABLE XIX
OIL CONSUMPTION RATE DURING FRYING

FRYING TREATMENT		OIL CONSUMPTION RATE (g /kg of fish)
TEMP (°C)	TIME (MIN)	
120°	3	56.00
140	3	69.17
160	3	78.40
180	3	88.85

TABLE: XX MEAN PANEL SCORES OF SENSORY ATTRIBUTES OF FRIED FISH CAKES AT DIFFERENT FRYING TREATMENTS

FRYING TREATMENT		SAMPLE	COLOR & APPEARANCE	FLAVOR	TEXTURE	OVERALL ACCEPTA-BILITY
TEMP (^{o}C)	TIME (MIN)					
180	2-3	1	5.83	6.16	6.0	5.33
160	3-4	2	7	6.66	7.0	6.66
140	4-6	3	6.83	6.83	5.33	6.33

TABLE: XXI ANALYSIS OF VARIANCE (ANOVA) OF OVERALL ACCEPTABILITY OF FRIED FISH CAKES SUBJECTED TO DIFFERENT FRYING TREATMENTS

Source of variation	Degree of Freedom	Sum of Squares	Mean Squares	F Value	
				F ratio	F critical
Due to treatments	2	5.78	2.89	2.408*	3.68
Error	15	18.0	1.2		
Total	17	23.78			

*Insignificant at 5% level

6 minutes and 180°C for 2-3 minutes were found to obtain scores of 6.66, 6.33 and 5.33 respectively, for overall acceptability on 8-point hedonic scale.

4.6 STATISTICAL ANALYSES

The results of sensory score were statistically analyzed using analysis of variance technique (ANOVA) to know the significant difference of the flavor and texture between the batches of products and between treatments. The results are presented in table: XV. A significant difference in flavor and texture was observed between the batches however no significant difference was detected between the treatments as far as texture was concerned. To know the relationship between the various methods used for quality assessment correlation coefficient were calculated and tabulated in table: XIII.

ANOVA was also performed to assess any significant variation in over all acceptability of the fried fish cakes at different frying treatments. The results are expressed in table: XXI. The correlation coefficient and regression equation for frying loss and moisture content on frying time and moisture content on frying loss at different temperatures were also ascertained and represented in table: XVIII.

4.7 HACCP

The critical control point identified in the production of surimi is presented below:

Fig: XVII

Application of HACCP: The critical control point in the production of surimi

Processing step	**Hazard**	**Preventive measure**
Receiving raw materials	-Microbiological -Physical	-Control supply source -Have supplier provide raw material hygienically and with temperature control.
Raw material handling	-Microbiological -Cross contamination	-Time and temperature control -Hygienicity
Chilling	-Microbiological -Chemical	-Quality and quantity of ice used
Washing	-Microbiological -Chemical	-Use of potable water
Dressing	-Cross contamination -Microbiological -Physical	-Personal hygiene, factory sanitation, time and temperature control
Meat separation	-Microbiological -Physical	-Time, temperature control, cleanliness
Washing	-Loss of functional properties -Microbiological	-Temperature, meat water ratio and number of washing cycles.
Dewatering	-Presence of bones	-Refining
Addition of cryoprotectant	-Chemical	-Selection of efficient, food grade cryoprotectant and level of addition
Freezing	-Chemical and physical	-Time, temperature of freezing
Packing	-Chemical, physical and microbiological	-Glazing and packing
Storage	-Dehydration, physical, chemical	-Low and constant temperature

CHAPTER. V

DISCUSSION

V. DISCUSSION

The suitability of silver carp for the preparation of surimi and surimi-based products, its quality characteristics, changes during frozen storage and refrigerated condition, standardization of frying procedure and application of HACCP concept for value added products are the objectives of the present study. The results are discussed in the following sections.

5.1 RAW MATERIAL CHARACTERISTICS

The average total length and weight of silver carp used in present study were 53.2cm and 1600g respectively. The records of Chang *et al.* (1983) have shown that silver carps in their second year have a body length of 50cm and corresponding weight being 1803g. Chonder (1978 Ms) reported that in West Bengal silver carps attains sexual maturity within 9 to 14 months and the weight varies between 0.7-1.1kg. An average weight of 1734g and length 52.2cm was also reported by Chonder, 1999.

The dressing yield of the silver carp was 68.3%. Chonder (1999) reported similar result. Gelman *et al.* (1985) found that males can yield 10% more meat than the females. Due to this reason for the entire study male fishes were selected over females as raw materials. The yield of picked meat was 44.18% from round fish. Much lower yield was reported by Finne *et al.*, (1980) for other fishes like tilapia where the yield was as low as 26.1% of the original weight. The increased yield of picked meat may be attributed to the efficient meat picking operations as well as to the fairly large size of the fish used.

The proximate composition of the fresh fish is presented in table: V (B). The result of moisture, protein, ash and fat percentage of the fish was 78.4%, 16.75%, 1.5% and 2.86% respectively.

Dogra *et al.* (1985) reported that the moisture content of silver carp ranges between 76.1% to 77.8% and protein content ranges between 14.88% to 16.07%, which fairly tallies with the result of the present study. According to Gelman *et al.,* (1985) the fat content level of 5-15kg sized silver carp form Brauch reservoir (Israel) was 8.3%. In the present study, the fat content of the fish was found to be much lower which may be because of the average weight of the fish studied was only 1.6 kg. A low fat content is very important to get good quality gel or emulsion type and analog products (Suzuki, 1981; Flick *et al.,* 1990). The variation of fat may also be attributed to the feeding and spawning cycle of the fish and variation in agro ecological condition.

The TVB-N value of 2.55mg % was well within the acceptable limit as suggested by Lakshmanan, 2000. According to him a level of 35-40mg TVB-N /100g of muscle is usually regarded as the limit of acceptability beyond which fish can be regarded as too spoiled for use. The SSN content of fresh fish usually varies between 70-85% of total protein (Dyer *et al.*, 1950). In the present study the SSN content of 77.42% clearly indicates the fresh quality of the fish. The mean sensory score for fresh fish (table:VII) also supports the freshness state of the fish. The NPN value of the fish was 0.3 g/100g of fish. The result is in conformation with the values obtained for common carp (0.17 g% of washed mince) and tilapia (0.25 g%) by Hassan and Mathew (1999) and Finne *et al.* (1980).

The PV is a good index to judge quality of fat. The PV is a measure of the first stage of oxidative rancidity and according to Lakshmaman (2000), a PV value above 10-20 miliequivalent of O_2 /kg of fat, the fish in all probability will smell and taste rancid. The PV recorded in the present investigation in 13.4 miliequivalent of oxygen/kg of fat, which is within the acceptable limit.

The recommended microbiological limits for fresh and frozen fish (ICMSF, 1986) is an aerobic plate count of $5x10^5$ /g. The TPC/g of the fish under study was $2.04x10^5$, which is well within the limit.

5.2 PREPARATION OF SURIMI

The quality of the surimi depends on the raw material and also on the separation process. According to Lanier and Lee (1992) a higher meat yield and lower bone content (<0.5%, USDA, 1975) are the prerequisites for efficient deboning. The use of mechanical deboner substantially increases the yield (Martin, 1972). Flick *et al.* (1990) suggested the use of belt and drum type deboners. In the present study the above recommendations are followed and meat picking was successfully done in a roll type meat-picking machine.

One of the most critical steps in surimi manufacturing is the washing of minced fish flesh. According to Park and Morrissey (2000), nearly one third of minced fish meat consists of blood, myoglobin, fat and sarcoplasmic proteins, which impede the final quality of the surimi gel. Washing necessarily helps in removal of these undesirable matters. Gopakumar *et al.* (1992) have shown that washing time, mince: water ratio and number of washing cycles required have to be varied depending upon the species of fish and its freshness. For most tropical species of fish, two washing operations, each of two minutes duration, using a mince: water ratio 1:2 (W/V) is optimal (Gopakumar, 1997). The minced meat obtained from silver carp was thus subjected to two washing operations, each of two minutes duration. A mince: water ratio of 1:2 (W/V) was maintained as suggested above.

During the washing process intermediate dewatering is done after the first washing cycle. The process helps in eliminating any problem during final dewatering (Lee, 1986). The quality and yield of surimi also appears to increase by intermediate dewatering (Swafford *et al.*, 1985). The final dewatering was achieved in a screw press. Park and Morrissey (2000) also suggested the use of screw press, which can draw out water to a level of 82-85% moisture, quiet similar to a fish fillet. Similar results were obtained in the present study. The moisture content of 80-84% was obtained in the dewatered minced meat after final dewatering in screw press.

After the final dewatering the fat content of the DWM was found to be 0.8%. Lin and Morrissey (1995) reported a 39% reduction of lipid in fresh water squawfish mince after third water washing. The high level of lipid reduction (72.02%) in the present study may be attributed to the characteristic of mince that contained less fatty muscle.

After the washing procedure the protein content was 15.43%. Many authors have reported the decrease in protein content during washing. Crawford *et al.*, (1989) reported a protein content of 15.45% in whiting washed mince. Adu *et al.*, (1983) obtained 77% protein recoveries for rockfish and Babbitt (1985) recovered 75% of protein from Alaska Wally pollock. In the present study, 92% of protein recovery was achieved. The protein recovery was much higher may be because of the reduction in the number of washing cycles, which helped in minimizing unnecessary loss of myofibrillar proteins. This was quiet in conformation of the report by Lin and Park (1996), which indicated that most sarcoplasmic proteins are removed in the initial washing steps. Subsequent washing removes the residual sarcoplasmic proteins along with a small amount of myofibrillar proteins (Lin and Park, 1996).

The washing resulted in a bland color and notable reduction in odor of the mince due to removal of pigments and odor producing components. Similar result was observed by Nowsad *et al.* (1999) in tropical major carp mince.

Surimi was prepared from dewatered minced meat by adding cryoprotectant. In the present study a mixture of sucrose (4%), sorbitol (4%) and polyphosphate (0.3%) was used as suggested by Lee, 1984. Regenstein and Regenstein in 1991 and Akahane in 1982 also reported very similar formulations. Cryoprotectant helps in preventing the changes in surimi during freezing, frozen storage or thawing.

The cryoprotectants were incorporated into the dewatered minced meat by using silent cutter because it helps in uniform distribution of the cryoprotectants faster and temperature increase during chopping is less. The time for mixing was maintained around 2 ½ minutes as suggested by Park and Morrissey (2000). Care was taken to keep the temperature of the mix within 10^0C because at temperature greater than 10^0C protein functionality could be damaged.

5.3 PREPARATION OF FISH CAKES

The production procedure adopted for preparation of fish cake is outlined in Fig: III. The recipe of the fish cake is given in table: IV. The recipe was formulated based on the two recipes outlined by Gopakumar, (1997) .The amount of surimi incorporated was 60%. Gopakumar (1997) reported an incorporation of 50% fish meat while preparing non-spicy fish cakes. The quantity of surimi was increased to improve the fish flavor intensity. The spice ingredients are determined based on the popular taste of the people of West Bengal. The batter used in

preparation of fish cakes was egg albumen. Flick *et al.* (1990) reported the use of egg as a battering material. Egg albumen was also reported to be used for battering crabsticks and crab cutlets (Raju *et al.*1997). The breading was done using toasted bread crumbles. Sasiela, (2000) reported that crumbs could be toasted to impart the desired color to the product. The granulation of the coating was maintained very fine as suggested by Flick *et al.* (1990). Fine particles increase the batters' ability to absorb liquid. A coarse coating on the other hand can result in a loosely adhering product that will fall off during handling. Cold water was used to mix the batter to a point where no unwanted lumps remain. This was in conformation to Flick *et al.*, 1990, who indicated that cold water (10^0C) helps in increasing batter adhesion.

5.4 QUALITY CHANGES DURING STORAGE

5.4.1Nitrogenous Compounds

5.4.1.1 Total Volatile Base Nitrogen (TVB-N)

TVB-N refers to all the volatile basic compounds and comprises mainly TMA and ammonia. According to Lakshmanan (2000), a level of 35-40 mg% is regarded as the limit of acceptability. As per the EEC directive and standards the TVB-N should not be more than 30mg%. In the present study, the TVB-N value for DWM and surimi during frozen storage ranged between 8.05mg% to 17.03mg% and 4.62mg% to 12.92mg% respectively. Thus, both the samples were within the acceptable limits till 90 days of storage study. The fish cakes prepared from fresh raw material recorded a TVB-N content of 5.02mg% and 4.97mg% for DWM and surimi respectively. After 90days of storage, the product from fresh surimi was still acceptable with a TVB-N value of 27.84 mg%. This may be because the cryoprotectant treatment in surimi

necessarily reduced protein denaturation. However the product from control sample (DWM) crossed the acceptability limit after 60 days. TVB-N values for subsequent batches of products showed an increasing trend may be because the raw materials (frozen DWM and surimi) used already had an increased TVB-N content. However the product prepared from 30, 60 and 90 days old surimi had lesser content of TVB-N when compared to the 30, 60 and 90 days old product under storage. This indicates that surimi when stored as such has a better stability than when incorporated in a value added product and stored for the same period of time. The effect of the ingredients may be also be responsible for the increase in TVB-N in product as compared to raw surimi. In all the batches, the products from surimi were found to keep better than those prepared from DWM. This result is in confirmation with the result obtained by Dora and Chandrasekher (1998), where there was an increase from 3.27 mg% to 12.6 mg% after 120 days of storage for polyphosphate treated samples as compared to 18.69 mg% after 120 days for control. Similar observations was obtained by Siddaiah *et al.*(1999), where the silver carp mince treated with sodium tripolyphosphate had a value of 10.26 mg % after 120 days of storage.

The TVB-N content of products stored in RDU was recorded to be 17.69 mg% and 15.42 mg% for both the control and treated samples after 7 days. However, the product lost its acceptability after 3 days, may be because of high PV. Hegde *et al.* (1990) working on storage of fish sausage at 0 to 5^{0}C reported TVB-N values of 13.21 mg% even after 56 days of storage though the simultaneous PV was as high as 25.26-millimoles/ kg of fat.

5.4.1.2 Salt Soluble Nitrogen (SSN)

SSN in considered as an index of protein denaturation in fish (Joseph and Perigreen, 1986; Shamasunder and Prakesh, 1994). In the present study a gradual decrease in SSN was observed throughout the period of storage. The decrease was more in DWM (from 80.52% to 61.78%) as compared to surimi (from 82.65% to 71.33%). Similar trend of decline was noticed in the four batches of the products as well. Dora and Chandrasakher (1998) reported that the decrease in SSN was marginally more in control sample (78.10% to 65.06% after six months) as compared to the polyphosphate treated (78.10% to 73.68%) one. This may be because of the cryoprotective effect of sucrose, sorbitol and tripolyphosphates. Srikar and Verma in 1994 also reported similar result. Sarkar (1997) reported that SSN value of surimi prepared from sardine decreased from 74.08% to 50% after 4 months of frozen storage. Chakraborty (2002) also reported a SSN value of 50.05% for surimi from tilapia after 120 days of frozen storage. Among the different batches of the products, the products made from 30, 60 and 90 days old materials showed a corresponding decrease in initial SSN values as evident from the table: IX. This may be because of decrease in SSN values in the raw materials itself.

5.4.1.3 Non Protein Nitrogen (NPN)

The observations for NPN values are tabulated in table: X. The non-protein nitrogen content had a decreasing trend in both the samples (0.21 g/100g to 0.17g /100g of surimi and 0.18g/100g to 0.11g /100g of DWM) during the three months of frozen storage. Dora and Chandrasakhar (1998) while working on pink perch minced meat reported a decrease in NPN values from 101.3mg% to 42.2mg% for polyphosphate treated sample as

compared to a decrease from 92.4mg% to 41.4mg% in control sample. Siddaiah *et al.* (1999) also reported an initial decrease in NPN values from 362.5mg% to 359.6mg% after 90 days of storage for sorbitol treated silver carp mince. In the present study the rate of decrease was more in case of untreated sample. This may be due to the drip loss through which considerable amount of NPN is lost (Dora and Chandrasakhar, 1998). Further, the depletion of NPN may be due to its utilization by the microorganism (Jhaveri and Constaitinides, 1982). The products also exhibited a similar decreasing trend as the raw materials, the rate of decrease being slightly higher.

5.4.2 Lipid

Tiwari in 1995 reported that a reduction of 73.5% fat was observed after 3 washing cycles. In the present study a reduction of 72.02% fat was observed. The residual lipid is the main cause of quality deterioration of surimi during frozen storage.

5.4.2.1 Peroxide Value (PV)

The changes in peroxide value are summarized in table: XII. From the data of the present study it is evident that the surimi showed a much lower increase in PV (9.1 to 17.76 milliequivalent of oxygen / kg of fat) as compared to DWM (14.65 to 23.57 milliequivalent of oxygen / kg of fat). This may be due to the addition of polyphosphates in surimi, which have antioxidant properties (Tableros, 1980). Similar, results were also reported by Dora and Chandrashekhar (1994) where the PV for control (49.36 milliequivalent of O_2/kg of fat) is marginally higher than the value for polyphosphate treated sample (32.52 milliequivalent of O_2/kg of fat) after 180 days of storage. According to Lajolina *et al.* (1983), the PV up to 30 milliequivalent of oxygen / kg of fat is considered

acceptable without any objectionable off taste and odor. Thus, both the surimi and DWM have their PV within acceptable limits up to 90 days of storage. However, the products kept in storage crossed the limit of acceptance on the 20th day for DWM and 80th day for surimi-based product. The higher PV for the product may be attributed to the oxidation of the oil used in frying the spice ingredients during preparation of the product.

The product stored in RDU showed very high PV values, 25.67 milliequivalent of O_2/kg of fat for control and 24.15 milliequivalent of oxygen / kg of fat for treatment samples. The product crossed the limit of acceptance between 3 to 5 days as per Lajolina *et al.* (1983).

5.4.2.2 Free Fatty Acid (FFA)

The results of the present study (Table:XI) reveal a correspondingly higher FFA results for DWM (11.76% as oleic acid) as compared to surimi (9.58% as oleic acid) after 90 days of storage. Similar results were reported by Srikar and Verma (1994) where a FFA value of 17.63% as oleic acid was obtained for untreated pink perch meat. Dora and Chandrasekher (1998) reported a FFA value of 12.14% as oleic acid for polyphosphate treated sample and 14.36% as oleic acid for control sample. Higher PV were obtained for the products, which conform to the findings of Reddy *et al.* (1980), who reported FFA values of 0.43% as oleic acid for products as compared to the raw materials (0.34% as oleic acid). The higher initial results may be due to temperature abuse during the processing operation, which might have led to oxidation and autolysis of the lipid.

The FFA values of products stored in RDU were 8.57% as oleic acid and 7.46% as oleic acid for fish cakes from DWM and surimi respectively after 7 days. Hegde *et al.* (1990) reported a FFA

value of 4.74% as oleic acid in control after 7 days storage at 0 to 5°C. In the present study the FFA values are quite high in RDU stored samples, which may be because the temperature was maintained at 10±2°C instead of the cooler temperature of 0 to 5°C.

5.5 SENSORY CHARACTERISTICS

The mean panel scores of sensory attributes of fried fish cakes produced from fresh and frozen stored raw materials are presented in table: XIV. The scores were found to decrease for both the DWM and surimi based products during frozen storage. The sensory scores for overall acceptability for products from DWM dropped suddenly after 60 days. Product from surimi also showed a gradual decline. The product from 90 days old surimi was found to be acceptable. This result conforms well to the observation reported by Siddaiah *et al.*, (1999) for silver carp mince treated with sugar, sorbitol and sodium tripolyphosphate.

5.6 STANDARDIZATION OF FRYING TREATMENTS

Frying has several effects on physical, biochemical and organoleptic characteristics of the fish and fish products. In this study attempt was made to standardize the frying operation. It was carried out by employing different frying treatments and then studying their effects on frying loss, moisture content, moisture loss and organoleptic characteristics.

5.6.1 Effect of frying on weight loss

From the results presented in table: XVII, it is evident that with the increase of frying temperature and time, the frying loss increased accordingly. Similar trend was reported by Chand *et al.*

(2001). Das (2002) reported that with increase of frying temperature and time, frying loss increase accordingly from 15.1% at 120°C for 5 minutes to 47.8% at 180°C for 10 minutes. Bhat (1983) reported that mrigal fillets, precooked at 108.4°C for 60 minutes and 75 minutes lost 24.9% and 29.8% weight respectively. The loss in weight may be due to the loss in moisture during frying. Moreover fish cakes also loose weight owing to tiny particles of paste and flesh flaking off during frying. According to Chand (1991) frying loss is the difference between the sum of the losses in moisture, fat, flesh and paste, and the weight gain due to impregnation of frying oil. This loss depends on the temperature, frying time, thickness of the pieces and on fat content of products.

5.6.2 Effect of frying on moisture content and moisture loss

During frying a decrease in moisture content of the product was obtained primarily because of the evaporation of moisture. According to Zaitsev *et al.* (1969), evaporation of moisture is directly proportional to the frying time and temperature. The moisture loss is related inversely with frying time and temperature. Table: XVII and figure: XV and XVI represent the relationship of frying treatments with moisture content (%) and moisture loss (%). The highest moisture content of 63.21% was recorded at 120°C for 3 minutes and lowest of 54.73% at 180°C for 6 minutes. Das (2002) reported a decrease in moisture content from 79.92% in Catla before precooking to 71.8% after steam precooking at 108.4°C for 40 minutes. The result was in agreement to the findings of Chand *et al.* (1991) where a moisture content of 66.8% was observed at 120°C for 5 minutes and 52% at 180°C for 8 minutes. The corresponding moisture loss was 17.3% at 120°C for 5 minutes and 44.4% at 180°C for 8 minutes. Frying loss was less than moisture loss at each frying treatment. This was due to the

absorption of oil during frying. In the present study, oil consumption rate during frying at different temperatures was found and presented in table: XIX.

5.6.3 Effects of frying on organoleptic quality of fish cakes

Organoleptic quality of fish cakes showed that with increase in frying temperature and time, the texture of the product toughened, developed dark brown burnt color and lacks juiciness. Similar results were reported by Chand (1991) while working on fried canned mackerel. At low temperature of 120°C the frying was found to be inadequate. Therefore for best quality of fried product a frying temperature of 160°C for 3 to 4 minutes may be employed. This was based solely on the mean panel score of overall acceptability of the product fried at 160°C for 3 to 4 minutes. At this temperature the product developed the characteristic reddish brown color, distinct fried flavor, and acceptable texture. However a temperature of 120°C for 2 to 3 minutes may, however, be used as a precooking treatment of the products. In such case, it is recommended to fry the product again at 140°C for 4 to 6 minutes before serving.

5.7 STATISTICAL ANALYSES

The results of ANOVA for flavor showed a significant variation between batches ($P<0.05$) as well as between the treatments ($P<0.05$). As far as texture is concerned there was a significant variation between the batches ($P<0.05$) whereas between the treatments variation was insignificant. Therefore, from statistical analysis it may be concluded that the use of cryoprotectant might have some advantage in maintaining the flavor of surimi but there was no definite advantage as far as

texture is concerned. This may be due to a uniform reduction in rheological properties for both the treatments till 90 days under -35°C. However, for long-term storage, beyond 90 days, surimi based products may have an edge over products from control (DWM).

The correlation coefficient indicates a good correlation between all the analytical methods. Significant direct correlation was observed between TVB-N and PV ($r = 0.997$, $P<0.05$), TVB-N and FFA ($r = 0.994$, $P<0.05$). Significant inverse correlation was observed between SSN and PV ($r = -0.995$, $P<0.05$) and TVB-N and NPN ($r = -0.980$, $P<0.05$). Sarkar reported similar result in 1997. From this it may be inferred that it is necessary to use different methods to assess the quality of surimi and it is not safe to depend on a single method for quality assessment.

The correlation coefficient between frying time and frying loss at various frying temperature were significant ($P\leq 0.01$, $P\leq 0.05$) and indicates that a good positive correlation exists between them. A significant negative correlation was identified between frying time and moisture content, and frying loss and moisture content. In all the cases the values of correlation coefficient at different frying temperature were highly significant ($P\leq 0.01$). The results are in conformation with those obtained by Chand (1991).

The result of ANOVA for over all acceptability of fried fish cakes at different frying treatment yielded insignificant ($P\leq 0.05$) results. From this it may be inferred that the frying treatments of 140°C for 4-6 mins., 160°C for 3-4 mins and 180°C for 2-3 mins resulted in acceptable products without any significant variation.

5.8 USE OF HACCP CONCEPT IN SURIMI PRODUCTION

Hazard Analysis Critical Control Point is becoming popular as a tool for quality assurance of fish and fishery products. In HACCP system, control is transferred from end product testing to on-line checking, that is a change from 'testing for failure' to 'preventing failure' (Iyer, 2000).

In the production of surimi, the hazard in each step was identified and preventive measures suggested (Fig: XVII). The critical control points are quality of raw material at receiving division, handling, chilling, washing, and addition of cryoprotectants, freezing and temperature in frozen storage. Monitoring water quality, plant sanitation and personal hygiene are very important in preventing the cross contamination. Adoptions of HACCP will not only produce quality products but will also help in ensuring food safely as per the specification of ICMSF (Iyer, 2000).

CHAPTER. VI

SUMMARY

VI. SUMMARY

As the potential of surimi as functional ingredient in many fabricated fish products is explored further, its demand and consumption are bound to increase drastically all over the world. According to a market survey report (Anon, 1991), although a surimi produced from white meat fish such as croaker or threadfin bream enjoys good demand for manufacturing best quality kamaboko, the future outlook of surimi market in Japan is not bright. Hence, it is likely that in the near future, conventional surimi markets may tend to accept surimi from fish of lesser quality to compensate for the decline in the conventional fish species.

In the present study an attempt was made to investigate and explore the suitability of silver carp as a material for surimi manufacture and to test its acceptance when incorporated in fabricated fish products. A brief summary of the present investigation is given below:

1. Silver carps were used as raw material due to their comparatively low price and low acceptability among people as table fish. The physical, chemical, microbiological and sensory characteristics of fresh fish were analyzed.
2. The fishes were of average length of 53.2 cm and weighed 1600 g.
3. The chemical parameters such as TVBN, SSN, NPN and lipid characteristics such as PV and FFA were all within the acceptable limits.
4. The mince: water ratio, number of washing cycles and washing time were standardized with respect to silver carp mince. Two washing cycles, each of two minutes duration and a mince: water ratio of 1; 2 (w/v) was found to be sufficient to yield a bland odor free product.

5. A hand operated screw press was used to press out as much water as possible preferably to less than 80% moisture. The dewatered samples contained 80.84% moisture and 15.43% protein. The reduction in protein content from 16.75% to 15.43% is due to the removal of water-soluble proteins.
6. A mixture of sucrose (4%), sorbitol (4%) and polyphosphate (0.3%) was used as cryoprotectant.
7. Fish cakes were prepared by incorporating 60% surimi in the cakes and following a standard recipe as per the taste of the consumer. Egg albumen was used as batter and toasted bread crumbles as breading.
8. The storage study of DWM, surimi and the products from fresh and frozen raw materials was analyzed over three months storage period. An increase in the TVBN, PV and FFA was observed accompanied by a decrease in the SSN and NPN values.
9. A marginal benefit was observed in cryoprotectants treated samples.
10. The sensory analysis of the products prepared indicated a good acceptance up to three months. The decrease in sensory scores may be attributed to protein and lipid changes during storage. The sensory scores however did not indicate any advantage of product from surimi over the products from DWM, though in between the batches of products, surimi based products exhibited insignificant variation in attributes as compared to control samples.
11. The statistical analysis of the sensory scores also confirmed these findings.
12. The shelf life of the products was found to be 3 days in refrigerated display unit.

13. A frying treatment of 160°C for 3 to 4 minutes was found best. Other frying treatments such as 180°C for 2 to 3 minutes and 140°C for 4 to 6 minutes also yielded good color and texture.
14. A positive correlation exists between frying time and frying loss. In between frying time and moisture content, and frying loss and moisture content a significant negative correlation was observed.
15. The critical control points for surimi production are quality of the raw material, handling, chilling, washing, addition of cryoprotectants, freezing and temperature of frozen storage.

CHAPTER. VII

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VII.REFERENCE

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APPENDIX: I

Individual Rating	Excellent Very good		Good	Fairly good	Fair Below average		Poor	Very poor	Bad
	10	9	8	7	6	5	4	3	2
Gills	Bright red gills, no mucous		Less bright red gills, white mucous		Faint pink gills, pinkish white mucous		Reddish brown gills with reddish brown mucous		Dark brownish gills and brownish mucous or dry
Odor	Fresh seaweedy		No odor, neutral odor		Bready, malty, yeasty		Grassy, slightly sweet		Ammoniacal, putrid
Appearance	No bruises, very bright distinct colors,lustrous sheen		No bruises, bright with lustrous sheen, but colors not distinct		No bruises, tarnished		Slight bruises, dull		Bluish skin, damaged, very dull
Texture	Very firm, elastic and cannot be easily pressed		Firm elastic and leaves no thumb impression when pressed		Very slightly soft and leaves no thumb impression when pressed		Soft		Very soft muscle, falling apart
Eyes	Shiny cornea, black bright pupil, convex		Shiny cornea, black pupil, eyes not sunken, slight blood spots		Cloudy cornea,black pupil, blood spots visible		Cloudy cornea, faded pupil sunken, very bloody		Very cloudy and broken, completely sunken
Color	Very bright lustrous sheen,with discrete varied colors		Bright lustrous sheen, but varied colors not very distinct		Tarnished with colors fading		Dull		Dull and brownish spot
Total score	58 56 54 52 50		46 44 42 40 38		34 32 30 28 26		22 20 18 16 14		10 8 6 4 2
60			48		36		24		12

ORGANOLEPTIC SCORE CARD FOR FRESH FISH

APPENDIX: II

SCORE SHEET

NAME OF THE FISH DATE :		
QUALITY OF FISH, EVALUATED BY SENSORY METHODS		
CHARACTERISTICS	**DESCRIPTIVE ITEMS**	**SCORE**
APPEARANCE		
EYES		
GILLS		
ODOR		
TEXTURE		
COLOR		
OVERALL		

APPENDIX: III
SENSORY EVALUATION OF FISH PRODUCT

SCORE / ATTRIBUTE	8	7	6	5	4	3	2	1
Color and Appearance	Extremely Bright	Bright	Moderately Bright	Slightly Bright	Slightly Dull	Moderately Dull	Dull	Extremely Dull
Flavor	Extremely Desirable	Desirable	Not Detectable	Not Easily Detectable Off Flavor	Slightly Detectable Off Flavor	Moderately Detectable Off Flavor	Detectable Off Flavor	Putrid Flavor
Texture	Extremely Desirable	Desirable	Not Detectable	Not Easily Detectable Poor Texture	Slightly Detectable Poor Texture	Moderately Detectable Poor Texture	Detectable Poor Texture	Poor Texture
Fish Flavor Intensity	Like Extremely	Like	Like Moderately	Like Slightly	Dislike Slightly	Dislike Moderately	Dislike	Extremely Dislike
Overall Acceptability	Like Extremely	Like	Like Moderately	Like Slightly	Dislike Slightly	Dislike Moderately	Dislike	Extremely Dislike

SAMPLE COLOR & APPEARANCE FLAVOR TEXTURE FISH FLAVOR INTENSITY OVERALL ACCEPTABILY

REMARKS: SIGNATURE