Journal of Entomology and Zoology Studies
Available online at www.entomoljournal.com

E-ISSN: 2320-7078
P-ISSN: 2349-6800
JEZS 2019; 7(3): 1400-1405

Received: 06-03-2019
Accepted: 10-04-2019

S. Nath
Department of Fish Processing Technology, College of Fisheries Science, Birsa Agricultural University, Ranchi, Jharkhand, India

AK Singh
Department of Aquaculture, College of Fisheries Science, Birsa Agricultural University, Ranchi, Jharkhand, India

Correspondence
S Nath
Department of Fish Processing Technology, College of Fisheries Science, Birsa Agricultural University, Ranchi, Jharkhand, India

Dry surimi powder from *Pangasianodon hypophthalmus*: A raw material for protein fortification

S Nath and AK Singh

Abstract
Surimi, the deboned concentrated myofibrillar protein extracted from fish flesh mixed with cryoprotectant, can be converted to a dried form, surimi powder can be used in dry mixing. Thus, the objective of the study was to determine the shelf life of prepared surimi powder from *Pangasianodon hypopthalmus* under refrigerated storage. The proximate composition, TPC (3.65±0.44 log cfu/g) and the quality parameters like TVB-N (10.97±0.23 mg/100gm), PV (4.57±0.18 meq active O_2/kg) and pH (6.3±0.21) suggested a good quality of raw material with a final yield of surimi powder 13.10±0.75%. The biochemical parameters and TPC of both surimi and surimi powder were found to be well within the limit of acceptability. During shelf life estimation of surimi powder stored at 4^{O}C, the significant ($p<0.05$) gradual increase in biochemical parameters over 210 days of storage suggesting that the surimi powder was acceptable till 210 days under refrigeration without crossing limit of acceptability.

Keywords: Pangasianodon hypophthalmus, surimi, dry surimi powder, biochemical changes

Introduction
Fish mince has been the focus of research for development of functional food or ready-to-eat 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 [1]. During preparation of surimi, washing of the fish mince with cold water is done to remove fat and other water-soluble contents. The myofibrillar protein, the primary muscle portion of fish, is isolated and then mixed with a cryoprotectant, to get surimi [2]. 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 [3]. 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. 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 [4]. 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 prepared from frozen surimi blocks by adopting different drying Technologies to prolong its shelf life.

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.

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 [1]. Another advantage of surimi powder is its usefulness in dry mixtures [5] that could help industries to modify the formulation of surimi-derived products, resulting in more homogenous blends and easier protein standardization.

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 [6]. 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.

Freshwater fish are excellent sources of high-quality protein since they are well balanced in essential amino acids and highly digestible [7]. The surimi making ability of many freshwater species could be upgraded by manipulating processing techniques [8]. Some investigations have been done on the quality of the mince of fresh water fish like silver carp, tilapia and Thai pangas for the manufacture of surimi [9]. *Pangasianodon hypophthalmus*, also known as *Pangasius sutchi*, is an exotic catfish that is endemic to the waters of Mekong basin in south-east Asia, belonging to the family Pangasiidae and commonly known as river/silver stripped cat fish, sutchi catfish and iridescent shark. *Pangasianodon hypophthalmus* was first introduced into India possibly during 1997 via Bangladesh and adopted for culture. According to DADF, GOI, 2017, it is called as "GAME CHANGER" because of its domestication through extensive culture and large-scale production and become an important fishery due to its remarkable growth rate (attains almost 1 kg in 90 days) in Indian environment. Pangas fillets were characterized by high moisture levels (75-80%) and lipid (16-18%) contents, medium protein (12.5-14.5%) and low ash (1-1.5%) contents. The *Pangasius* meat has high nutritive qualities and excellent sensory properties such as tender flesh, sweet taste, absence of fishy odour and spines, delicate flavour and firm texture when cooked; these are the attributes that favor consumer preference for sutchi catfish. There is a great potential for development of convenience products from surimi and surimi-based products such as fish fingers, fish cutlets, fish cakes, fish balls, fish pickles, smoked fish, canned fish, fish curry in retort pouches from *Pangasius* [10]. *Pangasius* also can be used as a raw material for development of surimi powder.

In context to Jharkhand, *Pangasius sp*., a widely cultured reasonably priced aquaculture produce, can be opted as an excellent raw material for fishery value added products. Surimi powder may prove useful for making friable food products such as crackers. Production of acceptable surimi powder from pangas will certainly put this fish species into suitable and profitable use, increasing the income of the farmers, creating employment opportunities and strengthen rural economy.

With the advancement of food technology, processing of surimi into dried form is flourishing so that it can be used in dry mixing. So, the purpose of the study is to establish and standardize the hypothesis that the functional properties of surimi powder from *Pangasius* is acceptable as a commercial preparation. Thus, the objective of the study was to determine the shelf life of prepared surimi powder under refrigerated storage.

Materials and Methods

Preparation of raw material

Fresh pangas also known as Sutchi Catfish (*Pangasianodon hypopthalmus*) was bought from the market by simple random sampling and used for the present study. The fish was transferred to the laboratory within an hour from the market in iced condition and processed immediately. The fish (*Pangasius hypophthalmus*) were weighed, beheaded, descaled, filleted and skinned manually. The fillets were fed into silent cutter and the mince thus collected was washed thoroughly by following three washing cycles using chilled water. The meat was pressed using screw press to drain off the excess water. Mince was prepared under good hygienic and sanitary conditions to prevent any cross contamination and was used for further studies. The yield of picked meat was calculated based on the whole fish and dressed fish weight respectively.

Experimental layout

Surimi production was carried out according to the method of Rawdkuen *et al* [11]. As illustrated in Figure 1. Surimi samples were dried in 60ºC drying temperature to prepare dry surimi powder (Figure 2), following the oven drying method Huda *et al.* [12] with slight modifications.

Chemical composition or proximate composition of the fresh fish, surimi as well as dry surimi powder was determined. Moisture of the experimental samples was measured by Moisture Balance (Precisa, Dietikon, Switzerland). Total nitrogen was estimated by Kjeldahl method [13]. Crude protein value was calculated by multiplying the total nitrogen value by a factor of 6.25. Estimation of total lipid was done by the method described by Bligh and Dyer [14]. The ash content was measured by the method of AOAC [13]. All the results were expressed on wet weight basis.

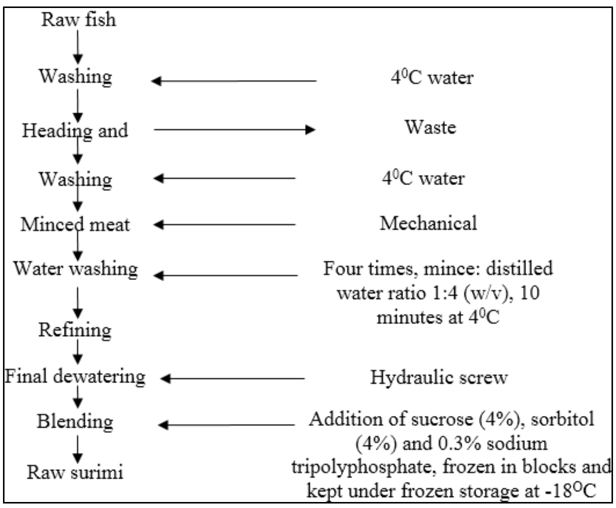

Fig 1: Flow diagram of surimi processing

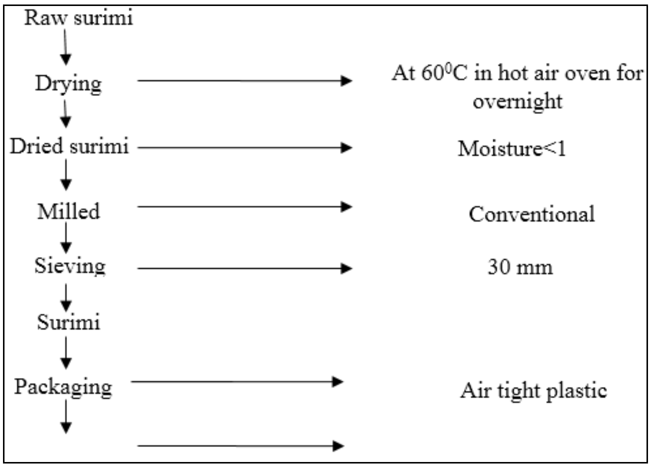

Fig 2: Flowchart of surimi powder preparation

The fresh fish, surimi as well as dry surimi powder were subjected in triplicate for Total Plate Count (TPC) and physicochemical analyses to determine the microbiological count and quality parameters respectively. TPC was determined as described by Nath *et al.* [15], plates were incubated at 37°C temperature for 48 hours and results were expressed as log cfu/g. The physicochemical indices determined were TVBN (by the method described by Nath *et al*. [15], PV (by the method described by Kirk and Sawyer[16]) and pH using a pH meter (by Ozyurt *et al* [17]. using pH meter Five EasyTM FE20, made by MettlerTodelo AG, Switzerland).

Surimi powder, stored under refrigerated temperature (4°C), were drawn at every 30 days interval and brought to room temperature to determine the shelf life of prepared surimi powder. The quality parameters like TVBN, PV and pH as well as TPC were measured for Surimi powder following the methods as described above.

Statistical data analysis

All of the data were checked for normal distributions with normality plots prior to analysis of variance (ANOVA), to determine significant differences among means at $\alpha = 0.05$ level, using statistical tools of Microsoft Office Excel (2007) and R software (Version 2.14.1).

Results and Discussion

In the present study, surimi powder was prepared from surimi of Sutchi Catfish (*Pangasianodon hypopthalmus*). The quality of surimi prepared from fish vary depending on species and the factors related with the composition of the fish like seasonal variation, feeding habit, pH of the habitat water, adaptation, temperature, lipid content, sex and spawning. In the present study, Sutchi Catfish (*Pangasianodon hypopthalmus*) was chosen due to easy availability and low price.

The proximate composition values for moisture, protein, lipid and ash were 76.01±1.18%, 16.87±0.44%, 6.29±0.04% and 0.83±0.02% respectively for the whole fish. Hasan *et al.* [18] reported values of moisture, protein, lipid and ash in Pangus were 72.86%, 15.30%, 8.17% and 1.75% respectively which is fairly consistent with the present findings. Carlos *et al*. [19] exhibited moisture, protein, lipid, and ash values in pangus as 84.71%, 13.52%, 1.78%, and 1.57% respectively. The variations in proximate composition is however may be due to variation among species, catching season, environment, diet, age, sex [20].

The quality parameters like TVB-N (10.97±0.23 mg/100gm), PV (4.57±0.18 meq active O_2/kg) and pH (6.3±0.21) were all within the limit of acceptability suggesting a good quality of raw material. The limit of acceptability of TVB-N is 35 mg/100gm as reported by Ghaly *et al* [21]. Ikasari and Suryaningrum [22] reported that the initial TVB-N value of pangus fish fillet was 10.58 mg/100gm which supports the results of the present findings. The peroxide value (PV), regarded as a useful and reliable method to estimate the extent of auto-oxidation in the early stage [23], is considered as perfect without any objectionable off-taste or off-odour upto 30 miliequivalent of O_2/kg of fat [24]. Carlos *et al* [19]. reported the PV value of fresh sutchi pangus was 4.54 MEq O_2/Kg samples which is similar to the present finding. Abbas *et al*. [25] reported the pH value of fresh sutchi cat fish was 6.25, whereas, Viji *et al*. reported [26] initial pH value was recorded 6.33 for fresh sutchi cat fish which is in agreement with the values of pH of the present study. Buchtova and Ježek [27] suggested that Fresh fish muscle pH is most frequently in the range of 6-6.5. Storage time tends to increase the pH values which can be associated with the production of basic components such as ammonia, volatile alkali and trimetylamine due to internal enzymatic activity and the growth of bacteria [28]. As recommended by International Commision on Microboilogical Specification for Food [29], the TPC value exceeding 6 log cfu/gm is regarded as microbiologically spoiled fish muscle, unsafe for human consumption. Here, the TPC value of 3.65±0.44 log cfu/g suggests a good quality raw fish and safe for consumption. Ikasari and Suryaningrum [22] however report a higher initial TPC value for pangus fish fillet as 3.56×10^5/gm of sample.

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 meat [30], thus improving the functionality and sensory characteristic by eliminating the problems associated with colour, taste and odour [11]. Here, the fish mince was washed with cold water (4^{O}C) for 10 minutes duration using a mince/washing medium ratio of 1:4 (w/v) to remove sarcoplasmic proteins, blood, pigment, fat and other low molecular weight components as described by Rawdkuen *et al.* [11]. The process was repeated thrice and the third washing was carried out using 0.5% NaCl solution with mince to NaCl solution ratio of 1:4 (w/v). 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*. [11]. Finally, the meat was subjected to press and after addition of cryoprotectant the final yield of surimi to whole fish was 33.47±1.43% (Table 1). This may be attributed due to extra washing cycle added for pangus due to higher fat content of pangas as compared to tilapia.

Table 1: Yields (%) during production steps of surimi and surimi powder

Yields (%) during production steps of surimi	
Processing steps	**%**
Whole fish	100.00±0.00
Fillets to whole fish	52.39±1.15
Minced flesh to whole fish	38.05±0.72
Minced flesh to fillets	72.8±2.15
Surimi to whole fish	33.47±1.43
Surimi to fillet	64.03±2.25
Surimi to minced meat	87.95±1.56
Surimi powder to whole fish	13.10±0.75
Surimi powder to fillet	25.03±1.25
Surimi powder to minced meat	34.39±1.12
Surimi powder to surimi	39.1±0.63

After final dewatering, the washed mince was added with 4% sucrose, 4% sorbitol (as cryoprotectant) and 0.3% sodium tripolyphosphate, mixed well, frozen in blocks and kept under frozen storage at -18^{O}C till processing. Sucrose addition is known to stabilize proteins against heat denaturation [31] and protects fish myofibrillar protein during freezing [32]. Here, the moisture, protein, lipid, ash and carbohydrate content of frozen surimi were found to be 69.72±0.32%, 17.17±0.41%, 4.64±0.73%, 0.47±0.02% and 8.00±0.00% respectively. The protein values are fairly consistent with the reports of Hossain *et al.* [33], who showed that fresh silver carp and pangus surimi contain 16.12% and 16.8% crude protein respectively.

Commercial surimi can contain 75 to 85% moisture and 5 to 10% carbohydrate depending on its intended use [34]. According to Park, [3] moisture content of commercial surimi varies from 72 to 77%, whereas Chowdhury *et al.* [9] found that silver carp surimi contains 78.06% moisture. A gradual decrease in lipid content takes place at different stages of surimi processing. Repeated washing step resulted in final reduction to 4.64±0.73% of lipid content in surimi. Although, a low-fat content is very important to get good quality gel emulsion and analog products [23], in the present study, lipid content was fairly high even after four washing cycles which may be due to the initial higher lipid content in the fish. The ash content of surimi was determined to be 0.47±0.02% which is similar as reported by Hossain *et al* [33]. Of 0.43% ash in pungas surimi. Chowdhury *et al.* [9] stated the amount of total ash content in silver carp surimi was around 0.82%. The carbohydrate content of 8% reported is entirely contributed by the sucrose and sorbitol added to minced meat as cryoprotectant.

Surimi samples were dried at 60^{O}C overnight to prepare dry surimi powder following the oven drying method Huda *et al.* [12] with modifications until the moisture content was reduced below 15% or less with a final yield of surimi powder to whole fish of 13.10±0.75% (Table 1). Proximate composition of the surimi powder varies depending upon fish species and incorporation rates of cryoprotectants to protect the functional properties of surimi against freezing and drying. The final proximate composition for surimi powder was 11.47±0.58%, 59.43±0.33%, 10.42±0.35%, 1.79±0.43% and 16.89±0.59% for moisture, protein, lipid, ash and carbohydrate respectively. A study conducted by Ramirez *et al.* [36] 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 which corroborates with the results of the present investigation. The high content of carbohydrate in surimi powder was observed due to the addition of cryoprotectants during surimi preparation.

Bio-chemical parameters such as TVB-N and PV were determined to analyse the quality characteristics of both surimi and surimi powder. The values of all parameters (Table 2) were found to be well within the limit of acceptability. A pH value, 6.8 to 6.9 is considered to be optimum for good quality surimi [23] which is reflected in present finding (6.87±0.24). The present TPC values for surimi (Table 2) was found to be 3.53±0.61 log cfu/gm, which is within the safe recommended limit of ICMSF [29].

Table 2: Proximate composition and quality characteristics of frozen surimi and dry surimi powder

Parameters	Surimi	Surimi powder
TVBN (mg/100g)	14.83±0.54	27.97±1.09
PV (meq active oxygen/kg)	4.23±0.28	3.16±0.42
pH	6.87±0.24	6.73±0.53
TPC (log cfu/g)	3.53±0.61	3.94±0.61

*Results are mean of 3 determinations with s.d.

The changes in biochemical parameters of surimi powder (Table 3) reveals a gradual increase in TVB-N, PV, pH and TPC over 210 days of storage. The TVB-N values significantly ($p<0.05$) increased to a maximum value of 29.97±0.13 mg/100g after 210 days, although did not cross the limit of acceptability (35mg/100gm) as recommended by Ghaly *et al* [21]. Suggesting that the surimi powder was acceptable till 210 days under refrigeration. The cryoprotectants added during preparation of surimi helped in protecting the protein from denaturation during drying and subsequent storage as described by Suzuki [6] who postulated that cryoprotectants also serve as dryoprotectants. The significant increase ($p<0.05$) with final PV (6.16±0.42 meq active O_2/kg) and TPC (4.21±0.73 log cfu/g) values suggested that these parameters were within the limit of acceptability (Table 3) even after 210 days at 4^{O}C. A significant change ($p<0.05$) in pH was observed during the storage study ranging from a value of 6.73±0.53 to 7.58±0.32 over 210 days at 4^{O}C.

Table 3: Quality Changes in Surimi Powder stored under refrigerated storage ($4^{O}C$)

Days	pH	TVBN (mg/100g)	PV (meq. Active oxygen/kg)	TPC (logcfu/g)
0	6.73±0.53	27.97±1.09	3.16±0.42	3.94±0.61
30	6.79±0.01	28.09±0.72	3.39±0.24	3.73±0.16
60	6.87±0.06	28.17±0.77	4.17±0.24	3.79±0.18
90	7.01±0.06	28.23±0.84	4.53±0.22	3.82±0.13
120	7.25±0.20	28.94±1.40	4.77±0.21	3.91±0.11
150	7.43±0.06	29.21±1.27	5.25±0.31	4.03±0.18
180	7.53±0.01	29.82±0.69	5.87±0.39	4.14±0.13
210	7.58±0.32	29.97±0.13	6.16±0.42	4.21±0.73

*Results are mean of 3 determinations with s.d.

Conclusion

Thus, the storage study revealed its safe use for a period of 210 days under refrigerated storage conditions defending its utility for a long duration of time. So, it can be inferred that, collectively the product has good quality standards and may be further developed into “ready to use” labelled product like dairy products in the future.

Acknowledgement

The authors are grateful to Department of Animal Nutrition, Ranchi Veterinary College, Birsa Agricultural University and Department of Fish Processing Technology, Faculty of Fishery Sciences, West Bengal University of Animal and Fishery Sciences, Kolkata for the prerequisite and necessary support during the research work.

References

1. Santana P, Huda N and Yang TA. Technology for production of surimi powder and potential of applications. Int. Food Res. J. 2012; 19(4):1313-1323.
2. Okada M. History of surimi technology in Japan. Edn Lanier TC and Lee CM *Surimi Technology*. Marcel Dekker Inc, New York, 1992, 3-21.
3. Park JW and Lin TMJ. Surimi: manufacturing and evaluation. Edn Park JW (2nd) *Surimi and Surimi Seafood*. CRC Press, Boca Raton, 2005, 33-98.
4. Majumder A, Chowdhury S, Dora KC, Nath S and Mondal K. Phisico-chemical properties and proximate composition of surimi powder from Tilapia (*Oreochromis mossabicus*). JASFT. 2017; 4(1):31-37.
5. Green D and Lanier TC. Fish as the `soybean of the sea'. (Ed R.E. Martin & R.L. Collete), Proceedings of the International Symposium on Engineered Seafood Including Surimi. National Fisheries Institute, Washington, 1985, 42-52.
6. Suzuki T. Fish and Krill Protein: processing technology. Applied Science Publishers, London, 1981; 46-52.6
7. Karmas E and Lauber E. Novel products from underutilized fish using combined processing technology. J. Food Sci. 1987; 52:7-9.
8. Onibala H, Takayama T, Shindo J, Hayashi S and Miki H. Influence of freshness on occurrence of setting and disintegration in heat-induced gels from tilapia. Fish Sci. 1997; 63:276-280.
9. Chowdhury S, Sarkar S and Dora KC. Quality changes in fish cakes prepared from washed silver carp mince under frozen storage ($-20^{0}C$). Ind. J. Nutr. Dietet. 2009; 45:78.
10. Rathod N and Pagarkar A. Biochemical and Sensory Quality Changes of Fish Cutlets, made from pangasius fish (*Pangsius hypophthalmus*), during storage in refrigerated display unit at -15 to $-18\ ^{0}$ C. JFAV. 2013; 3(1):1-8.
11. Rawdkuen S, Sai-Ut S, Khamsorn S, Chaijan M and Benjakul S. Biochemical and gelling properties of tilapia surimi and protein recovered using an acid-alkaline process. Food Chem. 2009; 112:112-119.
12. Huda N, Abdullah R, Santana P and Yang TA. Effect of different dryoprotectants on functional properties of threadfin bream surimi powder. Journal of Fisheries and Aquaculture Science. 2012; 7(3):215-223.
13. AOAC (Association of Official Analytical Chemistry). Edn 16th, *Official Methods of Analysis*, Arlington, VA, 1995.
14. Bligh EG and Dyer WJ. A rapid method of total lipid extraction and purification. Can. J. Biochem. Phys. 1959; 37(8):911-7.
15. Nath S, Chowdhury S and Dora KC. Effect of lactic acid bacteria application on shelf life and safety of fish fillet at $6\pm1^{O}C$. IJAR. 2014; 2(4):201-207.
16. Kirk S and Sawyer R. Pearson's composition and analysis of foods. Edn 9th, Longman Group Ltd. 1991.
17. Özyurt G, Kuley E, Özkütük S and Özogul F. Sensory, microbiological and chemical assessment of the freshness of red mullet (*Mullus barbatus*) and goldband goatfish (*Upeneus moluccensis*) during storage in ice. Food Chem. 2009; 114(2):505-10.
18. Hasan GMMA, Hossain MS, Juliana FM and Begum M. Nutritional analysis of three different cultured fishes of Bangladesh. IARJSET. 2015; 2(9):1-4.
19. Carlos FMG, Eliane TM, Maria LGM, Môsar L, Sergio Borges M and Carlos ACJ. The chemical quality of frozen Vietnamese *Pangasius hypophthalmus* fillets. Food Sci. Nutr. 2016; 4(3):398-408.
20. Boran G and Karacam H. Seasonal changes in proximate composition of some fish species from the black sea. Turkish J. Fish. Aquat. Sci. 2011; 11:1–5.
21. Ghaly AE, Dave D, Budge S and Brooks MS. Fish spoilage mechanism and preservation techniques: Review. Am J Appl Sci. 2010; 7(7):859-877.
22. Ikasari D and Suryaningrum TD. Quality changes of Pangasius fillets during ice storage. Squalene Bulletin of Marine & Fisheries Postharvest & Biotechnology. 2015; 10 (3): 109-120.
23. Chakraborty A, Dora KC, Sarkar S and Chowdhury S. Shelf-life of surimi prepared from tilapia (*Oreochromis niloticus*) during frozen storage. TAJAS. 2009; 4(1):18-21.
24. Lajolina P, Laine J and Linko P. Quality changes in mince fish during cold and frozen storage. Edn Zerthan *et al*. *Thermal Processing and Quality of Foods*. Elsevier Applied Science Publisher Ltd. 1983.
25. Abbas KA, Mohamed A, Jamilah B and Ebrahimian M. A Review on Correlations between Fish Freshness and pH during Cold Storage. American Journal of

Biochemistry and Biotechnology. 2008; 4(4):416-421.

26. Viji P, Tanuja S, Ninan G, Lalitha KV, Zynudheen AA, Binsi PK and Srinivasagopal TK. *et al* Biochemical, textural, microbiological and sensory attributes of gutted and ungutted sutchi catfish (*Pangasianodon hypophthalmus*) stored in ice. J. Food Sci. Technol. 2015; 52(6):3312-3321.
27. Buchtová H and Ježek F. A New Look at the Assessment of the Silver Carp. Czech Journal of Food Science. 2011; 29(5):487-497.
28. Chamanara V, Shabanpour B, Gorgin S and Khomeiri M. An investigation on characteristics of rainbow trout coated using chitosan assisted with thyme essential oil. Int. J. Biol. Macromol. 2012; 50:540-544.
29. ICMSF (International Commission on Microbiological Specifications for Foods). (1988). *Micro-organisms in Foods,* Toronto, Uni. Toronto Press.
30. Amiza MA and Nur-Ain K. Effect of washing cycle and salt addition on the properties of gel from silver catfish (*Pangasius* sp.) surimi. UMT 11th International Annual Symposium on Sustainability Science and Mangement, 9th – 11th July, Terengganu, Malaysia, 2012.
31. Park JW and Lanier TC. Effects of salt and sucrose addition on the thermal denaturation and aggregation of water leached fish muscle. J Food Biochem. 1990; 14:395.
32. Nopianti R, Huda N and Ismail N. (Loss of functional properties of proteins during frozen storage and improvement of gel-forming properties of surimi. As J Food Ag-Ind; 3(6):535-547.
33. Hossain MI, Kamal MM, Shikha FH and Hoque S. Effect of Washing and Salt Concentration on the Gel Forming Ability of Two Tropical Fish Species. Int. J. Agric. Biol. 2004; 6(5):762-766.
34. Lee CM. Surimi manufacturing and fabrication of surimi-based products. Food Techno. 1986; 40(3):115-124.
35. Park JW. Surimi and surimi seafood. CRC press. 2013.
36. Ramírez JA, Díaz-Sobac R, Morales OG and Vázquez M. 1999. Evaluation of freeze-dried surimi from tilapia and fat sleeper as emulsifiers. Ciência e Tecnologia de Alimentos. 1999, 2(4):210-214.