International Journal of Bio-resource and Stress Management https://pphouse.org/ijbsm.php

Crossref

IJBSM February 2022, 13(2):144-154 Print ISSN 0976-3988 Online ISSN 0976-4038 **Article** AR2435

Review Article *Natural Resource Management*

DOI: HTTPS://DOI.ORG/10.23910/1.2022.2435

Surimi Powder Inclusion with Semolina-based Pasta Product– A Potential Method of Protein Fortification

Asik Ikbal, Supratim Chowdhury, Prasanta Murmu, K. C. Dora, Swarnadyuti Nath, Sayani Roy and Pooja Saklani

Dept. of Fish Processing Technology, Faculty of Fishery Sciences, West Bengal University of Animal and Fishery Sciences (WBUAFS), Kolkata (700 094), India

Open Access

Corresponding asikikbal25@gmail.com

0000-0001-5156-4891

ABSTRACT

Starch-based foods are the rich source of carbohydrates with a high glycaemic index and lack of essential amino acids as well as essential fatty acids causing unhealthy attributes. Thus, these are nutritionally imbalanced foods. As demand for convenience, nutritionally balanced foods are gradually increased in many developing countries, the cereal industries have also taken the challenge to provide healthier food with increased shelf life. Fish and fisheries products are a good source of polyunsaturated fatty acids (mainly docosahexaenoic acid and eicosapentaenoic acid), essential amino acids (particularly methionine, lysine, histidine, etc.), important vitamins (A, D, B6, and B12), and minerals (iron, zinc, iodine, selenium, potassium, and sodium), making it a global highly traded commodity with an average per capita consumption of 20.5 kg worldwide. In the meantime, semolina-based pasta is highly popular in some Asian as well as western countries because of its low cost, ease of preparation, and saving much time. Market demand for such products is increasing day by day because of industrialization and the need for diversified ready-to-serve or instant ready products in so-called busy societies. Pasta is a very popular food product in China, Korea, Japan, USA, India because of its' versatility, low cost, ease of preparation. Thereafter, adding values by fortification of healthy nutrients according to consumers' preference, it will also be triggered with high market value in terms of nutritional quality. With this view, cereal products can be fortified with protein as well as lipid-rich constituents such as surimi powder or fish protein powder.

KEYWORDS: Fortification, fish protein powder, pasta, surimi powder

***Citation* (VANCOUVER):** Ikbal et al., Surimi Powder Inclusion with Semolina-based Pasta Product– A Potential Method of Protein Fortification. *International Journal of Bio-resource and Stress Management,* 2022; 13(2), 144-154. HTTPS://DOI.ORG/10.23910/1.2022.2435.

Data Availability Statement: Legal restrictions are imposed on the public sharing of raw data. However, authors have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study.

Conflict of interests: The authors have declared that no conflict of interest exists.

RECEIVED on 16th June 2021 RECEIVED in revised form on 10th January 2022 ACCEPTED in final form on 16th February 2022 PUBLISHED on 28th February 2022

1. INTRODUCTION

Fish and fisheries products are a well-known source of easily digestible protein that contains a good balance of important amino acids (Fujibayashi et al., 2018) which make these items important from a nutritional standpoint. Because of its strong connections with other proteins and great gelling capacity, fish protein is used in the food business as a binder, emulsifier, or dispersing agent (Sasidharan et al, 2020). This has sparked the curiosity of researchers and food processing specialists in adding fish protein to cereal-based products (Zhang et al., 2021). In economically developing countries, cereals contribute 60% to 80% of calories directly. Cereals, on the other hand, supply 30% of total food calories in the developed world (Anonymous, 2002).

These countries majorly look forward to meat and related foods for better calories options because the protein content of cereal food is comparatively lower than fish and meat products and also, they are nutritionally incomplete due to their deficiency in several essential amino acids (EAAs) and have a higher carbohydrate content than protein. Cereal products can be fortified with fish proteins to provide healthy and balanced nutrition to human diets (Desai et al., 2018). The nutritional profile of fortified foods is determined by a number of factors, including the amount of protein incorporated and its digestibility score (Digestible Indispensable Amino Acid Score, DIAAS), the number of important vitamins and minerals present, and the presence of EAAs. (Anonymous, 2013). Fish proteins are more readily digested than those of plant protein (Desai et al., 2019). Thus, fish protein incorporation in staple foods is triggering much attention.

Consumption of fish and fishery products around the world has been increasing tremendously with a projected per capita growth of 20.5 kg in 2018 which is much higher than previous years (Anonymous, 2020). Seafood-based products are gaining a lot of interest and popularity among consumers in recent trends where cereal products like pasta, noodles are of huge market value (Binsi et al., 2018). Along with proteins, long-chain omega-3 fats, iodine, vitamin D, iron, calcium, zinc, etc. are present in fish and fishery products (Venugopal, 2018) which help to reduce malnutrition, hypertension, and cardiovascular disease as well as essential for brain development, neurodevelopment, mental health growth, child's development, smooth functioning of the immune system in human beings (Kadam and Prabhasankar, 2010; Ashraf et al., 2020). These nutrients can be accomplished by the human body through the fish powder (Anbudhasan et al., 2014). Snack-foods, mainly made from wheat, corn, maize, barley, soybean, or rice are rich in carbohydrate (Wanjala et al., 2020) and lack adequate amounts in protein, ω-3 fatty acids, and essential amino acids (particularly methionine, lysine, histidine, and valine), LC-PUFA (Long Chain Polyunsaturated Fatty acid) including docosahexaenoic (DHA) and eicosapentaenoic (EPA) acid. Therefore, they are considered nutritionally imbalanced food (Giuberti et al., 2018; Larretxi et al., 2019). For that reason, the cereal food industry has introduced and endorsed fortified foods to boost the nutritional quality of such type of staple food items by addition of protein-lipid enrich ingredients with it. Therefore, these cereal products can achieve more values while fortified with fish protein concentrate, fish protein powder, surimi powder, etc. (Brennan et al., 2004). Fish powder or fish protein concentrate, the fish processing by-products can be utilized in these starch-based foods as they are the cheap source of high-quality nutrients as well as rich source of essential amino acids and polyunsaturated fatty acids especially EPA and DHA (Oliveira et al., 2013; Stevanato et al., 2010). Few studies have reported successful incorporation of fish protein powder into starch-based foods to manufacture nutritionally balanced diet and have also observed consumers' acceptance.

2. VALUE ADDITION IN FISH AND FISHERY PRODUCTS

Value addition is one of the most promising areas in the fish processing industry and has great potential. Value addition means any additional activity that changes the nature of a product with an increase in value at the time of sale. According to Coltrain et al. (2000), adding value to a food product defines as a transformation from its unique original state to a progressively more valuable form. The requirement of product diversification and so on improving the economy through value-added fishery products has persuaded numerous manufacturers to turn out to be progressively resourceful. In an extensive term, value addition is changing any product's current place, time, and method characteristics through economical perspective into preferable marketing appearances. Such type of goal can be accomplished by cereal-based products such as pasta and noodles, through fortification of the same with nutritionally rich fish and fishery products like mince, surimi, surimi powder, etc. Adding one or more functional components to food for fulfilling the nutrients deficiencies as well as increasing the biochemical activity of newly formed food is the main tenacity of fortification (Lorusso et al., 2017). Fortification of pasta with fish protein is noteworthy as both products have their importance in the marketplace. As pasta is also a convenient ready-to-cook product like noodles, the demand for such products is gradually growing (Yerlikaya et al., 2005). On the other hand, fish is an important source of protein (about 18–20%) and is an important item in the diet (Tacon

and Metian, 2013). Considering the demand for ready-to-eat fish products especially in developing countries like India and Southeast Asia, there is an instant need as well as opportunities to diversify seafood-based products. Preparation of fish pasta is one of such technologies for value-added product diversification. Various fish species, mostly the economically less important ones are used for the preparation purpose to prevent post-harvest losses. In previous years, pasta has been fortified using different ingredients including quinoa flour (Gimenez et al., 2016), lentil flour (Aryee and Boye, 2016), beef meat (Liu et al., 2016), and freeze-dried shrimp powder (Ramya et al., 2015). For fortification of wheat-based products, stabilized fish proteins particularly surimi are a very fit material. Presently a wide variety of fish are used for surimi preparation although lean varieties with about 70% of myofibrillar proteins are preferable. Among some freshwater fish silver carp (Chowdhury et al., 2009a; Chowdhury et al., 2009b), common carp (Hu et al., 2010), *Labeo calbasu* (Yathavamoorthi et al., 2010), and tilapia (Sampels, 2015) were reported to be suitable for the production of surimi. The utilization of freshwater species such as tilapia, carps, etc. for value addition offers many advantages to the producer country i.e., local labor can be hired easily, additional ingredient's available from local markets, by-products problems resolved, and moreover the final product can be shipped more efficiently and earn additional high price per kg. This contributes to the increase in the average price for end products in international markets as well despite prices contribution from feed, fuel, and transport (Fitzsimmons, 2008).

3. COMMON PASTA, ITS VARIATIONS, AND PROCESSING

Pasta is the most commonly consumed paste product made from durum wheat. The term 'pasta' has generally been reserved to describe paste products fitting the Italian style of extruded foods such as spaghetti or lasagna and is usually distinguished from the Oriental style of sheeted and cut foods called 'noodles', which are commonly made from wheat other than durum (Dick and Matsuo, 1988). Pasta is a traditional food product with origins dating back to the first century B.C. (Agnesi, 1996) which is becoming increasingly popular worldwide because of its convenience, nutritional quality, and palatability (Cubadda, 1994). Italians, who are the largest consumers of pasta products in the world, call these products *'pasta alimentare'* (alimentary paste) (Dick and Matsuo, 1988; Donnelly and Ponte, 2000). In 2019, near about 10 million tonnes pasta were produced in the world according to International Pasta Organisation. Pasta consumption per capita in Italy is 26 kg. Venezuela follows Italy with 13.2 kg, Tunisia with 11.9 kg, Greece with 10.6 kg, Switzerland with 9.2 kg and Turkey with 6.6 kg. The average per capita consumption stands at 5.3 kg in 2019 all over the world. The average revenue per person in the Pasta and Noodles segment amounts to US$10.95 in 2019 with high market growth in Europe (Anonymous, 2020a).

World pasta production are given below (Table 1 and Figure 1):

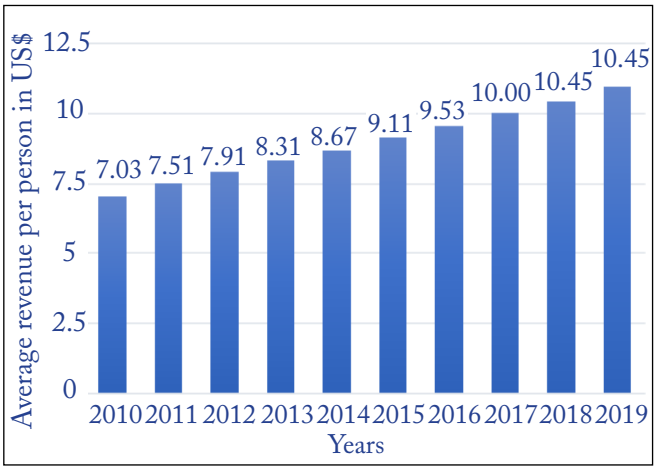

Figure 1: Revenue per person in the Pasta and Noodles segment (Source: Anonymous, 2020b)

Pasta can be categorized into four main groups or types: a. long-goods such as spaghetti, vermicelli, and linguine; b. short-goods include elbow macaroni, rigatoni, and ziti; c. egg pasta, consists of pasta made with egg; d. specialty items such as lasagna, manicotti, jumbo shells, and stuffed pasta. Over 600 pasta shapes are produced, however, the number of sizes and shapes that can be produced is virtually unlimited and depends on the shape of the die from which the product is extruded or the cutter with which it is cut. Spaghetti which is in the form of solid rods, elbow macaroni, lasagna, shells, and various noodle shapes are among the most popular shapes (Dick and Matsuo, 1988). Traditionally in the kitchen, egg is typically added to pasta and so too in manufacturing egg pasta is very much important. The presence of egg and/or egg albumen adds both strength and color to the product and makes it a delicious dish. Fortified pasta, made by adding vitamin mixes, is a relatively important variety, mainly for the US market. The presence of vitamins not just adds to the nutritive value of the target products, addition of riboflavin improves color by providing a yellow tone. There is a small market for whole wheat pasta. Pasta made from whole wheat is quite different in appearance and texture and naturally has a higher fiber content. In Italy, it is considered sufficiently different from plain pasta to be not 'durum wheat' pasta, even though it is generally made from such, and pasta makers there require a license to produce it just as they do when they are

Table 1: World pasta production by countries (Source: Anonymous, 2014)

Country	Production (Tonnes)	Country	Production (Tonnes)	Country	Production (Tonnes)
Italy	3,326,750	Canada	170,000	Bolivia	43,000
United States *	2,000,000	Greece	165,000	Guatemala	38,000
Brazil	1,191,847	Japan	144,500	United Kingdom	35,000
Russia	1,083,000	Colombia	118,647	Netherlands	23,335
Turkey	1,000,000	Chile	126,080	Slovak Republic	22,000
Iran	560,000	Portugal	77,000	Costa Rica	20,873
Venezuela	372,515	Czech Republic	70,000	Sweden	20,200
Egypt	400,000	Hungary	66,000	Croatia	13,000
Germany	334,179	Rep. Dominicana	65,000	El Salvador	13,000
Mexico	330,000	Ecuador	56,000	Slovenia	6,261
Spain	254,876	Austria	54,778	Lituania	5,976
Peru	250,000	Romania	52,600	Panama	4,364
France	233,566	Australia	50,000	Latvia	1,845
Argentina	327,293	Switzerland	43,140	Estonia	1,400

*The figure includes dry pasta production for retail, food services, and industrial use (dry pasta used as an input into value-added products, such as soups, prepared frozen foods, boxed pasta dinners, etc.)

including soft wheat in their mix. There are many issues of concern when considering the quality of pasta at all stages of production. These include both quality and safety issues. Examples include drying faults, microbiological loads, and infestation.

The composition of durum wheat semolina can be divided into 3 main constituents, the main fraction being starch, varying between 70 and 80 % of the total weight, followed by proteins, reaching up to 15 % of the total weight, and the remaining part is composed of small amounts of fiber, lipids, vitamins, and minerals (Petitot et al., 2010). The most simple and common method for the production of pasta is through cold extrusion. In this process, the semolina flour is mixed with water, usually about 30-35% moisture (Brennan et al., 2004). Mixing is an important part of the pasta-making process to ensure homogeneity and diffusion of water into the center of semolina particles to form a dough. After mixing, the dough is extruded under high pressure through a die to obtain a desirable pasta shape. Cereal-based food products (pasta, noodles, and bread) are mainly made up of a variety of micronutrients including protein, lipid, and starch. During food processing, these micronutrients undergo different complex interactions which influence physicochemical, nutritional (starch and protein digestibility), sensory, and antioxidant properties of the final product (Parada and Santos, 2016). During the extrusion process, the protein molecules interact strongly and form a strong gluten network which determines the final cooking and texture quality of the pasta (Bustos et al., 2015). The major protein fractions in the semolina are glutenins and gliadins. Gluten is responsible for the development of dough during mixing and extrusion, entrapping the starch granules in its network. During the processing of pasta, these proteins interact with each other and form intra- and inter-molecular disulfide (SS) bonds that will help to develop the strong viscoelastic gluten network (Lamacchia et al., 2010). This viscoelastic network restricts starch swelling, maintaining the structure of pasta during cooking, and thus preventing cooking losses. During cooking, protein coagulation and starch gelatinization occur. Due to the faster rate of starch swelling compared to the slower rate of protein interaction a weaker protein network is formed inside the pasta (Petitot et al., 2010) (Figure 2 and Table 2).

4. PASTA FROM DURUM WHEAT

Pasta today is a food that is accepted and used worldwide at varying degrees of importance. It is also a sophisticated industry that now utilizes advanced technologies to maximize efficiency, output, and quality. Pasta in the Italian style is almost universally made from the milled product of durum wheat: semolina. Makers are not permitted to produce pasta from anything other than durum wheat unless a special license is obtained because of high regulation in the market. These limitations in Italy may have assisted with sustaining the conviction somewhere

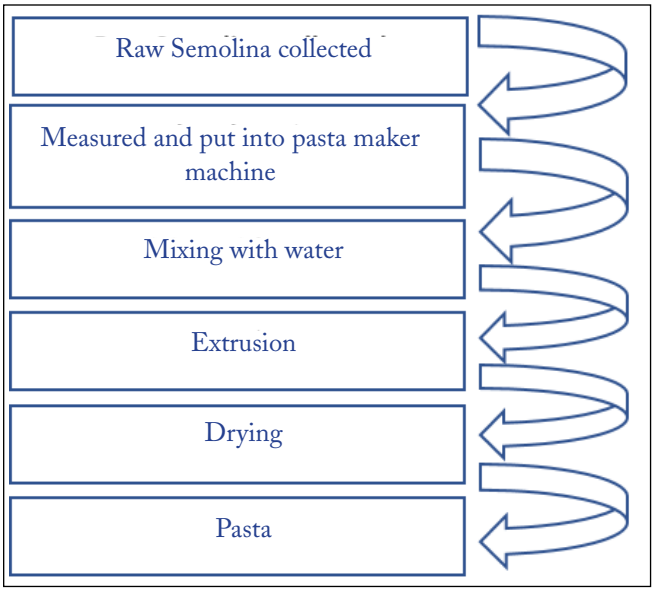

Figure 2: Basic pasta production procedure

Table 2: Composition content (per 100 g) (Source: Kore, 2021)

Moisture (g)	12.4	Calcium (mg)	17.0
Proteins (g)	10.8	Phosphorus (mg)	165.0
Lipids (g)	0.3	Sodium (mg)	5.0
Carbohydrates (g)	82.8	Potassium (mg)	160.0
Starch (g)	72.2	Vit. B1 (mg)	0.14
Soluble (g)	2.7	Vit. B2 (mg)	0.11
Dietary fiber (mg)	2.6	Vit. pp (mg)	2.0
Iron (mg)	1.3	Energy (kcal)	356

else that great quality pasta may just be produced using durum wheat. Semolina is the coarsely ground endosperm of durum, hard spring wheat with a high-gluten content and golden color. It is hard, granular, and resembles sugar. The term 'semolina' is derived from the Italian word 'semolina' and the French equivalent 'semoule' and is defined as the purified millings of durum wheat, which has been ground so that all of the products pass through a No. 22 U.S. sieve and not more than 3% shall pass through a No. 100 U.S. sieve (Donnelly and Ponte, 2000). Durum flour is finely ground semolina. It is usually enriched and used to make noodles, pasta. Although the major quality issues which are given the maximum yield of semolina during milling are particle size, ash content, different speck count, the color of the yield, moisture content of the end product Semolina milling is a specialized part of the wheat milling industry (Figure 3).

The final quality after drying of pasta may depend on factors such as particle size and uniformity of particle size. The absence of specks, dark or light color, is also critical for visual, and sometimes physical quality. The second

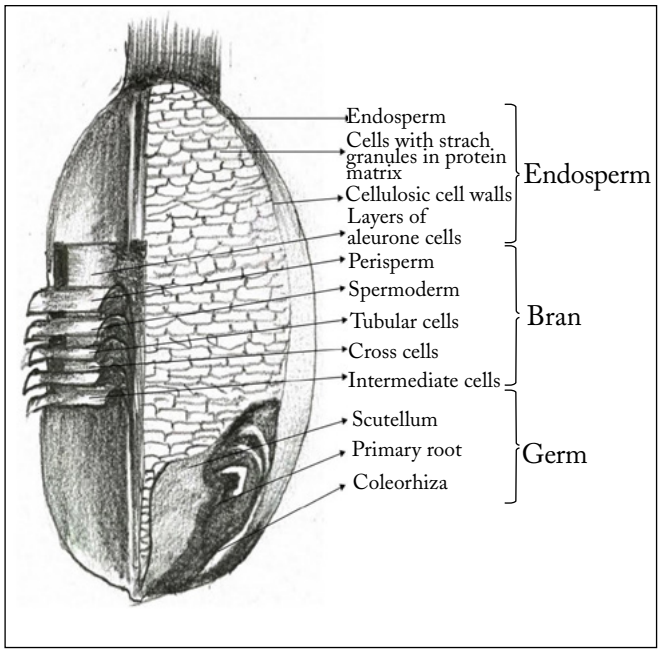

Figure 3: Durum wheat kernel structure

important thing is the blending and production of the dough. To form pasta mainly semolina is mixed with water with other basic ingredients maintaining their quality. The usual basic ingredients are wheat flour or semolina and water. Alternatives include potato flour and maize flour. Despite being produced only from durum wheat semolina, pasta is in some cases additionally produced using non-durum wheat flour, or farina or blends of durum and common wheat since normal wheat is exchanged at a lower cost than durum wheat. (Kill and Turnbull, 2008).

5. SURIMI POWDER OR FISH PROTEIN POWDER (FPP)

Surimi is primarily stabilized myofibrillar fish protein extracted from mechanically deboned fish flesh by washing minced meat that has been separated from bones, skin, and guts (Shaviklo, 2015) with water and blended with cryoprotectant. In general, surimi is processed through mincing, washing, mixing with cryoprotectant, and freezing (Park, 2005a). Washing with cold water removes fat and any other water-soluble contents and insoluble myofibril protein is isolated. After being mixed with a cryoprotectant, this protein is called surimi (Okada, 1992). This mixture is then frozen and stored at -25°C or below (Santana et al., 2015). During frozen storage of fish muscle, denaturation and/or aggregation of myofibrillar proteins cause a loss of functional properties (Xia et al., 2010). Freezing of surimi is done commercially by incorporation of sucrose (4%), sorbitol (4%), and polyphosphates (0.2%) which protect fish myofibrillar proteins during long periods of frozen storage (Majumder et al., 2017). The wet surimi is dried to produce surimi powder. The drying process involves

the removal of volatile substances (mostly moisture) from a product (Santana et al., 2012). The main purpose of drying technologies developed in food industries is to prolong the shelf life of a food product (Sarkar et al., 2020). Drying refers to dewatering, which means removing liquid water from the product (Ishwarya et al., 2015). In thermal drying, energy transfer 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. However, both drying and heating can lead to protein denaturation (Carvajal et al., 2005). For a heat-sensitive material such as protein, the heating temperature of evaporation can be lowered by lowering pressure using a vacuum (Menon and Mujundar, 1987). Available drying methods for making surimi powder include freeze-drying, spray drying, oven drying, solar drying, and mechanical drying.

Meanwhile, surimi powder (the dried form of surimi) does not require frozen storage, which lowers the distribution and storage costs relative to frozen surimi. Surimi powder also offers advantages such as ease of handling and the ability to be used in dry mix applications (Santana et al., 2012). Surimi powder, the dry form of surimi is a useful raw material for making various fish-based products due to its good physicochemical properties (Shaviklo, 2015). The nutritional value and physicochemical properties of surimi powder make it ideal for producing formulated seafood and other food products (Park and Lin 2005b).

6. FISH PROTEIN POWDER (FPP) OR SURIMI POWDER AS AN ADDITIVE

Among the various additives i.e., polyphosphates, hydrocolloids, antioxidants, starches, etc., fish protein powder is widely used to make fortified dishes to improve pasta's nutritional quality. Fish protein powder is a dried and stable fish product used for human consumption in which protein is more concentrated (65-90%) than in the original fish flesh (Shaviklo et al., 2010). Due to its strong interaction with other proteins and high gelation ability FPP has been used in the food industry as a binder, emulsifier, and dispersing agent in preparing herring roe, fillet blocks, and restructured products from beef, pork, and chicken (Pires et al., 2012). Colour is also an important quality attribute of fish protein ingredients. The color of FPP varies from light grey to creamy or pinkish depending on the type of fish used (Shaviklo et al., 2010). Research has shown that FPP is a valuable protein supplement to improve protein quality particularly in the diets of preschool children where it may aid in the increase of weight and height of the children (Pee and Bloem, 2009). FPP helps to increase the protein content of the diet and is beneficial for the growth of infants and children under five (Vakily et al., 2012). Fish protein powder is better utilized with vegetable protein and increased the content of nutrients in the diet. Friedman (1996) revealed that the nutritive value of cereal protein increased when combined with an FPP. The addition of 3% of FPP to wheat flour having a protein content of 10.4% increased its protein content to 12.4% with an increase of net protein utilization from 50 to 67%. These types of products have good quality characteristics and consumer acceptance (Shaviklo et al., 2011).

Fortification of starchy snacks with fish proteins could be a healthy way to boost nutritional intake and increase fish protein consumption. However extensive researches illustrate that the potential uses of fish protein ingredients are affected by functional properties of proteins such as water holding capacity, gelation, foam stability, and emulsion capacity (Halim et al., 2016). Similarly, making gluten-free pasta is a wise tendency of various manufacturers because of high consumers' preference (Vijaykrishnaraj et al., 2014). Extruded snack products with a high expansion ratio and low product density are also produced to provide quality foods in the market (Pansawat et al., 2008). In summary, while there is convincing evidence of the ability to incorporate fish protein into cereal products, there is a need for further research in understanding the effect of incorporation of fish protein and lipid on the physicochemical, nutritional (starch, protein digestibility and antioxidant activity) and sensory properties of the product. Usually, cereal products (pasta and bread) have a low protein content (6-10%) which is also limited in some essential amino acids (Singh et al., 2014). To increase the nutritive value of cereal products, the incorporation of protein-rich fish powder could be important. The level and composition of protein in wheat or semolina flour are of great importance for the cooking and eating qualities of cereal products (Fu, 2008). Fish proteins are more highly digestible than those of plant protein. Digestibility is the hydrolysis of protein by enzymes into amino acids or peptides for absorption in the intestine. Protein digestibility is the potential parameter to access the use of protein in the body. Many factors play an important role in digestion and absorption such as phenolic compounds, anti-nutritional factors, protein inhibitors, and processing parameters (Gilani et al., 2012). In extruded food products, the interaction of protein, starch, and dietary fiber diminish the hydrolysis of protein. During the processing of the food product, protein molecules experience many changes including lysine residue when high thermal treatment is used and these ultimately affect the overall digestibility of the product. Majumder et al. (2017) reported that dry surimi powder is the way to decrease the huge cost of freezing and frozen storage and can be transferred to the wet surimi by rehydrating it with water. So, this can be a way better option for partial substitution with various staple foods to increase the protein content.

7. PREPARATION OF SURIMI PROTEIN FORTIFIED PASTA

Fortification of pasta using dried minced fish meat or dried fish meat powder like *Katla Katla* (Devi et al., 2013), *Pseudophycis bachus* (Desai et al., 2018), *Oncorhynchus tschawytscha* (Desai et al., 2019), *Oreochromis niloticus* (Monteiro et al., 2016) is extensively researched in recent times. Pasta can fortify with different percentage together with a control pasta (100% semolina) resulted in significantly ($P < 0.05$) increased value of protein (12.88–23.40%), lipid (0.46–7.20%), ash (0.39–0.57%) and energy (122.26–161.08 kcal) and also higher redness values. While pasta fortified with 5%, 10%, 15%, and 20% of tilapia surimi powder showed that pasta with 10% of tilapia surimi powder can be technologically altered in the food industry for the nutritional enrichment of traditional pasta with minimal negative effects on the chemical stability of the final product during 45 days at ambient temperature. Although very high concentrations of surimi powder in the pasta may decrease the consumer's acceptability in terms of color, taste, hardness, and elasticity as well as the overall acceptance.

8. QUALITY ASPECTS IN PASTA PROCESSING

The quality of raw materials such as semolina, raw fish need to check thoroughly because they largely affect the final quality of the pasta produced. Color, flavor, texture, cooking quality, water holding capacity as well as quality checks during extended storage periods are also vital quality parameters that need to be checked in every step of processing and storage. The cooking quality of pasta depends on the content and quality of protein, ash, and starch as well as it can be influenced by the thickness of the pasta. The color parameter of raw pasta is an important factor responsible for consumer acceptance (Petitot et al., 2010). Generally, consumers like pasta with a bright yellow color (Pongpichaiudom and Songsermpong, 2018). The Colour of pasta depends on the properties of flour used such as carotenoids and the composition of proteins (Ohm et al., 2008). Therefore, maintaining color within consumer acceptance levels is essential. The heating during dry pasta manufacturing potentially promotes reactions between amine groups from protein and reducing polysaccharides favoring Maillard reaction (Dickinson, 2008). A good quality pasta should have the yellowish color (Doxastakis et al., 2007; Cavazza et al., 2013). Texture analysis is used to determine many texture parameters of pasta like hardness, cohesiveness, springiness, chewiness, gumminess, adhesiveness, and resilience. Hardness and tensile (breaking) strength are two good properties to ensure the acceptance of products. The textural properties of pasta are mainly controlled by a gluten network, which is a structural network of starches, protein, lipid additions, and other ingredients (Chang and Wu, 2008). Hardness or firmness is basically a replication of the integrity of the protein matrix and the bond strength of protein after the cooking process is done (Larrosa et al., 2016). Desai et al. (2018) reported a decrease ($p < 0.05$) in the firmness of pasta as the inclusion of salmon fish powder (SFP) level increased and the firmness decreased. Tensile (breaking) strength was examined as the maximum force applied before the pasta broke (Chang and Wu, 2008). Salt or other ingredients also influence the texture. Cooking quality is generally measured based on water holding capacity, cooking time, and cooking loss. The cooking quality of pasta depends on the content and quality of protein, ash, and starch. Cooking quality of pasta was the most important aspect from the consumer's point of view, including optimal cooking time, swelling or water uptake during cooking, the texture of the cooked product, stickiness, aroma, and taste (Devi et al., 2013). These cooking factors of pasta are related to the gelatinization rates and chemical composition of the pasta used. Sensory analysis of pasta involves the evaluation of cooked pasta samples for appearance, color, aroma, taste, texture (in mouth), and overall acceptability (Khan et al., 2014). Production of dry pasta is accomplished by water removal. So sufficient and somewhat accurate heat treatment needs to be checked. In order to keep the production cost lower, the use of excessive raw materials should be avoided. And finally, cautions should be taken in production premises with proper maintenance of cleaning approach.

9. CONCLUSION

Pasta is one of the bakery food products which has been endorsed and marketed seamlessly in the 21st century. It is established as important convenience food in various Asian countries due to its excellent flavour and instant preparation process. Besides that, nowadays, the world's population rely more on an affordable source of protein. So, focuses are made on the development of nutrition-enriched food products with a lower glycemic index (rich in carbohydrate) by fortification of fish protein with prolonged shelf-life.

10. REFERENCES

Agnesi, V.F., 1996. The history of pasta. Piazza Scenderberg 00187, Rome, Italy. (Also, at this address is the National Museum of Pasta.)

Anbudhasan, P., Asvini, G., Surendraraj, A., Ramasamy, D., Sivakumar, T., 2014. Development of functional pasta enriched with omega-3 fatty acids. Fishery Technology 51, 242–246.

Anonymous, 2002. Food and Agriculture Organization of the United Nations. Agricultural commodities: profiles

and relevant WTO negotiating issues, Prepared by the Commodities and Trade Division as a background document for the Consultation on Agricultural Commodity Price Problems, Rome. Available from http://www.fao.org/3/Y4343E/y4343e00.htm

Anonymous, 2013. Food and Agriculture Organization of the United Nations. Dietary protein quality evaluation in human nutrition. Report of an FAO Expert Cosultation, 92: 1-79. ISBN 978-92-5-107417-6. Available from http://www.fao.org/3/i3124e/i3124e.pdf

Anonymous, 2014. International pasta organization (IPO)-Survey. The world pasta industry in 2013. Available from http://www.internationalpasta.org. Czech Journal of Food Sciences, 26(6), 421–427.

Anonymous, 2020a. The Agricultural and Processed Food Products Export Development Authority (APEDA). Available from https://agriexchange.apeda.gov.in/Weekly_eReport/Cereal_Preparations_Report. Accessed in May 2021

Anonymous, 2020b. The Agricultural and Processed Food Products Export Development Authority (APEDA). Available from https://agriexchange.apeda.gov.in/Weekly_eReport/Cereal_Preparations_Report. Accessed in May 2021

Aryee, A.N., Boye, J.I., 2016. Improving the digestibility of lentil flours and protein isolate and characterization of their enzymatically prepared hydrolysates. International Journal of Food Properties 19(12), 2649–2665.

Ashraf, S.A., Adnan, M., Patel, M., Siddiqui, A.J., Sachidanandan, M., Snoussi, M., Hadi, S., 2020. Fish-based bioactives as potent nutraceuticals: Exploring the therapeutic perspective of sustainable food from the sea. Marine drugs, 18(5), 265.

Binsi, P.K., Sreelakshmi, K.R., Kumar, K.A., 2018. Value added fish products. ICAR-Central Institute of Fisheries Technology, Cochin, Chapter 4, 2–14.

Bourre, J.M., Paquotte, P., 2008. Seafood (wild and farmed) for the elderly: contribution to the dietary intakes of iodine, selenium, DHA and vitamins B12 and D. The Journal of Nutrition Health and Aging 12(3), 186–192.

Brennan, C.S., Kuri, V., Tudorica, C.M., 2004. Inulin-enriched pasta: effects on textural properties and starch degradation. Food chemistry 86(2), 189–193.

Bustos, M.C., Perez, G.T., Leon, A.E., 2015. Structure and quality of pasta enriched with functional ingredients. RSC Advances 5(39), 30780–30792.

Carvajal, P.A., Lanier, T.C., MacDonald, G.A., 2005. Stabilization of proteins in surimi. In: Surimi and surimi seafood. Taylor & Francis, Boca Raton, USA, 2, 163–225.

Cavazza, A., Corradini, C., Rinaldi, M., Salvadeo, P., Borromei, C., Massini, R., 2013. Evaluation of pasta thermal treatment by determination of carbohydrates, furosine, and color indices. Food and bioprocess technology 6(10), 2721–2731.

Chang, H.C., Wu, L.C., 2008. Texture and quality properties of Chinese fresh egg noodles formulated with green seaweed (*Monostroma nitidum*) powder. Journal of Food Science, 73(8), S398-S404. DOI: 10.1111/j.1750-3841.

Chauhan, N., Vaidya, D., Gupta, A., Pandit, A., 2017. Fortification of pasta with white button mushroom: Functional and rheological properties. International Journal of Food and Fermentation Technology 7(1), 87–96.

Chowdhury, S., Sarkar, S., Dora, K.C., 2009a. Quality changes in fish cakes prepared from washed silver carp mince under frozen storage (-20°C). Indian Journal of Nutrition and Dietetics 46(2), 78–85.

Chowdhury, S., Sarkar, S., Dora, K.C., 2009b. Study on shelf life of fish cake prepared from surimi of silver carp (*Hypophthalmichthys molitrix*) during frozen storage. Bangladesh Journal of Fisheries Research, 13(1): 77-82. Available from http://aquaticcommons.org/id/eprint/18932

Coltrain, D., Barton, D., Boland, M., 2000. Value added: opportunities and strategies. Arthur Capper Cooperative Center, Department of Agricultural Economics, Cooperative Extension Service, Kansas State University.

Cubadda, R., 1994. Nutritional value of pasta. Effects of processing conditions. Italian Food Beverage Technology 3, 27–33.

Desai, A.S., Beibeia, T., Brennan, M.A., Guo, X., Zeng, X.A., Brennan, C.S., 2018. Protein, amino acid, fatty acid composition, and in vitro digestibility of bread fortified with Oncorhynchus tschawytscha powder. Nutrients 10(12), 1923.

Desai, A.S., Brennan, M.A., Brennan, C.S., 2019. Influence of semolina replacement with salmon (*Oncorhynchus tschawytscha*) powder on the physicochemical attributes of fresh pasta. International Journal of Food Science and Technology 54(5), 1497–1505.

Devi, L.N., Aparna, K., Kalpana, K., 2013. Utilization of fish mince in formulation and development of pasta products. International Food Research Journal, 20(1): 219. http://www.ifrj.upm.edu.my/20%20(01)%202013/29%20IFRJ%2020%20(01)%202013%20Aparna%20(058).pdf

Dick, J.W., Matsuo, R.R., 1988. Durum wheat and pasta products. In: Wheat: Chemistry and technology, 3 rd edn. American Association of Cereal Chemists, St.

Paul, Minnesota, USA, 2, 507–547.

Dickinson, E., 2008. Interfacial structure and stability of food emulsions as affected by protein-polysaccharide interactions. Soft Matter 4(5), 932–942. DOI: 10.1039/b718319d.

Donnelly, B.J., Ponte Jr, J.G., 2000. Pasta: raw materials and processing. In: Handbook of Cereal Science and Technology, Revised and Expanded, 2 nd edn., CRC press, India, 663–674.

Doxastakis, G., Papageorgiou, M., Mandalou, D., Irakli, M., Papalamprou, E., D'Agostina, A., Resta, D., Boschin, G., Arnoldi, A., 2007. Technological properties and non-enzymatic browning of white lupin protein enriched spaghetti. Food Chemistry 101(1), 57–64.

Fitzsimmons, K., 2008. Tilapia product quality and new product forms for international markets. In: 8th International Symposium on Tilapia in Aquaculture. Available from https://cals.arizona.edu/azaqua/ista/ISTA8/Fitzsimmons.pdf

Friedman, M., 1996. Nutritional value of proteins from different food sources. A review. Journal of Agricultural and Food Chemistry, 44(1), 6–29.

Fu, B.X., 2008. Asian noodles: History, classification, raw materials, and processing. Food Research International 41(9), 888–902.

Fujibayashi, M., Tanaka, N., Hashido, S., Takasawa, A., Nishimura, O., 2018. Nutritional quality of fish faeces is enhanced by highly unsaturated fatty acid-producing heterotrophic protozoa. Acta Oecologica, 89, 21-26. https://doi.org/10.1016/j.actao.2018.04.003.

Gilani, G.S., Xiao, C.W., Cockell, K.A., 2012. Impact of antinutritional factors in food proteins on the digestibility of protein and the bioavailability of amino acids and on protein quality. British Journal of Nutrition 108(2), 315–332.

Gimenez, M.A., Drago, S.R., Bassett, M.N., Lobo, M.O., Samman, N.C., 2016. Nutritional improvement of corn pasta-like product with broad bean (Vicia faba) and quinoa (Chenopodium quinoa). Food Chemistry 199(11); 150-156. DOI: 10.1016/j.foodchem.2015.11.065.

Giuberti, G., Gallo, A., 2018. Reducing the glycaemic index and increasing the slowly digestible starch content in gluten-free cereal-based foods: A review. International Journal of Food Science & Technology 53(1), 50–60.

Halim, N.R.A., Yusof, H.M., Sarbon, N.M., 2016. Functional and bioactive properties of fish protein hydolysates and peptides: A comprehensive review. Trends in Food Science & Technology 51(5), 24–33.

Hu, Y., Morioka, K., Itoh, Y., 2010. Participation of cysteine protease cathepsin L in the gel disintegration of red bulleye (*Priacanthus macracanthus*) surimi gel paste. Journal of the Science of Food and Agriculture 90(3), 370–375.

Ishwarya, S.P., Anandharamakrishnan, C., Stapley, A.G., 2015. Spray-freeze-drying: A novel process for the drying of foods and bioproducts. Trends in Food Science & Technology 41(2), 161–181.

Kadam, S.U., Prabhasankar, P., 2010. Marine foods as functional ingredients in bakery and pasta products. Food Research International 43(8), 1975–1980.

Khan, I., Yousif, A.M., Johnson, S.K., Gamlath, S., 2014. Effect of sorghum flour addition on in vitro starch digestibility, cooking quality, and consumer acceptability of durum wheat pasta. Journal of Food Science 79(8), 1559–1566.

Kill, R., Turnbull, K., 2008. Pasta and semolina technology Ed. John Wiley and Sons ISBN 978–0–4-470-99936-3.

Kore, T., 2021. Partial replacement of durum wheat flour with the blend of non-traditional cereals and legume flour on pasta quality: review. Food Science and Quality Management, 107(4), 30-31. DOI: 10.7176/FSQM/107-04

Lamacchia, C., Baiano, A., Lamparelli, S., Padalino, L., La Notte, E., Di Luccia, A., 2010. Study on the interactions between soy and semolina proteins during pasta making. Food Research International 43(4), 1049–1056.

Larretxi, I., Simon, E., Benjumea, L., Miranda, J., Bustamante, M.A., Lasa, A., Eizaguirre, F.J., Churruca, I., 2019. Gluten-free-rendered products contribute to imbalanced diets in children and adolescents with celiac disease. European Journal of Nutrition 58(2), 775–783.

Larrosa, V., Lorenzo, G., Zaritzky, N., Califano, A., 2016. Improvement of the texture and quality of cooked gluten-free pasta. Food Science and Technology 70(6), 96–103.

Liu, J., Cao, Y., Wang, Q., Pan, W., Ma, F., Liu, C., Chen, W., Yang, J., Zheng, L., 2016. Rapid and non-destructive identification of water-injected beef samples using multispectral imaging analysis. Food Chemistry 190(1), 938–943.

Lorusso, A., Verni, M., Montemurro, M., Coda, R., Gobbetti, M., Rizzello, C.G., 2017. Use of fermented quinoa flour for pasta making and evaluation of the technological and nutritional features. Food Science and Technology 78(5), 215–22.

Majumder, A., Chowdhury, S., Dora, K.C., Nath, S., Mondol, K., 2017. Physicochemical properties and proximate composition of surimi powder from Tilapia (*Oreochromis mossambicus*). Journal of Agricultural

Engineering and Food Technology 4(1), 37–41. e-ISSN: 2350-0263. https://krishisanskriti.org/Publication.html

Marchini, D., Montanari, R., Bottani, E., Tagliavini, G., Digiuni, S., 2016. Lifecycle modelling of an innovative durum wheat debranner. The 14th International Multidisciplinary Modeling & Simulation Multiconference, September 26-28, Larnaca, Cyprus.

Menon, A.S., Mujumdar, A.S., 1987. Drying of solids: principles, classification, and selection of dryers, vol. 3. Marcel Dekker, New York.

Monteiro, M.L.G., Marsico, E.T., Junior, M.S.S., Magalhaes, A.O., Canto, A.C.V., CostaLima, B.R., Alvares, T.S., Junior, C.A.C., 2016. Nutritional profile and chemical stability of pasta fortified with tilapia (*Oreochromis niloticus*) flour. PloS one 11(12), e0168270.

Ohm, J.B., Ross, A.S., Peterson, C.J., Ong, Y.L., 2008. Relationships of high molecular weight glutenin subunit composition and molecular weight distribution of wheat flour protein with water absorption and color characteristics of noodle dough. Cereal Chemistry 85(2), 123–131.

Okada, M., 1992. History of surimi technology in Japan. In: Lanier TC, Lee CM (eds) Surimi Technology. Marcel Dekker, New York, 1992, chap. 1, 30–50.

Oliveira-Segundo, J.N., Lima, F.R.D.S., Akao, M.M.F., 2013. Small crumbled diet versus powdered diet in restricted feeding management of juvenile Nile tilapia. Acta Scientiarum. Animal Sciences 35(2), 127–131.

Pansawat, N., Jangchud, K., Jangchud, A., Wuttijumnong, P., Saalia, F.K., Eitenmiller, R.R., Phillips, R.D., 2008. Effects of extrusion conditions on secondary extrusion variables and physical properties of fish, rice-based snacks. Food Science and Technology 41(4), 632–641.

Parada, J., Santos, J.L., 2016. Interactions between Starch, Lipids, and Proteins in Foods: Microstructure Control for Glycemic Response Modulation. Critical Reviews in Food Science and Nutrition 56(14), 2362–2369.

Park, J.W., 2005a. Ingredient technology for surimi and surimi seafood. In: Park, J.W. (Ed). Surimi and Surimi Seafood, 2nd edn., Boca Raton, FL: CRC Press, 650–708.

Park, J.W., Lin, T.J., 2005b. Surimi: manufacturing and evaluation. Surimi and surimi seafood, 33–106.

Pee, S., Bloem, M.W., 2009. Current and potential role of specially formulated foods and food supplements for preventing malnutrition among 6 to 23 month old children and for treating moderate malnutrition among 6 to 59 month old children. Food and Nutrition Bulletin 30(3), S434–63.

Petitot, M., Boyer, L., Minier, C., Micard, V., 2010. Fortification of pasta with split pea and faba bean flours: Pasta processing and quality evaluation. Food Research International 43(2), 634–641.

Pires, C., Costa, S., Batista, A.P., Nunes, M.C., Raymundo, A., Batista, I., 2012. Properties of protein powder prepared from Cape hake by-products. Journal of Food Engineering 108(2), 268–275.

Pongpichaiudom, A., Songsermpong, S., 2018. Evaluation of microstructure and quality characteristics of microwave-dried instant noodles enriched with chicken meat, egg yolk, and seaweed. Journal of Food Measurement and Characterization 12(1), 22–34.

Ramya, N.S., Prabhasankar, P., Gowda, L.R., Modi, V.K., Bhaskar, N., 2015. Influence of freeze-dried shrimp meat in pasta processing qualities of Indian *T. durum* wheat. Journal of Aquatic Food Product Technology 24(6), 582–596.

Sampels, S., 2015. The effects of processing technologies and preparation on the final quality of fish products. Trends in Food Science & Technology 44(2), 131–146.

Santana, P., Huda, N., Yang, T.A., 2012. Technology for production of surimi powder and potential of applications. International Food Research Journal 19 (4), 1313–1323. Available from http://www.ifrj.upm.edu.my/19%20(04)%202012/4%20IFRJ%2019%20(04)%202012%20Nurul%20(402).pdf

Santana, P., Huda, N., Yang, T.A., 2015. Physicochemical properties and sensory characteristics of sausage formulated with surimi powder. Journal of Food Science and Technology 52(3), 1507–1515.

Sarkar, P., Chowdhury, S., Nath, S., Murmu, P., Rahman, F.H., 2020. Effect of drying temperature on the quality of dry surimi powder from Pangasius. Current Journal of Applied Science and Technology 39(6), 147–155. DOI: 10.9734/cjast/2020/v39i630569

Sasidharan, A., Venugopal, V., 2020. Proteins and co-products from seafood processing discards: Their recovery, functional properties and applications. Waste and Biomass Valorization 11(11), 5647–5663.

Shaviklo, A.R., 2015. Development of fish protein powder as an ingredient for food applications: a review. Journal of food science and technology 52(2), 648–661.

Shaviklo, G.R., Arason, S., Thorkelsson, G., Sveinsdottir, K., Martinsdottir, E., 2010. Sensory attributes of haddock balls affected by added fish protein isolate and frozen storage. Journal of Sensory Studies 25(3), 316–331.

Shaviklo, G.R., Thorkelsson, G., Rafipour, F., Sigurgisladottir, S., 2011. Quality and storage stability

of extruded puffed corn-fish snacks during 6-month storage at ambient temperature. Journal of the Science of Food and Agriculture 91(5), 886–893.

Singh, R.K.R., Majumdar, R.K., Venkateshwarlu, G., 2014. Effect of process conditions on physico-chemical and sensory properties of fish-cereal-based extruded snack-like products. Journal of Food Processing and Preservation 38(1), 68–82.

Stevanato, F.B., Cottica, S.M., Petenuci, M.E., Matsushita, M., Desouza, N.E., Visentainer, J.V., 2010. Evaluation of processing, preservation and chemical and fatty acid composition of Nile Tilapia waste. Journal of Food Processing and Preservation 34(2), 373–383. DOI: 10.1111/j.1745-4549.2009.00429.x

Tacon, A.G., Metian, M., 2013. Fish matters: importance of aquatic foods in human nutrition and global food supply. Reviews in fisheries Science 21(1), 22–38.

Vakily, J.M., Seto, K., Pauly, D., 2012. The marine fisheries environment of Sierra Leone. Fisheries Centre Research Reports 20(4), 102–130.

Venugopal, V., 2018. Nutrients and nutraceuticals from seafood. In: Mérillon J-M, Ramawat KG, eds. Bioactive Molecules in Food. Springer International Publishing. Cham, Switzerland, 1397–1440.

Vijaykrishnaraj, M., Bharath Kumar, S., Prabhasankar, P., 2014. Green mussel (*Perna canaliculus*) as a marine ingredient to enrich gluten free pasta: product quality, microstructure and biofunctional evaluation. Journal of Food Measurement and Characterization 9(1), 76–85.

Wanjala, W.N., Mary, O., Symon, M., 2020. Optimization of protein content and dietary fibre in a composite flour blend containing rice (*Oryza sativa*), sorghum [*Sorghum bicolor* (L.) Moench] and Bamboo (*Yushania alpine*) shoots. Food and Nutrition Sciences 11(8), 789–806.

Xia, X., Kong, B., Xiong, Y., Ren, Y., 2010. Decreased gelling and emulsifying properties of myofibrillar protein from repeatedly frozen-thawed porcine longissimus muscle are due to protein denaturation and susceptibility to aggregation. Meat Science 85(3), 481–486.

Yathavamoorthi, R., Sankar, T.V., Ravishankar, C.N., 2010. Effect of ice storage and washing on the protein constituents and textural properties of surimi from *Labeo calbasu* (Hamilton, 1822). Indian Journal of Fisheries 57(4), 85-91.

Yerlikaya, P., Gokoglu, N., Uran, H., 2005. Quality changes of fish patties produced from anchovy during refrigerated storage. European Food Research and Technology 220(3-4), 287-291.

Zhang, T., Dou, W., Zhang, X., Zhao, Y., Zhang, Y., Jiang, L., Sui, X., 2021. The development history and recent updates on soy protein-based meat alternatives. Trends in Food Science & Technology 109, 702–710.