Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 28(4): 381 – 400 (2024)
www.ejabf.journals.ekb.eg

An Improved Method of Good Quality *Shidol* Production in the Northern Part of Bangladesh: from Biochemical and Microbiological Aspects

Md. Moniruzzaman[1], David Rintu Das[1], Shishir Kumar Dey[1], Mahmudul Hasan Mithun[1,*], Anuradha Bhadra[2], Mohosena Begum Tanu[3], Yahia Mahmud[3], Md. Zulfikar Ali[3]

[1]Bangladesh Fisheries Research Institute, Floodplain Sub-station, Santahar, Bogura, Bangladesh
[2]Bangladesh Fisheries Research Institute, Freshwater Station, Mymensingh, Bangladesh
[3]Bangladesh Fisheries Research Institute, Headquarters, Mymensingh, Bangladesh

[*]Corresponding Author: mithun3622bsmrau@gmail.com

ARTICLE INFO

Article History:
Received: May 23, 2024
Accepted: July 2, 2024
Online: July 21, 2024

Keywords:
Improved methods,
Shidol production,
Proximate composition,
Biochemical and microbiological analysis,
Bangladesh

ABSTRACT

The present study aimed to develop a suitable method for the production of good quality *shidol* at the Floodplain Substation, Bangladesh Fisheries Research Institute (BFRI), Santahar, Bogura, Bangladesh. For this purpose, an improved quality *shidol* was prepared following scientific methods by BFRI, while traditional *shidol* was collected from Rangpur, Kurigram, Dinajpur, Lalmonirhat, Bogura, Nilphamary, Syedpur region. In the present study, proximate composition, biochemical and microbiological analysis of the BFRI made *shidol* and the traditional *shidol* were carried out during the 90 days of storage period after vacuum packaging. In proximate composition analysis, higher level of protein and fat content were found in BFRI made *shidol* than the traditional *shidol*. However, the traditional *shidol* samples showed poor quality due to the high total volatile base nitrogen (TVB-N), peroxide values, and moisture along with a promising microbial load; in contrast, the results obtained in the BFRI *shidol* samples were within the acceptable limit for human consumption. The presence of coliform bacteria in the traditional *shidol* also reflected the improper handling, unawareness of good hygiene and sanitation during production. The results of this study indicate that vacuum packaging can be an effective method in maintaining the quality of *shidol* by preventing cross-contamination and delaying the degradation of nutrients. Additionally, an improved BFRI technology for *shidol* production can minimize the biochemical and microbiological quality loss of *shidol*.

INTRODUCTION

Fish fermentation and drying are the most conventional and affordable methods of producing and preserving fishery products in Bangladesh **(Nayeem *et al.*, 2010; Das *et al.*, 2022a; Das *et al.*, 2023a)**. Traditionally produced fermented fish products, which vary in terms of nutrition, flavor, palatability, and texture, comprise the fundamental components of diets for numerous ethnic groups in this region **(Majumdar *et al.*, 2016;**

Das *et al.*, 2023b). In addition to their preservation benefits, foods that have undergone fermentation may also have an improved flavor, increased digestibility, and enhanced medicinal capabilities. Rice and fish make up the majority of Bengali cuisine; however, there are also additional dishes that are unique to each Bangladeshi region. People from the northern regions of the country have a very diverse range of foods **(Sunny *et al.*, 2019; Das *et al.*, 2023c)**. *Shidol Bharta* is one such famous dish. People in Bangladesh's northern region frequently consume *shidol*, which is a fermented fish product, and it is popular due to its flavor. The fermented variety of *shidol* is never consumed, it is rather used as a sauce-like dish which is locally called *Shidol bhorta*. It is prepared as a side dish for eating with rice or bread. Shidol is important for the nutrition of poor and economically deprived people as it involved low-cost during processing **(Majumdar *et al.*, 2016; Das *et al.*, 2023d)**. A number of people in our country, particularly in the regions of Rangpur, Kurigram, Dinajpur, Lalmonirhat, Bogura, Nilphamary, and Syedpur, are involved in the production and distribution of these fermented dried fish products, which significantly improves their socioeconomic status **(Bjerke *et al.*, 2019; Das *et al.*, 2022b: Das *et al.*, 2023e)**. The people in the northern region of Bangladesh cook *shidol* almost every day. Most dried fermented fish items are made on a small scale in homes with minimum process control to ensure the safety and quality of the finished product **(Bjerke *et al.*, 2019; Kuddus *et al.*, 2022)**. The products of fermented fish are generally kept at room temperature until consumption, and the processes that prevent pathogens, like cooking or pasteurization, are not included in the processing methods. The process of fermentation used to make traditional *shidol* is mostly uncontrolled and natural. Furthermore, the unhygienic conditions in which the *shidol* is processed increase a risk of contamination **(Bjerke *et al.*, 2019; Sunny *et al.*, 2021b)**. The primary causes of the product's deterioration are rancidity, autolysis, bacterial, fungal, or yeast activity, as well as additional processes that depend on water activity and temperature **(Mithun *et al.*, 2020)**. Few reports exist regarding the quality of traditional *shidol* sold in Bangladeshi markets; however, there is a dearth of information regarding the quality of *shidol* trade in the country's north. The present study was carried out to develop a suitable technology for the production of good quality fermented fish product (*Shidol*), and to compare the biochemical and microbiological quality of BFRI made *shidol* with traditional *shidol* collected from the northern part of Bangladesh.

MATERIALS AND METHODS

Experimental site

The study was carried out at the Bangladesh Fisheries Research Institute's Flood Plain Sub-station in Santaher, Bogura, Bangladesh, between 24.7762° N latitude and 88.9940° E longitude.

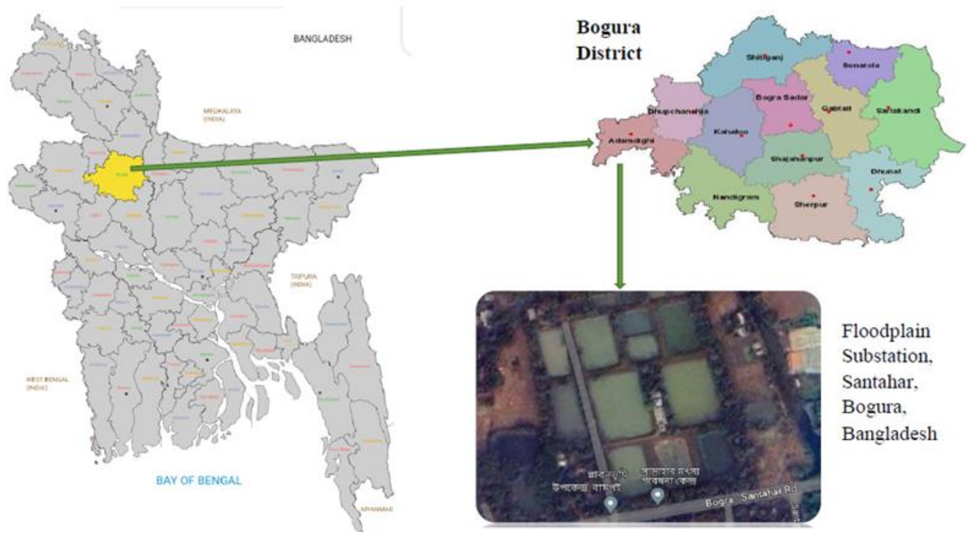

Fig. 1. Location of the experimental area

Collection of raw materials

After visiting countless fish markets, different types of locally available small indigenous species like the puti (*Puntius sophore*), the taki (*Channa striata*), the kholisha (*Colisa fasciata*), the mola (*Amblypharyngodon mola*), the chanda (*Chanda nama*), the chela (*Chela cachius*), the batashi (*Neotropius atherinoides*), and the dhela (*Osteobrama cotio*), etc. were collected from the floodplain region of the northern part of Bangladesh. Moreover, other ingredients like the arum green (*Colocasia esculenta*), salt, garlic, ginger, turmeric powder, and mustard oil were purchased from the local market.

Dressing and gutting of fishes

The fish were dressed and gutted immediately after collection to decrease the rate of microbial spoilage and extend the shelf life of the final product. The viscera of *Puntius sophore* was used to extract fish oil, which was further used to increase the distinctive flavor of dried fish powder.

Salting

After gutting the fish, salting was done to protect the fish from the fly insect, or larval infestation. Generally, 125g of salt was used per kg of fish.

Smoked of fish in smoking kiln

The smoke was generated using an upgraded version of a traditional kiln, which is generally similar in structure to kilns. The steel rectangular box measuring 105 x 75 x $45cm^3$ served as the smoking kiln or chamber (Fig. 2A). A horizontally perforated iron net-frame separated the chamber into four equal sections. The bottom part served as a basis for burning sawdust or hardwood chips as a smoke source. The upper chamber featured a rack for hanging iron rods that measured 4- 6mm and were supported by two sides. There were separate doors in each chamber that could be opened as needed. An outlet for smoke control was located on top. The upper fish chamber's smoke temperature could be adjusted by adjusting the outflow cover. To monitor the temperature within the hot chamber, a sensitive thermometer was inserted through a tiny opening on top. The burning of wood sawdust produced smoke. In the upper chamber, where salted fish were spread out separately, the slightly smoke airflow (between 50 and 55^{0}C) ascended through the iron net. The mango (*Mangifera indica*) tree sawdust was collected from a nearby sawmill and used to generate smoke. To support the sawdust fire, a few little wood chips of the same kind were also used. Fish samples were smoked for three to four hours at a temperature between 50 and 55^{0}C to give it a smoky flavor. Additionally, this process extends the shelf life of the fishery product and lowers the rate of spoilage.

Fig. 2. (A) Smoking kiln; **(B)** Smoking of fish

Sun drying of smoked fish and arum green stems

After smoking, the fish were placed on a bamboo platform covered with a net and dried in the sun for four to six days. Compared to other dryers (solar tunnel dryer, rotary dryer), the drying bamboo platform has a very simple structure and is very easy to prepare and install (Fig. 3). Fish were shielded from bug infestation and/or animal, bird, or rodent attacks by a net frame. The arum green (*Colocasia esculenta*) stems were also semi-dried in the sun at the same time; the drying period varies according to the sun's heating rates. Moreover, the arum green stems were chopped into small pieces, peeled, and cooked in water to soften them before drying.

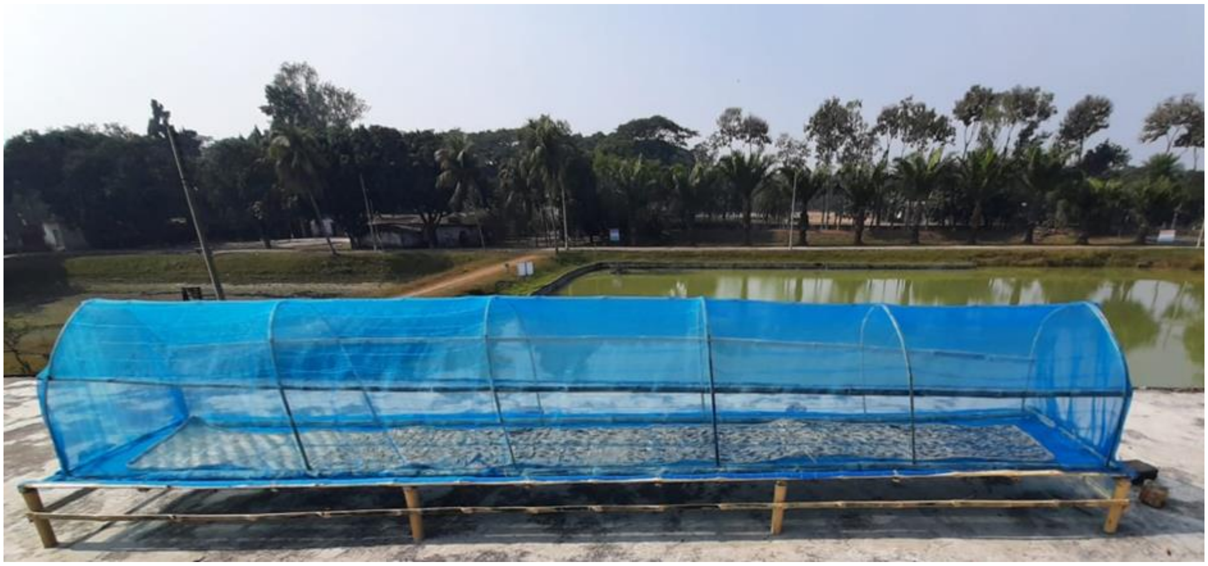

Fig. 3. Fish drying into net covered bamboo platform

Grinding of dried fish and Arum green stems

The dried fish and arum green stems were grounded in an electric blender to make fish powder and the arum green paste. During this time, garlic and ginger were also blended to make paste.

Processing of *shidol*

After grinding, the arum green stem pulp was mixed with fish powder to make paste. The arum green and fish powder ratio was 2:1, and other ingredients like garlic, ginger, and salt were added in the required amounts. Once all mixed, the paste was rubbed with turmeric powder and mustard oil and made into a round ball by hand (Fig. 4A). A turmeric powder and mustard oil mixture was used to protect the cake from blowflies, beetles, or other insect attacks. After that, it was kept in a sealed earthen pot for anaerobic fermentation for 3– 4 days (Fig. 4B, C). Carbohydrates of the arum green stems serve as media for fermentation bacteria to grow and draw their metabolic energy. This fermentation process added desirable flavor and taste to the final product. After fermentation, the paste was again well mixed and made into a round shape by hand. Then the round-shaped *shidol* was dried under sunlight for another 4- 6 days in a ring tunnel fish dryer to protect it from fly, insect, bird, and rodents (Fig. 4E).

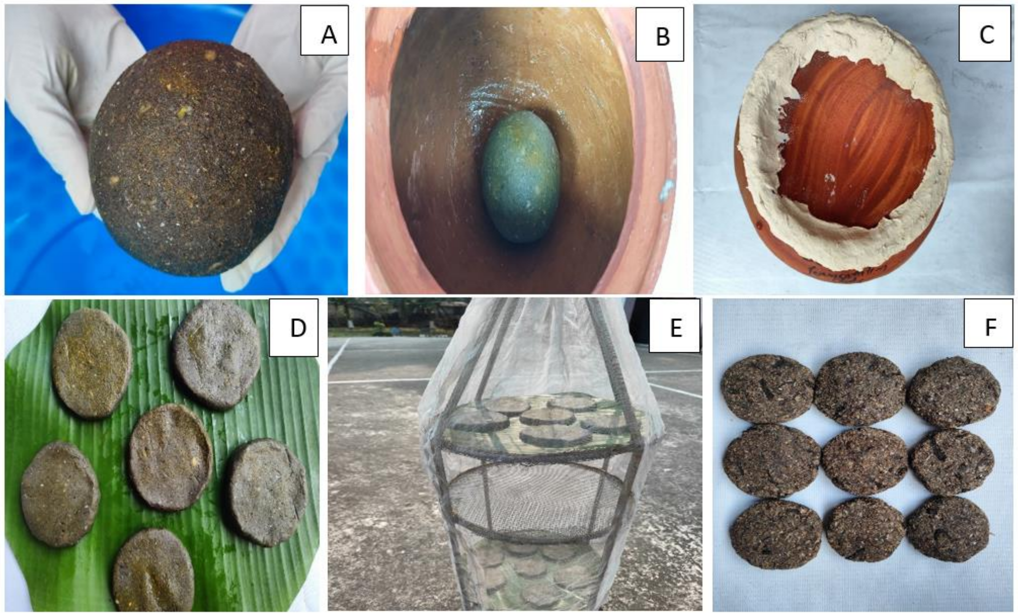

Fig. 4. (A) *Shidol* paste after mixing all ingredients, **(B, C)** kept in airtight earthen pot for anaerobic fermentation, **(D)** round shape of shidol **(E)** drying shidol in ring tunnel fish dryer **(F)** final product of shidol after drying

Vacuum packaging

After processing, the dried *shidol* was vacuum-packed in sealer bags using vacuum machine (DZ-280/2SD) to increase shelf life, and decrease oxidative reactions with lowest possible bacterial count at a comparatively low cost. Since vacuum packaging effectively reduces oxidative reactions in the product at comparatively lower prices, it is a popular static form of hypobaric storage in the food business. When a product is vacuum-packed, it is kept inside a container with little oxygen permeability that is sealed tightly once the air has been removed (Fig. 5A, B).

Fig. 5. (A) *Shidol* vacuum packaging by vacuum sealer machine; **(B)** Vacuum packaged shidol

Proximate composition

Standard methods were used to determine the proximate composition of the shidol samples **(AOAC, 2000)**. Crude fat was extracted using the Bligh and Dyer method, moisture content was measured using the hot air oven method, ash content was measured using the Muffle furnace method at 550± 50° C, and total protein content was estimated using the Kjeldahl method. Total volatile base nitrogen (TVB-N, mgN 100 g^{-1}) was measured using the Conway micro diffusion method, which was first reported by **Beatty and Gibbon (1937)**. Using the iodometric approach, the lipid extract was utilized to determine the lipid's peroxide value (PV) **(Jacobs, 1958)**.

Microbiological analysis

The stomacher lab - Blender 400 (Seward Medical, London, U.K.) was used to homogenize 10g of *shidol* sample in 90ml of 0.1% peptone water (oxoid) for 30s at a normal speed in order to prepare samples for microbiological analysis. Sterile 0.1% peptone water solution was used to prepare decimal dilutions. The homogenate was diluted and used in one milliliter for the microbe count. The pour plate and spread methods outlined in the Food and Drug Administration **(FDA, 1998)** and the Compendium of Procedures for Microbiological Examination of Foods **(APHA, 2001)** were used to conduct the counts.

Statistical analysis

Every measurement was carried out in triplicate, and the experiments were run twice. The values were subjected to one-way analysis of variance and were expressed as mean ± standard deviation (SD). Duncan's multiple variety test was used to calculate the mean contrast, and a significant difference was defined as the one with $P< 0.05$.

RESULTS AND DISCUSSION

Proximate composition

The proximate analysis was used to estimate the quantity of moisture, crude protein, total fat, total carbohydrate, and dietary fiber in food and food constituents **(Puwastien *et al.*, 2011; Thangaraj, 2016; FAMIC, 2019)**. Moreover, the proximate composition of the BFRI-made *shidol* and the traditional *shidol* is shown in Table (1). Moisture content is the amount of water and volatile substances lost during drying **(Puwastien *et al.*, 2011; Thangaraj, 2016; FAMIC, 2019)**. Sometimes, food quality can be predicted using moisture content. However, as mold and fungus grow best in moist conditions, moisture content is one of the most important preservation factors **(Puwastien *et al.*, 2011; Thangaraj, 2016; FAMIC, 2019)**. Traditional *shidol* contains a significantly high amount of moisture, ranging from 24.42 to 26.72% with a mean value of 25.52%, whereas BFRI-made *shidol* contains moisture ranging from 17.56 to 19.73% with a mean value of 18.73% (Table 1). The findings of this study are higher than those found for the fermented cassava fish (Lanhouin), the tigger fish (Tirkin), and the traditional Ivorian fermented fish products (Adjuevan) **(Anihouvi *et al.*, 2009; Mohammed, 2010; Koffi-Nevry *et al.*, 2011)**. Crude protein is defined as the total nitrogen content multiplied by the constituents of proteins. Protein nitrogen plus a small amount of non-protein nitrogen made up the total nitrogen **(Puwastien *et al.*, 2011; Thangaraj, 2016; FAMIC, 2019)**. In this study, crude protein content of BFRI made *shidol* ranged from 30.21 to 37.15% with a mean value of 33.48%, which is significantly higher than the traditional *shidol* values which range from 29.55 to 34.56% with a mean value of 31.80% (Table 1). Results for momone, lanhouin, and tirkin fermented fish products were nearly similar **(Abbey *et al.*, 1994; Anihouvi *et al.*, 2009; Mohammed, 2010)**. Total fat is the quantity of fat that contains steroids, fatty acids, oil-soluble pigments, and fat-soluble vitamins **(Puwastien *et al.*, 2011; Thangaraj, 2016; FAMIC, 2019)**. The crude fat content of BFRI made *shidol* ranged from 18.15 to 20.19 % with a mean value of 18.92%, which is significantly higher than the traditional *shidol* values which range from 13.25 to 14.78% with a mean value of 14.05% (Table 1). According to the results of the present study, the dried fermented fish product, *shidol* had a higher fat content than the fermented fish product like Fassiekh in Sudan and Wadi Betok in South Kalimantan Indonesia **(Osman *et al.*, 2012; Petrus *et al.*, 2013)**. The quantity of total carbohydrates, which is one of the primary constituents of plant structural components **(Puwastien *et al.*, 2011; Thangaraj, 2016; FAMIC, 2019)** was analyzed in this study. In this investigation, the calculated mean carbohydrate values were 7.64 and 8.88% in BFRI-made *shidol* and traditional *shidol*, respectively, with a difference which is statistically insignificant (Table 1). Dietary fiber is defined as the total quantity of fiber in food **(Puwastien *et al.*, 2011; Thangaraj, 2016; FAMIC, 2019)**. The mean dietary fiber of BFRI made *shidol* and traditional *shidol* samples was found to be 5.70 and 6.37%, respectively. Ash content is the amount of total mineral residue left after incinerated leaf samples until constant weight **(Puwastien *et al.*, 2011; Thangaraj, 2016; FAMIC, 2019)**. Mean ash content of BFRI made *shidol* and traditional *shidol* samples was found to be 14.42 and 14.28%, respectively (Table 1). There is no significant different in dietary fiber and ash content between the two samples. A reduction in moisture levels may be the reason for the increase in protein and fat content of the BFRI-made *shidol*. The use of various fish species, processing environment, and processing technologies could all be contributing factors to these variations.

Table 1. Proximate composition of BFRI made shidol and traditional shidol

Parameter	BFRI made *Shidol*			Traditional *Shidol*		
	Mean	Minimum	Maximum	Mean	Minimum	Maximum
Moisture (%)	18.73	17.56	19.73	25.52	24.42	26.72
Crude lipid (%)	18.92	18.15	20.19	14.05	13.25	14.78
Crude Protein (%)	33.48	30.21	37.15	31.80	29.55	34.58
Ash (%)	14.42	13.98	14.92	14.28	14.10	14.82
Fiber (%)	5.70	5.43	6.20	6.37	5.90	6.87
Carbohydrate (%)	7.64	2.20	11.65	8.88	5.02	11.67

The pH values

The pH value is another crucial metric for evaluating the quality of any food. The average pH values in the BFRI-made and traditional *shidol* were found to be 6.37 and 7.53 in the current investigation, respectively, which was substantially different ($P > 0.05$) (Fig. 6). The slightly acidic *shidol* produced by BFRI inhibited the growth of microorganisms.

The total viable count increased as pH values increased in both *shidol* samples, indicating a positive correlation between pH changes and bacterial growth. According to **Kyrana *et al.* (1997)**, the fishery products' initial lower pH was caused by the generation of lactic acid during anaerobic glycolysis. Furthermore, when the fish spoiled during storage, the synthesis of alkaline bacterial metabolites was reflected in rising pH values, which also happened to correspond with rising total volatile basic nitrogen levels.

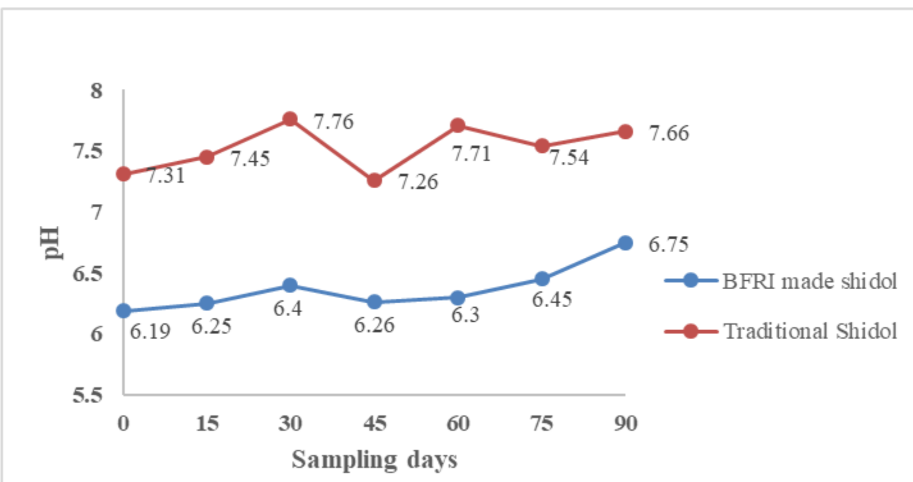

Fig. 6. pH value of BFRI made *shidol* and traditional *shidol*

Total volatile base nitrogen (TVB-N)

TVB-N, or total volatile base nitrogen measurement is essential to determine the quality of fish and fisheries products. TVB-N, which stands for total fish ammonia (NH3), dimethylamine (DMA), and trimethylamine (TMA), is commonly used as a fish freshness index and as a spoilage indicator **(Wu & Bechtel, 2008)**. Seafood spoilage is generally linked to volatile base nitrogenous compounds like TVB-N. In the event that the organoleptic test for fish freshness is unclear, the inspector is required under a European Union rule on fish hygiene to apply TVB-N as a chemical check **(Castro *et al.*, 2006)**. In the present study, the average TVBN value was determined to be 34.68 and 81.85mg/ 100g in BFRI-made *shidol* and traditional *shidol*, respectively, which is significantly different from each other ($P > 0.05$) (Fig. 7). The TVB-N value of 35 to 40mg/ 100 g is considered to be the highest acceptable limit for dried fish, and anything above that level is considered to render fisheries products unfit for human consumption **(Kimura & Kiamakura, 1934)**. Therefore, the TVB-N values of BFRI-made *shidol* were within the acceptable limit for human consumption, but traditional shidol was not within the acceptable limit after one month of storage. One possible explanation for the rapid rise in TVB-N during storage is the degradation of proteins and other nitrogenous compounds that are not proteins **(Nowsad, 2007)**. **Islam *et al.* (2006)** found that the ribbonfish and the Bombay duck, which were collected from a low-cost solar dryer in Cox's Bazar, had reduced levels of TVB-N values, measuring 27.3 and 30.9mg/ 100g, respectively. The results of the present study are consistent with the findings reported by **Anihouvi *et al.* (2012)**, who found that high TVB-N levels, ranging from 264.7 to 389.9mg/ 100g, were observed by the organically fermented cassava fish for lanhouin production. **Roy *et al.* (2014)** found similar results, showing that fish items from Telesech-fermented Tripura State, India, had a high TVB-N level (210.92mg/ 100 g). The activity of endogenous enzymes and deteriorating bacteria is associated with a rise in TVB-N, a typical biomarker of fish spoiling **(Ozogul *et al.*, 2004; Ruiz-Capillas & Moral, 2005)**. According to **Silva *et al.* (1998)**, TVB-N level of less than 2– 3.6mg N/ 100g indicates that the fish is fresh, whereas a level of more than about 50mg N/ 100g indicates the fish is unfit for human consumption.

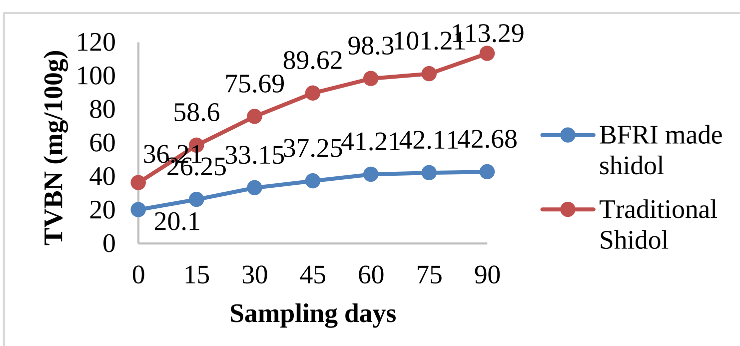

Fig. 7. TVBN value of BFRI made *shidol* and traditional *shidol*

Peroxide value

The amount of hydroperoxide in fat and oil is measured using the PV index. Free fatty acid is created when fat and oil are hydrolyzed, while hydro-peroxide is created when fat and oil are oxidized. When food is prepared, distributed, and kept fresh, it oxidizes. This response lowers the foods' nutritional content and degrades their texture, color, taste, odor, and appearance **(Frankel, 1988)**. For this reason, controlling this oxidation process is essential to maintaining the food's safety and quality.

In the present study, the average peroxide value ranged from 2.10 to 9.01mEq/ kg of oil, with an average of 6.78mEq/ kg of oil in BFRI-made *shidol*, and in traditional *shidol*, the PV value ranged from 7.10 to 31.58mEq/ kg of oil, with an average of 20.20mEq/ kg of oil, which was significantly different (P> 0.05) from each other (Fig. 8). Peroxide values of 10– 20mEq/ kg of oil are thought to be the maximum allowable limit for dried fish, and any fisheries products beyond that is thought to be unsafe for human consumption **(Connell, 1990)**. In the present study, the PV value of BFRI-made shidol was within the acceptable limit after three months of storage; whereas, the PV value of traditional *shidol* was within the acceptable limit for a maximum of 1.5 months. The PV value then surpassed the permissible threshold for human consumption. Additional *Puntius ticto* fish oil that was used to dry fish may have contributed to the high PV value of traditional *shidol*. This fish oil may enable traditional *shidol* to undergo somewhat higher oxidations. Several authors, however, agreed that limited oxidation products may be produced, although quite slowly. **Clucas and Ward (1996)** stated that during freezing and frozen storage, high-lipid fish experience extremely slow oxidation. Fish lipid oxidation was found to be influenced by the fish's initial lipid content, storage temperature, and duration of storage **(Saeed & Howel, 2002)**. The current findings also support the previous findings.

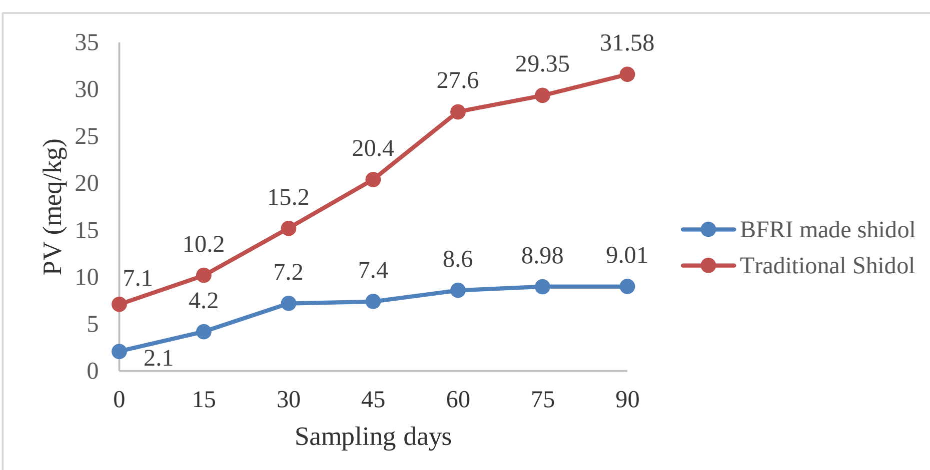

Fig. 8. Peroxide value of BFRI made *shidol* and traditional *shidol*

Microbiological qnalysis

Food's microbial activity is influenced by its nutritional composition as well as environmental factors like temperature and humidity **(Gram *et al.*, 2002)**. Dehydration inhibits the growth of spoilage microorganisms in products and numerous water-borne deteriorative reactions **(Kilic, 2009)**. The safety and quality of these dried products may be seriously jeopardized by the uncontrolled growth of microorganisms, according to **Abraham *et al.* (1993)**. Several species of microorganisms, including yeasts, molds, and aerobic and coliform bacteria, constitute the microflora of *shidol*. The BFRI-made *shidol* samples exhibited a microbial load ranging from 1.06 to 2.80, with an average of 1.54 log10 CFU/ g for the total viable count (Fig. 9A). In contrast, the count of yeast and mold varied from 1.15 to 3.15, with an average of 2.52 log10 CFU/g (Fig. 9B). Conversely, the traditionally made *shidol* sample that was collected from Rangpur, Nilphamari, Kurigram, Dinajpur, Gaibanda, and Lalmonirhat showed a total viable count and yeast and mold count ranging from 5.41 to 8.80 with an average of 6.41 log10 CFU/ g and 3.56 to 7.98 with an average of 6.44 log10 CFU/ g, respectively (Fig. 9A, B). There was no evidence of total coliform count in the BFRI made *shidol* sample, whereas it was found in the traditional *shidol* sample with a value ranging from 0.17 to 0.68 with an average 0.45 log10 CFU/ g (Fig. 9 C). A prior study **(Huang *et al.*, 2010; Rashid & Mithun, 2020)** indicated that *E. coli* was frequently detected in high moisture content dried fish products with concentrations between < 3 and 210 $MPNg^{-1}$. Many symptoms, including diarrhea, fever, stomach pain, and occasionally vomiting, can be brought on by *E. coli*. Eminently, fecal contamination is assumed to be the cause **(Feldhusen, 2000; Mithun *et al.*, 2024)**. Its presence in these products implied that the producers had not practiced basic cleanliness, and eating it could cause illness.

The average total viable count (TVC) of BFRI-made *shidol* and traditional *shidol* in this investigation showed a significant difference ($P > 0.05$) between them, with the traditional *shidol* exhibiting a significantly higher bacterial count. In neither of the samples *Yersinia* spp, *Campylobacter*, *Listeria monocytogenes*, or *Vibrio* spp were detected.

The upper acceptable level for dried fish products is 5 log CFU/ g, and in the present study, the total plate counts in traditional *shidol* samples exceeded this threshold **(ICMSF, 2002)**. However, the maximum total plate count in the BFRI-made shidol samples was 2.80 log10 CFU /g, which was below the acceptable level for dried fish products. Based on the microbiological count, the traditional *shidol* samples used in this investigation were therefore deemed unsuitable.

Fungal development and toxin production in fish that are attracted to hot, humid weather, moisture content greater than sixteen percent, and insect damage **(Hamblin, 2000; Mithun *et al.*, 2021; Sunny *et al.*, 2021a)**. The average total fungal count (TFC) of the traditional and BFRI-made *shidol* in this investigation was 6.44 and 2.52 log10 CFU /g, respectively. The fungus count in traditional *shidol* was found to be significantly higher (6.44 log10 CFU/ g) than in BFRI-made *shidol* (2.52 log10 CFU /g), with *P*-values less than 0.05. The Sri Lanka Standard Institute's upper acceptability limit for dried fish is 4 log CFU/ g, which the total fungal counts in the study's BFRI-made *shidol* samples (2.52 log10 CFU/ g) did not exceed. However, in traditional *shidol* samples, the total fungal counts were higher than the acceptability limit (6.44 log10 CFU/ g).

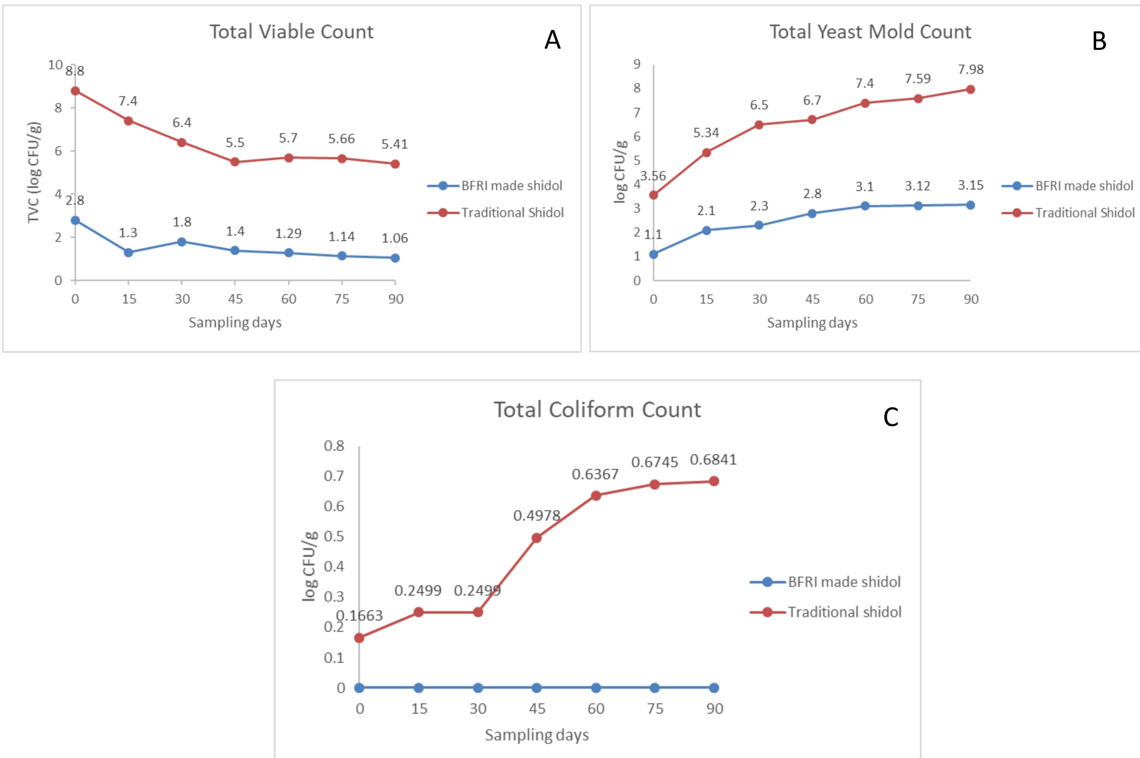

Fig. 9. **(A)** Total viable count; **(B)** Total yeast mold count, and **(C)** Total coliform count of BFRI made *shidol* and traditional *shidol*

According to the findings of **Mustafa (2017)**, the average microbial load in a typical salted-fermented fish (Hout-Kasef) product ranged from 2.81 to 4.72, with an average of 3.77 log10 CFU/ g for the total aerobic bacterial count; 3.61 to 5.14, with an average of 4.32 log10 CFU/ g for the count of the halophile bacteria; 2.71 to 3.85, with an average of 3.23 log10 CFU/ g for the count of *staphylococci*; and from 0.48 to 3.14, with an average of 1.33 log10 CFU/ g for yeasts and molds. The findings of the present study were comparable to those of the fermented and salted Atanatic herring, the fermented and salted *Mugil cephalous* fish (Fesskh), and the salted grey mullet and the kass **(Achinewhu *et al.*, 2004; Patir *et al.*, 2006; Ahmed *et al.*, 2010; Adegunwa *et al.*, 2013)**. The absence of coliforms and other harmful microorganisms in the BFRI-made shidol sample may be attributed to the salt that was added during fermentation, good manufacturing procedures, as well as proper hygiene. The results of this investigation are consistent with those of **Thapa *et al.*, (2004)**, who found that the predominant bacterial groups recovered from fermented fish products in North-East India, such as ngari, hentak, and tungtag, were *Staphylococci* and *Bacilli*. In a similar manner. *Staphylococci* and *Bacilli* were the two most prevalent bacterial species identified by **Anihouvi *et al.* (2007)** from the fermented fish products that the Republic of Benin traditionally prepared, including the cassava and lanhouin. However, **Koffi-Nevry *et al.* (2011)** found that the primary fermentation agent in Agjuevan, an Ivory Coast fermented fish, was lactic acid bacteria.

The higher bacterial and fungal plate count in the traditional *shidol* sample might have occurred due to high moisture content in this sample. The unhygienic process of making traditional *shidol* might be another cause of higher bacterial and fungal plate count in final product. During the processing of BFRI made *shidol* dressing, gutting and salting were done properly. Besides, smoking lowers the moisture content in fish and might add some antimicrobial property which ultimately lower the bacterial and fungal count in final product of shidol made in BFRI. The results of a combination of improper handling, inappropriate storage, and ignorance of proper hygiene and sanitation are indicated by the increased bacterial and fungal plate count in traditional shidhal in our study. For food safety, therefore, a lower level of contamination and control over bacterial growth are required. To reduce the amount of hazardous and decomposing bacteria present in fermented dried fish products, it is advised to enhance the preparation and processing methods by implementing good manufacturing principles (GMP) and wearing sanitary gloves when handling the product.

CONCLUSION

The present study demonstrated that the quality of BFRI-made *shidol* was in an acceptable condition with a good nutritive value compared to the traditionally collected sample in a vacuum packaging system during the storage period of 90 days. The lack of a proper packing system, hygienic circumstances, and sufficient understanding about quality among the traditional *shidol* manufacturers could all contribute to the inferior quality of the product. The BFRI-made shidol was found to have a high nutritious value based on the findings of the biochemical and microbiological study. Its total viable count and yeast mold count were both within the acceptable limits, and its protein, ash, and fat contents were noted to be high. After 90 days of storage, it was also found that the peroxide and TVBN values of the *shidol* produced by BFRI were within the acceptable limits. BFRI-made *shidol* did not exhibit any pathogenic coliform bacteria over the entire trial period, suggesting that good sanitary standards were followed during the manufacturing. We came to the conclusion that vacuum packing, which delays nutrient degradation and prevents cross-contamination, can significantly contribute to the preservation of *shidol* quality. Additionally, this improved technique of *shidol* production may reduce the biochemical and microbiological quality loss of *shidol*. These findings will have a major impact on human nutrition because *shidol*, a fermented dried fish product, is an essential source of necessary proteins for consumers and is a staple in the diet of northern Bangladesh.

Acknowledgements
The authors express their grateful appreciation and gratitude to the Bangladesh Fisheries Research Institute for the financial support of the research. The authors are also thankful to the staff of the Floodplain Substation, BFRI, Santahar, and Bogura for their support in the field and laboratory during the implementation of the study.

REFERENCES

Abbey, L.D.; Hodari-Okae, M. and Osei-Yaw, A. (1994). Studies on traditional processing and quality of fermented fish momone. *Aritisanal Fish Processing and Applied research Report*. Ed. Food Research Institute, Accra-Ghana; 48.

Abraham, T.J.; Sukumar, D.; Shanmugam, S.A. and Jeyachandran, P. (1993). Microbial stability of certain cured fishery products. *Fishery Technology*, 30(2): 133–138.

Achinewhu, S.C.; Amadi, E.N.; Barimalaa, I.S. and Eke, J. (2004). Microbiology of naturally fermented fish (*Sardinella sp*.). *Journal of aquatic food product technology*, 13: 47–53.

Adegunwa, M.O.; Adebowale, A.A.; Olisa, Z.G. and Bakare, H.A. (2013). Chemical and microbiological qualities of smoked herring (Sardinella eba,) in Odeda, Ogun state, Nigeria. *International Journal of Microbiology Research and Reviews*, 1: 085–087.

Ahmed, E.O.; Ali, M.E. and Hamed, A.A. (2010). Quality Changes of Salted Storage at Ambient Temperature (37±1º C). *Pakistan Journal of Nutrition*, 9: 877–881.

Anihouvi, V.B.; Kindossi, J.M. and Hounhouigan, J.D. (2012). Processing and quality characteristics of some major fermented fish products from Africa: A critical review. *International Journal of Biological Sciences*, 1: 72–84.

Anihouvi, V.B.; Sakyi-Dawson, E.; Ayenor, G.S. and Hounhouigan, J.B. (2009). Biochemical changes and aroma development during the spontaneous fermentation of cassava fish into Lanhouin and their influence on product acceptability. *Journal of aquatic food product technology*, 18: 370–384.

Anihouvi, V.B.; Sakyi-Dawson, E.; Ayernor, G.S. and Hounhouigan, J.D. (2007). Microbiological changes in naturally fermented cassava fish (*Pseudotolithus sp.*) for lanhouin production. *International journal of food microbiology*, 116: 287–291.

AOAC. (2000). Official Methods of Analysis, 17th edn, (Association of Official analytical Chemicals, Will behington, DC, USA).

APHA. (2001). Compendium of Methods for the Microbiological Examination of Foods. American Public Health Association, Washington, DC.

Beatty, S. and Gibbons, N. (1937). The measurement of spoilage in fish. *Journal of the Fisheries Research Board of Canada,* 3: 77–91.

Bjerke, G. A.; Rudi, K.; Avershina, E.; Moen, B.; Blom H. and Axelsson L. (2019). Exploring the Brine Microbiota of a Traditional Norwegian Fermented Fish Product (Rakfisk) from Six Different Producers during Two Consecutive Seasonal Productions. *Foods,* 8(2): 72.

Castro, P.; Padrón, J.C.P.; Cansino, M.J.C.; Velázquez, E.S.; and De Larriva, R.M. (2006). Total volatile base nitrogen and its use to assess freshness in European sea bass stored in ice. *Food Control,* 17(4): 245–248.

Clucas, I.J. and Ward, A.R. (1996). Preservation, Processing and Quality Chathan Maritime. 443 pp.

Connell, J.J. (1990). Control of Fish Quality, third ed. Fishing News Books, Oxford, p. 245. Clucas, I.J., Ward, A.R., 1996. Post-harvest Fisheries Development. A Guide to Handling, Preservation, Processing and Quality. Natural Resources Institute, Chatham (United Kingdom), p. 353.

Das, D.R.; Dey, S.K.; Mithun, M.H.; Moniruzzaman, M.; Rahman, M.K. and Mahmud, Y. (2022b). Growth and production performance of Mud Eel, *Monopterus cuchia* (Hamilton, 1822) using different types of feed in the Northern region of Bangladesh. *Archives of Agriculture and Environmental Science,* 7(4): 509-513, https://dx.doi.org/10.26832/24566632.2022.070404.

Das, D.R.; Khanom, M.; Moniruzzaman, M.; Mithun, M.H.; Rahman, M.K. and Mahmud, Y. (2022a). First Record of Induced Breeding of Indian Potasi, *Neotropius atherinoides* (Bloch 1794) in Bangladesh. *Egyptian Journal of Aquatic Biology & Fisheries*, 26(4): 59 – 74.

Das, D.R.; Mithun, M.H.; Moniruzzaman, M. and Mahmud, Y. (2023a). Some aspects of reproductive biology of gangetic ailia, *Ailia coila* (Hamilton, 1822) in Bangladesh. *Academia Journal of Biology*, 45(3): 1–11. https://doi.org/10.15625/2615-9023/18360

Das, D.R.; Mithun, M.H.; Moniruzzaman, M. and Mahmud, Y. (2023b). Reproductive Biology of Pialy Fish, *Aspidoparia jaya* (Hamilton, 1822) in Bangladesh. *Asian Journal of Fisheries and Aquatic Research*, 23(2):14-24.

Das, D.R.; Mithun, M.H.; Moniruzzaman, M.; Dey, S.K.; Begum, N. and Mahmud, Y. (2023c). Reproductive biology and gonadal cycle of Indian Potasi, *Neotropius atherinoides* (Bloch 1794) in Bangladesh. *Archives of Agriculture and Environmental Science*, 8(2): 198-204, https://dx.doi.org/10.26832/24566632.2023.0802016

Das, D.R.; Mithun, M.H.; Moniruzzaman, M.; Khanum, M. and Mahmud, Y. (2023d). Nursing and management of early produced larvae of Thai pangas (*Pangasianodon hypophthalmus*) using greenhouse concept. *Archives of Agriculture and Environmental Science*, 8(1): 28-34, https://dx.doi.org/10.26832/24566632.2023.080105

Das, D.R.; Moniruzzaman, M.; Khanom, M.; Mithun, M.H. and Mahmud, Y. (2023e). First record of induced breeding and fry production techniques of Pialy fish, *Aspidoparia jaya* (Hamilton, 1822) in Bangladesh. *Archives of Agriculture and Environmental Science,* 8(2): 205-213, https://dx.doi.org/10.26832/24566632.2023.0802017

FAMIC (Food and Agricultural Materials Inspection Center). (2019). Proximate Composition and Detergent Fiber;. Available from: http://www. famic.go.jp/english/index.html. [Last accessed on 2020 May 01].

FDA. (1998). Bacteriological Analytical Manual. Food and Drug Administration/ Association of Official Analytical Chemists.

Feldhusen, F. (2000). The role of seafood in bacterial foodborne diseases. *Microbes Infect,* 2(13):1651 60.

Frankel, E.N. (1988). Lipid Oxidation, The Oily Press, Dundee.

Gram, L.; Ravn, L.; Rasch, M.; Bruhn, J.B.; Christensen, A.B. and Givskov, M. (2002). Food spoilage—interactions between food spoilage bacteria. *International Journal of Food Microbiology*, 78(1-2): 79–97.

Hamblin, A.M. (2000). A focus on aflatoxin Smoked dried fishes samples stored for sale in contamination complication. Publication Papers 4.

Huang, Y.R.; Liu, K.J.; Hsieh, H.S.; Hsieh, C.H.; Hwang, D.F. and Tsai, Y.H. (2010). Histamine level and histamine forming bacteria in dried fish products sold in Penghu Island of Taiwan. *Food Control*, 21(9):1234-9.

ICMSF (International Commission on Microbiological Specifications for Foods). (2002). Microorganisms in Foods 7: Microbiological Testing in Food Safety Management. 1st Ed. Kluwer Academic/Plenum, New York: 1–362 pp.

Islam, M.T.; Kamal, M.; Islam, M.N.; Neazuddin, M. and Mehbub, M.F. (2006). Organoleptic, biochemical and bacteriological aspects of the low cost tunnel dried fish products. *Bangladesh Journal of Fisheries Research,* 10(2): 175–183.

Jacobs, M.B. (1958). The chemical analysis of foods and food products. New York Krieger Publishing Co. Inc., p. 393-394.

Kilic, A. (2009). Low temperature and high velocity (LTHV) application in drying: Characteristics and effects on the fish quality. *Journal of Food Engineering*, 91(1): 173–182.

Kimura, K. and Kiamukura, S. (1934). Detection of the onset of decomposition of fish meat as shown by the content of Ammonia. Proceeding of Pacific Science Congress 5: 3709.

Koffi-Nevry, R.; Ouina, T.S.; Koussememon, M. and Broi, K. (2011). Chemical composition and lactic acid microflora of Adjuevan, traditional Ivorian fermented fish condiment. *Pakistan Journal of Nutrition,* 10: 332–337.

Kuddus, M.A.; Sunny, A.R.; Sazzad, S.A.; Hossain, M.; Rahman, M.; Mithun, M.H.; Hasan, S.E.; Ahmed, K.J.; Zandonadi, R.P.; Han, H.; Ariza-Montes, A.; Vega-Muñoz, A. and Raposo, A. (2022). Sense and Manner of WASH and Their Coalition with Disease and Nutritional Status of Under-five Children in Rural Bangladesh: A Cross-Sectional Study. *Frontiers in Public Health,* 10: 890293. doi: 10.3389/fpubh.2022.890293

Kyrana, V.R.; Lougovious, V.P. and Valsamis, D.S. (1997). Assessment of shelf-life of Mari cultured gilthead sea bream (*Sparus aurata*) stored in ice. *International Journal of Food Science & Technology,* 32: 339–347.

Majumdar, R.K.; Roy, D. and Bejjanki, S. (2016). An overview of some ethnic fermented fish products of the Eastern Himalayan region of India. *Journal of Ethnic Foods,* 3(4): 276-283, 2016.

Mithun, M.H.; Alam, M.J.; Rashid, I. and Salam. M.A. (2021). Optimization of stocking density of Gulsha (*Mystus cavasius*) in circular shaped net cages in pond conditions. *Bangladesh Journal of Fisheries,* 33(2): 187- 194 https://doi.org/10.52168/bjf.2021.33.21.

Mithun, M.H.; Kar, A.; Prome, S.M.; Jahan, I.; Akter, A. and Hasan, S.E. (2024). A Comprehensive Review on Cell Death. *Journal of Knowledge Learning and Science Technology*, 2(3): 170-188. https://doi.org/10.60087/jklst.vol2.n3.p188

Mithun, M.H.; Rashid. I.; Salam. M.A. and Alam M.J. (2020). Influence of cage shapes on growth and production of silurid caitish (*Mystus cavanus*) in earthen pond. *Annals of Bangladesh Agriculture,* 24(2): 59- 68. www.doi.org/10.3329/abax 2412 55784.

Mohammed, H.M.H. (2010). Nutritive value of fresh and salted fermented fish (aleste dentex) Terkin. In: Food Science and Technology, Ed. Khartoum. Sudan.

Mustafa, A.G. (2017). Microbiological and chemical quality of a traditional salted-fermented fish (Hout-Kasef) product of Jazan Region, Saudi Arabia. *Saudi Journal of Biological Sciences,* 26: 137–140. http://dx.doi.org/10.1016/j.sjbs.2017.04.003

Nayeem, M.A.; Pervin, K.; Reza, M.S.; Khan, M.N.A.; Shikha, F.H. (2010). Present status of handling, transportation and processing of traditional dried Punti (punti shutki) and semifermented fish (chepa shutki) products in Mymensingh district, Bangladesh. *Journal of Agroforestry Environment,* 4(1): 13-16.

Nowsad, A.K.M.A (2005). Low-cost Processing of Fish in Coastal Bangladesh. BGD/97/017 Field Doc: 05/2005. Food and Agriculture Organization of the United Nations, Dhaka: 1– 73 pp.

Nowsad, A.K.M.A. (2007). Participatory Training of Trainers: A New Approach Applied in Fish Processing, Bengal Com-Print, 68/5, Dhaka, 151-191.

Osman, O.A.; Sulieman, A.E.; Elkhalifa, E.A. and Mustafa, W.A. (2012). Chemical and microbiological characteristic of fermented fish product, Fassiekh. *Food Public Health,* 2: 213–218.

Ozogul, F.; Polat, A. and Ozogul, Y. (2004). The effects of modified atmosphere packaging and vacuum packaging, on chemical, sensory and microbiological changes of sardines (Sardina pilchardus). *Food Chemistry*, 8: 49–57.

Patir, B.; Gurel, A.I.; Oksuztepe, G. and Irfan, I.O. (2006). Microbiological and Chemical Qualities of Salted Grey Mullet (Chalcalburnus tarichii Pallas, 1811). *International journal of science technology and management,* 1: 91–98.

Petrus Purnomo, H.; Suprayitno, E. and Hardoko, L. (2013). Physiochemical characteristics, sensory acceptability andf microbial quality of Wadi Betok a traditional fermented fish from South Kalimantan, Indonesian. *International Food Research Journal,* 20: 933–939.

Puwastien, P.; Siong, T.E.; Kantasubrata, J.; Craven, G.; Feliciano, R.R. and Judprasong, K. (2011). ASEAN Manual of Food Analysis. Institute of Nutrition, Mahidol University.

Rashid, I. and Mithun, M.H. (2020). Guidelines for Freshwater Pond Management in Bangladesh. *Bangladesh Journal of Multidisciplinary Scientific Research,* 2(2). ISSN 2687-850X E-ISSN 2682-8518 doi: 10.46281 bimsrv212.645.

Roy, D.; Majumbar, R.K.; Maurya, S.K.; Tripathi, D.B. and Priyadarshini, M.B. (2014). Understanding of traditional knowledge and characterization of Telesech a fermented fish product of Tripura state. *Indian Journal of Natural Products and Resources,* 5: 351–358.

Ruiz-Capillas, C. and Moral, A. (2005). Sensory and biochemical aspects of quality of whole bigeye tuna (Thunnusobesus) during bulk storage in controlled atmospheres. *Food Chemistry,* 89: 347–354.

Saeed, S. and Howel, N.K. (2002). Effect of lipid oxidation and frozen storage on muscle proteins of Atlantic mackerel (Scomber scombrus). *Journal of the Science of Food and Agriculture,* 82 (5): 579–586.

Silva, G.; Da Ponte, D.J. and Enes. Dapkevicius, S. (1998). Storage temperature effect on histamine formation in big Eye Tuna and Skipjack. *Journal of Food Science,* 63: 644–647.

Sunny, A.R.; Mithun, M.H.; Ahamed, G.S.; Islam, M.A.; Das, B.; Rahman, A., et al. (2019). Livelihood Status of The Hilsa (*Tenualosa ilisha*) Fishers: The Case Of Coastal Fishing Community of The Padma River, Bangladesh. *Journal of Coastal Zone Management,* 22:2.

Sunny, A.R.; Mithun, M.H.; Prodhan, S.H.; Ashrafuzzaman, M.; Rahman, M.A.; Billah, M.M.; Hussain, M.; Ahmed. K.J.; Alam. M.T.; Rashid. A.; Hossain, M.M. (2021a). Fisheries in the Context of Attaining Sustainable Development Goals (SDGs) in Bangladesh: COVID-19 Impacts and Future Prospects. *Sustaiability*, 13 (17): 9912. https://doi.org/10.3390/su13179912.

Sunny. A.R.; Sazzad, S.A.; Prodhan, S.H.; Ashrafuzziman, M.; Datta, G.C.; Sarker, A.K.; Rahman, M. and Mithun, M.H. (2021b). Assessing impacts of COVID-19 on aquatic food system and small-scale fisheries in Bangladesh. *Marine Policy*, 126: 104422. doi: 10.1016/j.marpol.2021. 104422.

Thangaraj, P. (2016). Pharmacological assays of plant-based natural products. Rainsford KD, editor. *Springer Nature*,71:21-9.

Thapa, N.; Pal, J. and Tamang, J.P. (2004). Microbial diversity in ngari, hentak and tungtaq, fermented fish products of North-East India. *World Journal of Microbiology and Biotechnology,* 20: 599–607.

Wu, T.H. and Bechtel, P.J. (2008). Ammonia, dimethylamine, trimethylamine, and trimethylamine oxide from raw and processed fish by-products. *Journal of Aquatic Food Product Technology*, 17(1): 27–38