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Surimi powder: Processing technology and potential application

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Abstract
Surimi refers to concentrated myofibrillar protein extracted from fish flesh by washing minced meat, separated from bones, skin, and guts with added cryoprotectant and is kept under frozen storage as block form. With the advancement of food technology, surimi is converted to dry surimi powder to use in dry mixing that could help industries to modify the formulation of surimi-derived products, especially surimi powder fortified value-added products, resulting in more homogenous blends and easier protein standardization, thus improving the nutritional quality and amino acid profile of cereal based snack products like pasta, noodles, biscuits, spaghetti etc. to satisfy the consumer preference of low-carbohydrate, protein and fiber rich ready-to-cook food products, and consumer gets the nutrition from fish; this leads to economic empowerment as well as development of a country aiming at achieving self-confidence and financial independence to fight the social disparities, livelihood insecurities and social barriers.

Keywords: Dry surimi powder, fortification of snacks, surimi technology, value-addition

Introduction

Fish is an excellent source of high nutritional value protein and contains omega-3 fatty acids, especially, eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) [1]. Omega-3 fatty acids are essential for normal growth and development and may prevent coronary artery disease, hypertension, diabetes, arthritis, inflammatory and autoimmune disorders and cancer [2]. Fish is also a good source of vitamins like A, D, B_6, and B_{12}. Minerals such as iron, zinc, iodine, selenium, potassium, sodium, etc. are also present in fish.

Fish mince has been the focus of research for development of functional food or ready-to-eat products like frozen surimi, frozen mince block, extruded product, and imitated products. Minced meat is the flesh separated from the skin, bones, scales and fins of the fish. It is used as a raw material for preparation of number of value-added products such as fish sausage, cakes, cutlets, patties, balls, pastes, texturized products, etc. The minced fish technology minimizes wastes, efficiently uses existing resources, helps in production of new versatile and nutritious foods and provides economic advantage to both the producer and consumer. One of the most important uses of minced meat technology is production of surimi and surimi-based products.

Surimi is a product of Japanese origin and the term surimi refers to concentrated myofibrillar protein extracted from fish flesh by washing minced meat that has been separated from bones, skin, and guts [3, 4]. The most important step in preparation of surimi is washing the fish mince with cold water. This is done to remove fat and other water-soluble contents. The myofibrillar protein which is primarily the muscle portion of fish is isolated. This isolated myofibrillar protein is then mixed with cryoprotectant, to get surimi [5]. The cryoprotectants are sugar or an alcohol which are required to retain the functional properties of the myofibrillar proteins. The most commonly used cryoprotectant in the surimi industry is a 1:1 mixture of sucrose and sorbitol at a concentration of 8%. Surimi generally comes in a block form and is stored in frozen condition. Surimi is the primary material used for gelling foods such as kamaboko and fish balls. Today, surimi is a popular food item not only in Japan but across different countries due to its unique textural properties and high nutritional value [6].

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. Higher water-soluble proteins yield lesser surimi. The quality of surimi prepared from each species of fish depends on factors like seasonal variation, feeding habit, pH of the habitat water, adaptation, temperature, lipid content, sex, and spawning.

Among the different species of white fleshed lean fish, Alaska Pollock has a very high content of myofibrillar protein with good gel forming ability and contributed 89 to 90% (2691000 metric tonnes) of total fish captured worldwide for surimi production [7]. Recent bans on pollock fisheries to stop the over-exploitation gradually decreased the global catch and forced the surimi processors to look for alternative species for quality surimi production. Many studies had been conducted in search of other potential raw material for surimi processing apart from the traditional species Alaska pollack. Now, a range of species have been identified as potential raw material for surimi like bigeye snapper [8, 9], pacific whiting [8, 10], threadfin bream [11, 12, 13], arrowtooth flounder [8, 10], cod [14, 15], lizard fish [12, 16], hake [14], croacker [16], mackerel [17, 18], sardine [17, 19], anchovy [20] and hoki [21]. Particularly in India, mainly fishes of marine origin such as threadfin bream (*Nemipterus japonicus*), ribbonfish (*Trichiurus lepturus*) and lizardfish (*Saurida tumbil*) are being used for surimi production [22]. However, with the continuous decrease in marine catch, there is scarcity of raw material for surimi production. The recent decline in traditional surimi resources together with the recent development in aquaculture industry worldwide provide a ground for freshwater fish to be an attractive raw material for surimi processing in the future. World aquaculture production of fish accounted for 44.1 percent of total production (including for non-food uses) from capture fisheries and aquaculture in 2014, up from 42.1 percent in 2012 and 31.1 percent in 2004. It is hoped that alternative use of freshwater fish other than fresh consumption will help to boost the local aquaculture industry. Recently some more works have also been done on the quality of surimi manufactured from freshwater fishes like silver carp [23, 24] Chowdhury *et al.*, 2009a, Common carp [25], *Labeo calbasu* [26] and tilapia [27, 28, 29], to investigate their compatibility as a raw material of surimi. Tilapia widely expected to play a substantial role as a food fish to meet the needs of the poor for animal protein in many developing countries; additional profits are earned in the country, labor is hired locally, additional ingredients can come from local markets, by-products can be sold, and the final product can be shipped more efficiently with a high price per kg. This contributes to the increase in the average price for tilapia products in international trade. Majumder *et al.* [30] reported that Tilapia is a suitable raw material for surimi processing with good colour and high gel-forming ability. Nath and Singh, [31] and Sarkar *et al.* [32] successfully prepared surimi followed by dry surimi powder from Sutchi Catfish *Pangasianodon hypophthalmus*.

Mechanical separation of fish meat

The fish meat separation process can be done either manually or mechanically and is an important processing step that determines the quality of the surimi. Mechanical separation of fish flesh from filleted fish started in Japan during late 1940s, which had set as a milestone in the commercial production of surimi [33]. The use of mechanical deboners or flesh separators substantially increases the yield of meat from fillets. Higher meat yield and lower bone content are the prerequisite for efficient deboning [34]. Deboners can be employed in the fish processing industry for two major purposes. Firstly, to ensure maximum recovery of fish flesh from fillets and secondly, the potential utilization of fish species that do not fit the traditional market [35]. Most separation techniques use a perforated filter to screen the fish from non-flesh components. Available perforation sizes for this type of deboner are 1 to 7 mm but 3 to 4 mm perforation size of drum appears to be optimal for retaining proper quality and yield of surimi [8]. 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. 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% [36, 37].

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 protein by removal of water-soluble proteins, blood, fat and other nitrogenous compounds from minced fish meats [38]. This process can improve the functionality and sensory characteristic of fish meat by eliminating the problems associated with colour, taste, odour etc. [27]. Myofibrillar proteins, the primary components of the formation of 3-dimensional gel structure, constitute about 70% of the total proteins of fish meat [8]. By reducing the amount of water-soluble proteins and undesirable matters from minced meat, this process helps to concentrate the myofibrillar proteins and thereby, improves the functional properties of surimi [8].

The washing process involves mixing minced meat with cold water (5 °C) and removing water by screening and dehydrators or centrifuging to about 5-10% solids [39]. 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. However, due to rising utility costs, limited water sources and pollution problems, minimization of water usage for leaching and reduction of wastewater disposal have become a major consideration for surimi manufacturers [40].

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 [8]. According to Karthikeyan *et al.* [41], during early 1990's a common water/ mince ratio of 3:1 to 8:1 with 3 to 4 cycles was practiced by most of the on-shore processors. Park [8] reported that about 29.1 litre of wastewater was generated during preparation of 1 kg of surimi, in an on-shore processing plant. Further, during surimi processing, after washing and dewatering process about 40 to 50% of solids are lost from minced fish and more than 75% of wastewater discharged containing 0.46 to 2.34% of total protein including myofibrillar proteins from screeners, screw processors and dehydrators. Yathavamoorthi *et al.* [26] recovered 60.54% protein from *Labeo calbasu* mince while washing it with its 4 times of water. Protein recovery of 67.9% from tilapia mince using 3 cycles with a 1:3 (w/w) ratio of mince to water was reported by Rawdkuen *et al.* [27]. For most tropical fishes, two washing operations with 2 minutes duration each, using a mince: water ratio of 1:2 (w/w) is reported to be optimum [41].

Refining

Before the final dewatering under a screw press, impurities (skin, fin bones, scales and connective tissues) are removed by refiner. Composition of a common refiner discharge was estimated as 81.4% moisture, 1.9 % lipid, 1.0 % ash and

15.4% protein [8] containing majorly stroma proteins, derived from connective tissues. This clearly indicates that the refining process is developed to eliminate the connective tissue from washed mince. In commercial application, a standard screen size of 1.5 to 1.7 mm is used, which results in 15-20 % of meat rejection from the primary refiner and this meat may be used for secondary surimi production containing higher impurities, lower whiteness and lower gel forming ability [8].

Dewatering by Screw press

The minced, washed and leached fish meat is wet slurry with about 90-92% of moisture [8]. Rawdknen *et al.* [27] and Chaijan *et al.* [17] accomplished the dewatering of leached meat through 4 layers of cheese cloth followed by the hydraulic press. A screw press, with a 0.5 mm perforation, draws water out with compression to a level of 82-85%, which is similar to that in the fish fillets [42]. According to Park, [8] in commercial application a perforation size of 0.5- 1.5 mm is most common. It is also common to use 0.1-0.3% salt mixture of NaCl and $CaCl_2$ for easier removal of water under the screw press. Chaijan *et al.* [17] found that 0.5% NaCl (w/v) for mackerel surimi and 0.2 % NaCl (w/v) for sardine surimi was optimum for proper dewatering and protein recovery. During the third washing step, 0.5% NaCl with a mince to NaCl solution ratio of 1:3 (w/w) was reported to be optimum for better gelation character for tilapia surimi [27].

Use of additives in surimi: **Cryoprotectants**

During frozen storage, a significant quality deterioration of surimi due to microbiological and autolytic changes is commonly observed. Moreover, several undesirable changes are also accounted in frozen surimi as a function of altered water/solid interactions. Most of the studies indicate that denaturation and aggregation of muscle protein plays dominant role in functional change/quality change of frozen surimi [8].

In raw surimi, certain compounds, referred as cryoprotectants, are added to frozen surimi to stabilise the myofibrillar protein from adverse quality changes during storage. Cryoprotectants are mainly sugar and polyol compounds that protect wet proteins after intimately mixing, from many of the deleterious influences during freezing and frozen storage [8]. Many compounds, including some low molecular weight sugars and polyols, amino acids, carbohydrate, polymers, synthetic polymers (polyethylene glycol), carboxylic acids and polyphosphates have been found to be used as cryoprotectant [43], although there is a restriction in their use due to high cost, food regulation and adverse sensory properties. Sucrose and sorbitol have become the most common cryoprotectants in surimi processing. Addition of sucrose is known to stabilize proteins against heat denaturation [44] and protects fish myofibrillar protein during freezing [43]. According to Nopianti *et al.* [43] carbohydrates like Sucrose, Sorbitol, Lactitol, Polydextrose, Litesse, Maltodextrin, Trehalose, Sodium lactate, Polyphosphates are suitable to reduce the freezing damage of protein.

The most common combination is 92% washed minced meat, 4% sugar, 4% sorbitol, which can be stored up to a year without loss of its gel forming ability [45]. Sucrose and sorbitol (1:1) with 0.3% sodium tripolyphosphate were reported to be the best cryoprotectant mixture [46] to exhibit highest gel forming ability of queen fish *(Chorinemus lysan)* surimi after 1 week of frozen storage [47]. It was also found that cryoprotective effect of 8% sucrose and sorbitol (ratio of 1:1) with 0.2% sodium tripolyphosphate helped to protect the surimi proteins against freeze denaturation [47].

In 1992, while commercial surimi processing of pacific whiting, enzyme inhibitors like beef plasma protein, egg white, whey protein and potato extract had been used in conjunction with 8 to 12% cryoprotective ingredients and gel enhancers, formulated with sucrose, sorbitol, tetrasodium pyrophosphate / sodium tripolyphosphate, calcium carriers (calcium lactate, calcium sulfate, calcium caseinate) and sodium bicarbonate [48]. Several authors have proposed the use of enzymatically modified gelation (EMG) due to their anti-freezing properties [49]. The current market preference for non-sweet, natural and proteinaceous cryoprotectants may make the EMG a desirable cryoprotectant ingredient.

Generally, cryoprotectants like sucrose and sorbitol impart a sweet taste and high calorific value to surimi [50]. Many studies have been reported using other cryoprotectants with no or reduced sweetness/calories content, such as lactitol, litesse, trehalose, palatinit, polydextrose and maltodextrin [13] as sugar and calories have become a consumer issue in recent days. Zhou *et al*. [51] reported that trehalose and sodium lactate at levels of 8% (w/w) effectively prevented the protein denaturation of tilapia surimi during frozen storage at -18ºC for 24 weeks.

Cryoprotectants were originally incorporated into the dewatered meat by a kneader. Presently, silent cutters are used instead because of its uniformity and fastness in distribution of cryoprotectants and lower temperature rise during chopping. Commercial practices for mixing cryoprotectants using a kneader and a silent cutter are 6 minutes and 2.5 minutes, respectively [8, 39]. The temperature of the mix must not exceed 10ºC because higher temperatures may damage protein functionality.

Mode of action of cryoprotectants in surimi

A number of scientists have proposed different theories about probable mechanism behind the action of the cryoprotectants. Matsumoto and Noguchi, [52] 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 augment protein hydration. The compounds such as carbohydrate and/or polyalcohol when added, they presumably cover the protein molecules by hydrogen bonding with OH^- groups of the protein. The extra OH^- groups of the additive molecules would form hydrogen bond with water, thereby increasing hydration of the molecules and hindering their aggregation [53].

Matsumoto, [54] proposed that globular proteins denature through unfolding during frozen storage. Largely the intermolecular non-polar bond maintains the native conformation of globular molecules. In the folded protein-water system, the non-polar groups on the polypeptide backbone are oriented inward so as to avoid contact with the water phase. In the unfolded protein-water system, some non-polar 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 an increased hydration of the protein molecules and higher resistance against displacement of water even under frozen condition, thus, hindering the unfolding of the protein molecules which otherwise would cause aggregation. According to Park, [8] increased surface tension of the medium found to be the most dominating factors resulting to the heat stability of proteins (particularly globular proteins).

An alternate mechanism involving the thermodynamics of interaction between proteins and solvent components have been investigated for sucrose/ water/ protein system [55]. 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 around the sugar and the polyols then reorient or rearrange themselves to form maximum number of new hydrogen bonds with each other. Cryoprotectants also protect muscle proteins during frozen storage by depressing the freezing point. Matsumiya and Otake, [56] 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%.

Surimi Powder

The principal factor that determines the quality of surimi is the freshness of the fish [57]. Frozen storage is often used to maintain the quality of fish as well as of surimi. Benjakul *et al.* [9] studied the effect of frozen storage (-18°C) on the gelling capacity of surimi from fishes like threadfin bream (*Nemipterus* sp.), lizard fish (*Saurida* sp.), croacker (*Pennahai macrophthalmus*) and purple spotted big eye (*Priacanthus layenus*). He found a significant difference in gel forming ability depending on storage time. Proper frozen storage is very important to maintain the functional properties of surimi. Park and Lin, [6] reported a freezing time of 2.5 hours was required to freeze a 10 kg surimi block up to a core temperature of -25°C in a plate freezer. After production of frozen surimi blocks, they needed to be kept under frozen storage before further processing to lengthen the shelf life. The Japanese Association of Refrigeration recommended a storage temperature of -23°C to -25°C for frozen surimi for 6-12 months [52].

Recent research indicates that surimi could be converted to a dried form, surimi powder. In its powdered form, surimi can be kept without frozen storage under normal refrigeration condition [4], thus reducing huge cost of freezing and frozen storage. The powdered surimi offers many advantages in commerce, such as ease of handling, lower distribution costs, more convenient storage and usefulness in dry mixes application [30]. The sugar or polyols that are used to protect the protein in surimi also acts as a dryoprotectant preventing protein denaturation during drying. The protective action is important to maintain the functional properties of fish protein, such as solubility, gelation, water-holding capacity, emulsion, foaming property and color, while incorporating into a food or dish as additives during preparation.

Surimi powder can be turned into wet surimi by rehydrating it with four times its weight of water, so that wet rehydrated surimi powder would have water content similar to that of a frozen surimi block [4]. Another advantage of surimi powder is its usefulness in dry mixtures [58] that could help industries to modify the formulation of surimi-derived products, resulting in more homogenous blends and easier protein standardization. Surimi powder can be prepared from frozen surimi blocks by adopting different drying technologies. The main purpose of drying technologies developed in food industries is to prolong the shelf life of a food product by dewatering, means removing liquid water from the product [59]. In thermal drying, energy transferred from the environment is used to evaporate the moisture from the product's surface, followed by the transfer of internal moisture to the surface of the product. As both drying and heating can lead to protein denaturation, the heating temperature of evaporation can be lowered by lowering pressure using vacuum for heat-sensitive material such as protein [32]. Available drying methods for making surimi powder include freeze drying, spray drying, oven drying, solar drying, and mechanical drying; where the heating temperature of evaporation can be lowered by lowering pressure using a vacuum to prevent the protein from heat denaturation [32].

Different drying methods for production of surimi powder

The freeze-drying process removes water from the matrix at a very low temperature (–50 to –70 °C) via the sublimation of frozen water to vapor in a vacuum chamber [60]. Although being more expensive than air drying due to the energy required to maintain the vacuum condition as well as also to keep the temperature low [60], freeze-drying is considered to be the most suitable for inhibiting protein denaturation compared to other drying methods [61]. Cryoprotectant prevents the denaturation of myosin and actomyosin, which are responsible for gelation properties of surimi during freeze drying which was further established by Shaviklo *et al.* [62] during reporting of better gelation (1%) property of freeze-dried surimi made from saithe (*Pollachius virens*) treated with cryoprotectant (2.5% sucrose and 0.2% sodium tripolyphosphate) as compared to surimi without additives (6%) [4]. Musa *et al.* [63] reported that freeze-dried surimi powder from different fish species has superior functional properties. Ramirez *et al*. [64] reported that although tilapia (*Oreochromis nilotica*) and fat sleeper (*Dormitator maculatus*) both species have potential use as a meat emulsifier, fat sleeper is superior than tilapia in this regard.

The spray-drying method removes water from products through spray–air contact. Masters [65] defined spray drying as the transformation of fluid (solution, suspension, or paste) material to a dried form (powder, granule, or agglomerate) by spraying it into a hot drying medium resulting in the evaporation of the moisture. The spray drying process initiates with the atomization of material into a spray section till the material contacts with hot air, thus, results in the evaporation of moisture. Spray drying is suitable for drying liquids, even heat-sensitive liquids containing protein [4]. Denaturation of protein is comparatively low because of the shorter exposure time of the liquid at higher temperature. The temperature of the inlet ranges from 150 to 300 °C and the outlet temperature ranges from 55 to 100 °C, varies on the material's characteristics. Shaviklo *et al*. [66] used a mixture of saithe surimi and water (5× weight) to obtain a solution with about 3% dry matter for feeding into the spray-dryer machine with inlet and outlet temperatures of 190 ± 5 °C and 95 ± 5 °C, respectively. The freeze-dried surimi powder made from saithe had better functional properties than spray-dried powder [66]. While examining the effect of addition of different saccharides (sucrose, sorbitol, and glucose) to fish meat to prevent protein denaturation during spray drying, Niki and Igarashi, [67] concluded that the ATP-ase activity of spray-dried AFPP was highest when sucrose was added, followed by sorbitol and glucose, which means sucrose had a better cryoprotective effect than sorbitol and glucose in protecting actomyosin from denaturation. Venugopal *et al.* [68] reported the inlet and outlet temperatures of 200^{O}C and 90 ºC, respectively with high emulsifying property to absorb 30 ml oil per 100 g powder during studying the properties of spray-dried protein concentrate made from capelin fish (*Mallotus villosus*).

The processes involved in low-cost oven drying technology in a closed chamber by heating at a relatively low temperature for developing dried fish protein are heating, drying and baking [69]. Huda *et al.* [70] reported the suitable oven drying temperatures was 60 ºC for a period of 12 h to bring down the moisture content less than 10% of fish protein concentrate (FPC) from lizardfish. Arone *et al.* [71] used both freeze drying and oven drying methods for preparation of dry surimi powder from surimi (itoyori), purchased from commercial industry.

Other potential drying methods for producing surimi powder are solar drying and mechanical drying. The environmental-friendly and less expensive solar air heaters depend on whether condition and the climate of the drying location [4]. Musa *et al.* [72] reported solar dried surimi powder has acceptable functionality which was successfully used in food products such as soup mixing, high protein cereals products bread and macaroni supplementation and non-casein-based dairy type products. Mechanical drying, another way to produce surimi powder, can be defined as ventilating fish granules with natural or heated air to evaporate the water [4]. Chavan *et al.* [73] used mechanical drying to make texturized dried fish granules with a salt concentration of 12 g/100 g minced meat, a boiling time of 10 min, and a mixing time of 6 min at 100 rpm for 12 h of drying period at 43–45 °C. The product was stable for up to 4 months due to its high salt concentration and low moisture level (6–7%).

Proximate composition of the surimi powder varies upon different fish and different incorporation rates of cryoprotectant sugars (sucrose, sorbitol, trehalose etc.), which were added with surimi to protect its functional properties against freezing and drying. As protein is the main constituent, a surimi powder having more than 65% protein can be classified as a fish protein concentrate (FPC) as per FAO [74]. In a study, the protein content of oven and freeze-dried threadfin bream surimi powder were found to be 72.60% and 72.90% respectively [75]. Shaviklo *et al.* [62] reported a protein content of 74.50% in spray dried surimi powder from saithe. According to Huda *et al.* [75] surimi powder from lizard fish was reported to contain 73.4% protein, 5.2% moisture, 1.9% fat, 1.9% ash and 17.5% carbohydrate. The protein content of tilapia and trout surimi powder were 57.8% and 64.8% respectively [75]. A study conducted by Ramirez *et al.* [64] postulated that freeze-dried tilapia surimi powder contains 62% protein, 4.6% moisture, 2.9% fat, 1.6% ash and 8% carbohydrate when 8% sucrose was used as cryoprotectant during surimi preparation. The high content of carbohydrate in surimi powder was observed due to the addition of cryoprotectants during surimi preparation. Huda *et al.* [75] found that incorporation of 8% cryoprotectant during tilapia and trout surimi preparation resulted a final carbohydrate content of 33.5% and 30.7% respectively.

Fortification of Dry Surimi Powder to Prepare The Snacks: Value Addition

Value addition, the most promising factor in the food processing industry, is defined as ‘any addition activity that in one way or the other change the nature of a product thus adding to its value at the time of sell’. In general, adding value is the process of changing or transforming a product from its original state to a more valuable state [76]. The need for diversification and increased income through value-added fishery product has convinced many producers to become more resourceful as they add value to their products. A broad definition of value addition is to economically add value to a product by changing its current place, time, and form characteristics to characteristics more preferred in the marketplace [76].

Demands for fish protein ingredients including dried fish protein to develop functional food or ready-to-eat products are gradually growing in the world [77]. Surimi powder also enjoys an advantage over Fish Protein Concentrate. Conventional FPC is produced by heating fish flesh with an organic solvent to remove fat and water, followed by conversion to powder. However, this process causes FPC to lose its functional properties (especially its rehydration ability). For this reason, FPC is not suitable for processing with other food ingredients [4]. However, surimi powder that retains its functional properties could be a solution to this problem, as it is more suitable for processing with other ingredients to make fish-derived products. Park and Lin, [6] indicated that the nutritional value and physicochemical properties of surimi powder make it ideal for producing formulated seafood and other food products. Fortification of food is the most convenient method which includes the addition of one or more functional components for the purpose of enhancing a biological activity of newly designed food products [78].

Till date a number of researches were done focusing on the application of surimi powder in food products, including rice-fish snacks [79], fish crackers [80], fish balls [81], corn-fish snacks [66], and fish cutlet mixes [82]. As a raw material surimi is being used for production of products like Kamaboko, Chikuwa, Hampen, Tempura etc. for a long time [8]. Cereal based products such as pasta and noodles offer the possibility for value-addition through fortification with protein rich fish mince, surimi and surimi powder. These incorporations were mainly done to improve the nutritional quality, mainly the protein content of these foods. Huda *et al.* [80] found that, in case of crackers; there was an increase in protein and ash content with a decrease in linear expansion, crispiness and colour lightness after fortification. He also reported that the overall acceptability of crackers formulated with 10% surimi powder was highest among all other incorporations. According to Subba, [83] the overall acceptability of fish snacks, based on texture and taste were 96% and 82% respectively.

Pasta, commonly prepared from wheat flour or semolina flour, is consumed everywhere throughout the world. Pasta is a popular food product because of its’ versatility, low cost, ease of preparation and nutritional quality [84]. Due to scarcity of Essential Amino Acids (EAA) like lysine, tryptophan, threonine and methionine [85], and other essential nutrients like dietary fiber and vitamins in wheat-proteins, enrichment with nutritious raw materials containing EAA-rich-protein and fatty-acid-rich-lipids increases the nutritional quality of pasta in terms of protein, dietary fiber, vitamins and minerals contents [86]. The nutritional value of fortification with proteins and lipids is dependent not only on the quantity of protein and lipid incorporated but also the quality of such proteins and lipids used, their potential digestibility and ability to form a complex with other food ingredients and the subsequent bioavailability. Fortification of pasta with fish surimi powder may prove to be nutritionally significant. In recent years, pasta has been fortified using different ingredients including quinoa flour [87], lentil flour [88], beef meat [89] and freeze-dried shrimp powder [90]. Considering the consumer's demand for ready-to-eat and nutritionally significant fish products especially in developing countries like India, there is an instant need to diversify seafood-based products. Preparation of fish pasta is one such technology for diversification. The plant and animal materials used in the preparation of food are important sources of dietary amino acids, fatty acids as well as functional components of foods [91]. Animal proteins differ in composition when compared to plant proteins. Cereal proteins such as rice, wheat, barley, and maize are low in lysine and methionine while legumes and oilseeds are deficient in methionine. These amino acids are often referred to as limiting amino acids as their concentrations in a protein are below the levels of a reference protein [92]. Due to this, incorporation of protein and lipids from other sources rich in essential amino acid [93] and fatty acids [94] such as dry fish surimi powder may be important to improve the nutritional quality of food products like pasta.

Noodles are consumed worldwide, especially in South-east Asia, and their global consumption ranks second after bread [95]. According to the report by World Instant Noodle Association [96], the annual production of noodles was 105.65 billion packs in 2013 and is increasing at a rate of 3% per year since 2010. Noodles formulations are based principally on cereals which are generally deficient in body building proteins and some micronutrients like vitamins, minerals and essential amino acids chiefly lysine, tryptophan and threonine [97]. Some of the noodles made from a mixture of lupin-*Canna edulis* may provide half of the protein daily intake, whereas soybean-*C. edulis* mixture may provide upto one third of the daily protein intake. So, incorporation of high value animal protein in snacks such as noodles has a great future. Various enriched noodles are commercially available in market especially in Asian food market [98], and lot of scope also exist for fortification of noodles with minerals, vitamins and proteins from other sources like pulses, groundnut, soybean and meat such as dry surimi powder. Therefore, deficiency problems could be solved by consuming noodles together with foods that are rich in protein or by enrichment of noodles with protein rich commodities.

Instant noodles are one of the main staple foods consumed in Asian countries and worldwide consumption is on the rise. As the economies of the Asia-Pacific region become increasingly developing, consumer expectations for the food they consume, including that of instant noodles, will increase. According to Fu, [99] high quality noodles should be bright in color with very little discoloration, have an adequate shelf life without visible microbiological deterioration or oxidative rancidity and have appropriate flavor and textural characteristics. Chin *et al.* [100] reported 5% surimi powder was considered the optimum concentration acceptable for fortification of wet yellow noodle. Dewi, [101] stated that washed minced trout can be incorporated into egg noodle products at levels up to at least 20% flour substitution by weight. For the fried noodles, adding fish tended to reduce the yellow color and yielded a product with texture profiles similar to the control at a 10% substitution level. Bhaskaran *et al.* [102] stated that 7.5% of skim milk powder fortified noodles was highly accepted due to its palatability and can be kept for 60 days in vacuum packed polythene containers. Electron Micrograph studies on this sample revealed porosity in the new product. Polpuech, [103] stated that it is feasible to fortify deep-fried instant noodles with lysine, though lysine fortification exhibited an undesirable color in the dried instant noodles after storage. It is feasible to improve protein quality of deep-fried instant noodles to 102% amino acid score of lysine by fortifying L-lysine monohydrochloride in noodle blocks at 0.23g/1 serving of 50g. The cost of fortification is 1.7% of the sell-price.

Due to increased market demand for fortified corn snack with higher amount of fish protein, fortification of corn snacks with fish protein powder was commercially growing in Iran in parallel with fish mince fortification [66]. Incorporation of functional ingredients into starchy snack products by using extrusion cooking can increase their nutritional value. Extrusion of corn grits with fish protein powder can produce an expanded fortified snack that is more nutritious than the widely consumed regular corn snacks. Shaviklo *et al.* [66] reported the corn snack fortified with 7% fish protein powder made from saithe (*Pollachius Virens*) surimi thus provide a unique avenue for fish utilization and increasing fish consumption. Therefore, fortification of starchy snacks with fish/fish proteins could be a healthy option to boost consumers' preference, especially children's nutritional intake [66].

Processing of fish crackers involves mixing fish flesh with starch and water. Huda *et al.* [104] used surimi powder obtained from threadfin bream and processed using the oven-drying method to make fish crackers. Fish flesh was replaced by surimi powder with the addition of water until the moisture content was similar to that of fish flesh. Shaviklo *et al.* [82] prepared a fish cutlet mix by mixing freeze-dried surimi powder made from saithe with potato flakes and other ingredients. The dry fish cutlet mix was stable at ambient temperature (27 ± 2 ºC) for 6 months. Surimi powder also is a potentially useful raw material for making seafood products such as fish sausage, as long as it retains high gelling and emulsifying properties [4] especially after addition of hydrocolloids such as CMC, alginate, and konjac at ~0.5% final concentration, thus improving the textural and sensory properties of sausage [105]. Although the functional properties of surimi powder are not as good as those of frozen surimi, Huda *et al.* [81] showed that freeze-dried surimi powder from threadfin bream (*Nemipterus japonicus*) is a potentially useful raw material for gel-based products such as fish balls.

The fish bouillon powder, processed from myctophid protein along with different spices, can be used as flavoring while consuming rice, noodles etc. Due to higher protein content (>65%), surimi powder is classified as fish protein concentrate type A. While investigating the effect of fortification with different levels of Fish Protein Powder (FPP) on chemical properties and sensory quality of a Persian ice cream with 0, 3 and 5% FPP (similar levels of fat, lactose, acidity and pH) during storage at −18 °C for 4 months, it was reported that the fortified ice creams had similar sensory quality after production, but it was changed significantly after 2 months of storage. Development of ice cream fortified with FPP could be an effective way to enhance nutritional and functional value of ice cream [106].

Acceptability of bread fortified with 5, 10, 15 and 20% FPP were studied, although no significant differences among the samples were found. It was found that 5% FPP is the best level of fortification of biscuits [106]. This 5% FPP fortification can act as a potential emulsifier in mayonnaises. Crackers fortified with 10% FPP were accepted by Malaysian consumers [106]. During studying the different fortification level of FPP in a traditional Pakistani weaning food (*Khitchri*), the protein efficiency ratio (PER), net protein utilization (NPU), true digestibility (TD) and biological value (BV) show remarkable improvement in weaning food incorporated with 10% FPP which implies the addition of 10% FPP to the prototypes can result in superior nutritional quality. The authors concluded that the FPP could be an ideal source of protein for enriching the weaning food [106].

Literature review reveals the successful fortification of fish mince, especially Tilapia mince, with Zn to overcome Zn deficiency and to improve the nutritional status of the food, and to improve the shelf life of the mince due to broad-spectrum antibacterial activity of ZnO Np against pathogenic bacteria such as *Staphylococcus aureus, Bacillus subtilis, Escherichia coli, E. coli O157:H7, Salmonella enteritidis, Salmonella typhimurium, Pseudomonas fluorescens, Campylobacter jejuni, Pseudomonas aeruginosa and Listeria monocytogenes*; thus, ZnO Np fortification is the ultimate precursor of a number of value-added fish and fishery products such as fish sausage, cakes, cutlets, patties, balls, pastes and texturized products and can be rational kickstart to alleviate protein as well as zinc malnutrition [107].

Chowdhury *et al.* [108] reported on fortification of carbohydrate-rich cereal-based-noodle instant noodles with various protein sources, especially with fish meat flour and surimi powder that makes the fortified noodles nutritionally significant and the sensory attributes facilitate greater consumption. To satisfy the consumers' preference of diet rich in fiber, protein and low fat, fish protein incorporated noodles can satisfy their nutritional requirement. Fish proteins are effectively more readily digestible than those of plant protein, thus cereal products can be fortified with fish proteins to reduce glycemic impact and provide a balanced nutritional profile for human being [108].

Conclusion

Value-addition by fortification of dry surimi powder to improve the nutritional quality and amino acid profile of cereal based snack products like pasta, noodles, biscuits, spaghetti can be done by applying simple, traditional and cost-effective methods from home or industry level to large-scale production by applying higher technology. With the upgradation of aquaculture practices and production in India, developing different value-added products is a genuine way of better utilization and distribution of the aquaculture produces. Moreover, research can be done to explore the potential uses of surimi powder in various food products and their quality, including texture properties and consumer acceptance of the products. Urban, semi-urban and rural illiterate and educated youths and progressive farmers of all sex, castes, and religions may develop their technical skills for self-employment and generate additional income through which they can earn money by preparing various snacks from surimi powder. This eco-friendly approach of value-addition is regarded as an integral part of economic empowerment as well as development of a country aiming at achieving self-confidence and financial independence to fight the social disparities, livelihood insecurities and social barriers. So, with the advancement of food technology in context to West Bengal where people are buying more industrialized and fast food products, the widely cultured reasonably priced fresh water aquaculture produce can be opted as an excellent raw material to produce dry surimi powder which can successfully be incorporated in dry mixing applications and fortified to improve the nutritional value of wide range of fish and fishery value-added products that will certainly lead to suitable and profitable use of the farmed species, increasing the income of the farmers, creating employment opportunities and strengthen rural economy. Thus, improvement of socio-economic status and up-gradation of the livelihood of poor fisherman community can be achieved by increasing per capita income, people involvement and increase the opportunity of employment**.**

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