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Determination of sensory attributes, microbiological, and biochemical analysis, and pesticide contents of the dried shark (*Scoliodon sorrakowah*) in the Bengal Bay of Bangladesh

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ABSTRACT

Fish drying is an ancient and traditional method of producing nutrient-dense nourishment for humans. The present study was performed to investigate the sensory quality, microbial, biochemical, and pesticide contents of dried sharks (*Scoliodon sorrakowah*) from four major fish drying centers in southern Bangladesh. Sensory attributes were determined by the expert panel members; whereas, microbial quality and biochemical compositions were assessed by standard validated methods. The QuEChERS separation was used in conjunction with gas chromatography and gas chromatography-mass spectrometry to assess pesticide residues. The sensory properties showed that the dried shark fish products were of acceptable quality for human consumption in all drying center samples and did not differ significantly ($P< 0.05$). The aerobic plate count (APC) for dried shark fish products exceeded the regulatory limit and varied significantly ($P< 0.05$) across all major fish drying centers, with the exception of the shark fish product ($9.6\pm0.09\times10^4$ cfu/g) of the Dublarchar counterparts. Likewise, the total fungal load was recorded and differed substantially ($P< 0.05$) in dried shark ($1.78\pm0.03\times10^3$ cfu/g) fish products. All dried fish products were free of pathogenic bacteria such as *Salmonella* spp., *Vibrio cholerae*, *Vibrio parahaemolyticus*, and *Listeria monocytogens*. The biochemical compositions (protein, lipid, ash and moisture) and quality indices of dried shark fish products were statistically significant ($P< 0.05$), except for ash and pH contents ($P> 0.05$). In addition, the organochlorine pesticide residues (DDT and heptachlor) were not found in all dried shark fish products, and the pesticides posed no health risk at any sampling station.

INTRODUCTION

The bay of Bengal is endowed with diverse coastal and marine ecosystems that represent a diverse range of species diversity, including fish, shrimp, mollusks, crabs, mammals, seaweeds, etc... An estimated number of 511 species of marine finfish and

shrimp are found in the Bengal Bay of Bangladesh water **(Murshed-E Jahan *et al.*, 2014)**. The production of marine fisheries accounts for only 14.74% of total national fish production **(DoF, 2022)**. The potential of the coastal fisheries sector has not been rationally harvested compared to the resources being abused. In Bangladesh, the marine capture fisheries industry is one of the most promising, especially when it comes to exporting chilled and frozen goods. Fish drying is one of the ancient and traditional processing methods that provide nutritious food for human consumption. Fish drying in Bangladesh is usually practiced in the remote coastal isolated islands and in inland depressions where the chilling and freezing facilities are lacking. Moreover, marine fishes play an important role concerning nutrition and economy, based on the processing methods.

Sharks fishery in Bangladesh is not a target fishery. There are about 11 species of sharks identified in Bengal Bay **(Roy *et al.*, 2012)**, of which four species are commercially important **(Hoq *et al.*, 2011)**. Because of lower market value and consumer aversion on raw shark fish, this species is delt with in separation from valuable fish before and during landing in the centers. Typically, shark species are dried at the high exposure to the sunlight and used for human consumption, particularly in soups and tannery industry in Bangladesh **(Hoq *et al.*, 2011)**. Although there is no doubt that sun drying is the convenient and cost-effective way of fish preservation but it still has many limitations. One of the key issues with sun-drying fish is insect infestation of the products by blow fly and beetle larvae **(Nowsad, 2007)**. Dried fish contaminated by both insects and insecticides accounts for approximately 60% of the total dried products regarded unfit for human consumption **(Nowsad, 2007)**. Apart from contaminated salted and dried fish, other common sources of contamination are air and dust in and around the fish processing place, in addition to the contaminated coastal water and soil as well as the unhygienic handling **(Prabhakaran & Gupta, 1990)**. Different pesticides are usually used during different stages of handling and processing in order to increase the shelf-life of the stored dried products.

In Bangladesh, the organoleptic qualities of most of the traditional sun- dried products available in the market are not satisfactory for human consumption **(Reza, 2002; Hasan, 2006)**. Customers perceive high-quality processed foods with negligible nutritional and sensory properties. The qualities of sun dried fishes are adversely affected by the occurrence of microorganisms. During the monsoon, when the humidity is high, the fish can absorb the moisture, serving as a habitat for microbial population **(Azam *et al.*, 2003)**. Determination of microbiological quality of such processed fishes is very important for guarding consumer's health and hygiene **(Lilabati *et al.*, 1999)**. The biochemical composition of dried fish is an important aspect in dried fish processing as it influences both the preservation of the quality and the physical characteristics of the dried fish. Dried fishery products are high in nutritional value and important nutrients for a balanced and healthy body **(Koffi-Nevry *et al.*, 2011; Sutharshiny & Sivashanthini,**

2011). Dried fishes are a low-cost dietary protein source that is widely used as an alternative for fresh fish when they are insufficient **(Rahman *et al.*, 2017)**. Approximately, 20% of the total marine catch from Bangladesh's coastline is sun dried and distributed in the domestic market **(Begum *et al.*, 2012; Hasan *et al.*, 2016).** Dried shark seafood products will play an integral part in the quality and safety of products for customers both nationally and internationally.

The major dried fish processing areas in Bangladesh are Banshkhali, Noakhali, Chandpur of Chittagong, Nizampur, Mohipur, Rangabali, Kuakata, of Patuakhali; Nazirartek, Moheshkhali, Sonadia, Kotubdia, Talipotti, Saint Martin, Teknaf of Cox's Bazar; Charfashion of Vhola and Sathkira **(Amin *et al.*, 2012; Nowsad, 2007)**. Dublarchar in Sundarban of Khulna is the largest marine fish drying center in the country **(Nowsad, 2007)**. However, globally good numbers of investigations have been conducted on the sensory, biochemical, and microbial composition of fishes but the quality of dried fish in coastal areas, notably by small-scale fisher groups, has received little attention. Similarly, no research on the sensory, microbial, and biochemical analysis of dried shark has been conducted in Bangladesh. The goal of the current study was to determine the sensory, microbial, biochemical, and pesticide contents of sun-dried shark in the major fish drying centers of Bangladesh's coastal region.

MATERIALS AND METHODS

Study area

Sun dried shark (*Scoliodon sorrakowah*) were collected from four major drying fish yards, viz. Dublarchar fish drying center (Bagerhat), Banshkhali fish drying center (Chattogram), Kuakata fish drying center (Patuakhali) and Kutubdiapara fish drying center (Cox’sbazar). The specific sampling locations are shown in Fig. (1).

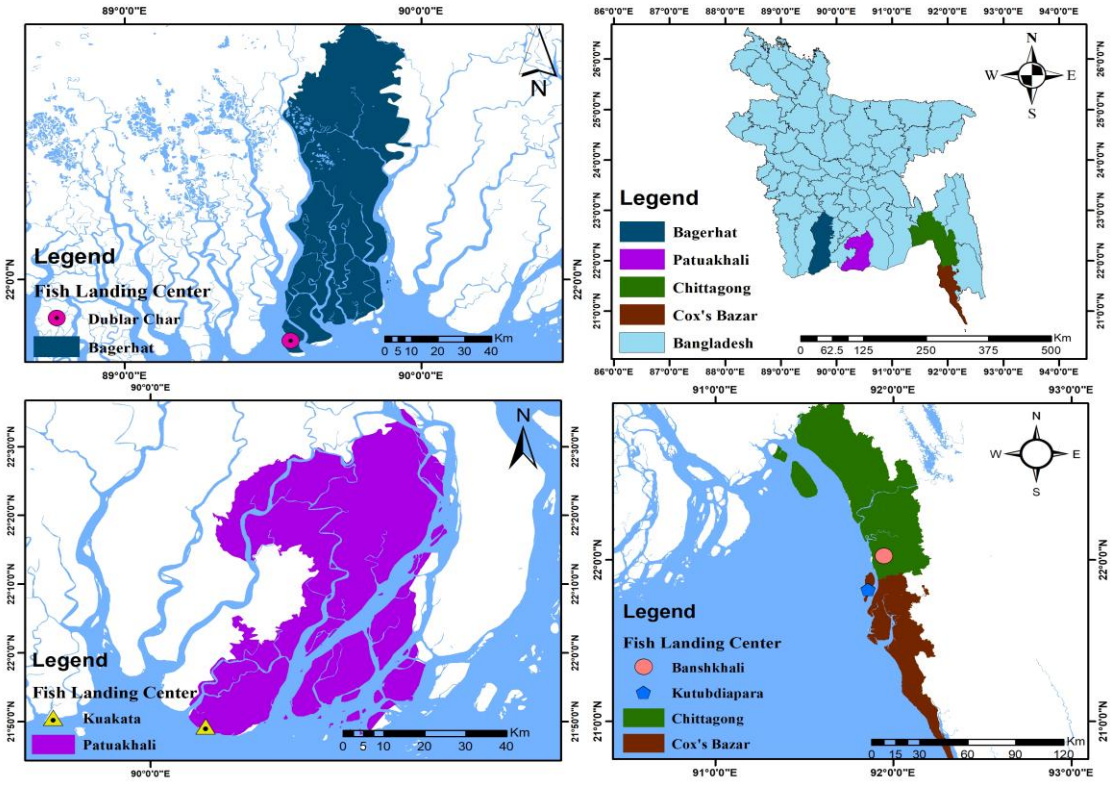

Fig. 1. Different colors showing sampling locations in Bangladesh

Sample collection and preparation

After collection, 3 kg of composites sun- dried shark (S. *sorrakowah*) were purchased in triplicate from each of the four drying centers, and the mean length (18.53±0.32cm) and mean weight (252.5±15.03g) were measured by a stainless steel ruler and an electric balance, respectively (Table 1).

Table 1. Biometric index of sun- dried shark (*S. sorrakowah*) from major fish drying centers

Sample	Kutubdiapara	Chattogram	Kuakata	Dublarchar	*P*-value
Shark	3.94 ± 0.03^{bc}	3.99 ± 0.03^{b}	3.92 ± 0.01^{cd}	4.01 ± 0.01^{ab}	0.031

Note: ND* = No samples. Values are mean ± SE of triplicate (n = 3) samples. In a row, values with different alphabetical superscripts differ significantly at ($P < 0.05$).

The collected samples were packed in an insulated icebox and transported to the Seafood Quality, and Safety Laboratory at the Patuakhali Science and Technology University, Bangladesh. The collected samples were properly labeled and kept in the refrigerator (SJ-VX79E-SL, Sharp, Japan) at normal temperature (4°C) until the pesticides residues, sensory, microbial, biochemical composition were obtained.

Sensory characteristics

Color, odor, texture, and insect infestation of the dried fish produced by the local fishermen (processors) were examined by sensory analysis according to the method of **Rasul *et. al.* (2018)**, which is shown in Table (2).

Table 2: Characteristics score for determining the sensory quality of dried fish

Organoleptic Characteristic	Description	Score	Comment on quality
Color	Ash and shiny color	1-2.99	Excellent
	Slightly brownish/whitish/yellowish	3-5.99	Average
	Brownish/Faded	6-7.99	Moderately unacceptable
	Blackish color	8-10	Highly unacceptable
Odor	Natural dried fishy odor	1-2.99	Excellent
	Slight decrease of dry fish odor	3–5.99	Good
	Slightly rancid	6–7.99	Average
	Prominence of herbal odor/absence of dry fish/rancid	8–10	Poor in quality and unacceptable
Texture	Firm and flexible	1–2.99	Excellent
	Some loss of firmness and elasticity	3–5.99	Average
	Soft in texture	6–7.99	Poor in quality and unacceptable
	Brittle/Fragmented	8–10	Unacceptable
Insect infestation	No infestation	1–2.99	Excellent
	Few insect infestation	3–5.99	Average
	Moderate insect infestation	6–7.99	Poor in quality and unacceptable
	Heavy insect infestation	8–10	Unacceptable

Microbiological analyses of sun- dried sharks

The bacteriological study was carried out using the aerobic plate count (APC) procedure **(Cappuccino & Sherman, 1992)**, and dried fish samples were prepared using the **ISO (1995)**. On nutritional agar media, a total bacterial colony count was obtained using standard plate count (SPC). A blended dried fish samples of about 1g was homogenously mixed with 9ml of sterile 1.5% peptone water obtained at a 1:10 dilution. Afterward, 1ml of supernatant was transferred from the centrifuge tube, and a 10-fold serial dilution of the sample with 0.9% physiological saline was performed. Aliquots of 0.1ml from each serial dilution were inoculated (triplicate) on to the nutrient agar media for APC. For specific bacterial count, 0.1ml of the stock solution onto eosin methylene blue (EMB), xylose lysine deoxycholate (XLD), Sabouraud dextrose agar (SDA) and thiosulfate citrate bile salts sucrose (TCBS) and *Listeria* enrichment broth

(LEB) agar media were used for total *E. coli* count (TEC), total *Salmonella* count (TSC), total fungal count, total *Vibrio* count (TViC) and total *Listeria* count, respectively. The colony colors on the respective selective media were used for identification after 48–72h. of incubation. Colorless or pale pink colonies on XLD agar were identified as *Salmonella* sp., purple colonies with black centers on EMB agar as *Escherichia coli*, and fuzzy edges white and buff with fungal sp., and yellow and bluish green colonies on TCBS agar as *Vibrio cholerae* and *Vibrio parahaemolyticus*, respectively, and blue-green color and an opaque halo round with LEB media. The APC, TEC, TSC, TFC, TViC and TLC were calculated using the following formula:

$$\text{cfu/g} = \frac{\text{No.of colonies on petridish} \times 10\times \text{ volume of total stock solution (ml)}}{\text{Weight of dried sample (g)}}$$

Determination of proximate compositions

For the sun- dried shark (*S. sorrakowah*) fish samples, the following procedures were analyzed following the standard methodology of **AOAC (2017)**. According to the method, moisture content was determined using a hot air oven (HAS/50/TDIG/SS, Genlab, UK) at 105°C until a constant weight (g) was obtained. Ash content was determined by muffle furnace (HM-9MP, Raypa, Spain) at 550°C for 20h. Crude protein content was analyzed by using the kjeldahl apparatus (Bloc Digest 12, JP Selecta, Spain), where a 6.25 conversion factor was used to convert total nitrogen to crude protein. The fat content was measured by using the Soxhlet apparatus (J-SH3, JISICO, Korea). The TVB-N and TMA-N values (mg N/100g) of dried fish samples were measured using the methodology of **Antonocoupoulos and Vyncke's (1989)**. Following this method, the digested sample was distilled using a semi-automatic distilling unit and then titrated with 0.01N H_2SO_4 solution mixed indicator for ammonia titrations. For pH, 10ml of distilled water was added to 10g of dried samples and homogenized for about 3min at 8000rpm with a homogenizer (Sonic Ruptor 400, OMIN, UK). The samples were prepared in triplicate, and the pH levels were determined by inserting the pH meter electrode (HI5522-01 Benchtop, Romania). For all the parameters, triplicate (n=3) samples were used.

Determination of pesticide residues in dried fish

Organochlorine pesticide residues (DDT and heptachlor) were determined in dried fish samples collected from the major fish drying yards in Bangladesh's coastal region.

Chemicals and reagents

Certified Reference Material (CRM) of 98–99% purity for the selected pesticides (DDT and heptachlor) was collected from Dr. Ehrenstorfer GmbH (Augsburg, Germany). Sigma-Aldrich Chemie GmbH (Taufkirchen, Germany) provided acetonitrile, sodium

chloride, PSA bond silica (primary secondary amine), and anhydrous magnesium sulphate.

Preparation of pesticide standard solution

DDT and heptachlor standard pesticide stock solutions were individually prepared in acetone at a concentration of 1000mg/L and stored at -20°C. An intermediate standard buffer acetone solution with a concentration of 50mg/L was equipped with acetone up to 50ml volumetric flask containing the appropriate volumes of each stock solution. The second mixed stock solution in acetone with a concentration of 10mg/L was also prepared from the 50mg/L mixed stock solutions. Afterward, standard solutions in acetone with concentrations of 0.1, 0.2, 0.5, 1.0, 2.0, 3.0, and 5.0mg/L were ready from the 10mg/L concentration. All of the standard solutions were kept at -20°C until they were used.

Sample preparation, extraction and clean-up of pesticide residues

The isolation and hygienic guidelines were done based on a modified QuEChERS sample preparation method for pesticides **(Prodhan *et al.* 2021).** The collected dried shark fish samples were sliced and blended separately in an electric blender with microcutters (Preethi Steel Max MF-212, Preethi Kitchen Appliances Pty. Ltd., India) to possess the relatively homogenous composite fish samples. About 10g of homogenized sample was incorporated with 10mL of acetonitrile in a 50ml centrifuge tube. The solution was vortexed for 1min, and then 4g of anhydrous magnesium sulphate and 1g of sodium chloride were added. The samples were centrifuged for 5min at 5000rpm, and the supernatant was shifted for cleaning. About 3ml supernatant was transferred into another centrifuge tube incorporating 120mg of primary and secondary amine (PSA) and 600mg of anhydrous magnesium sulphate. After centrifugation, 1ml of supernatant was filtered through a 0.2m PTFE filter and positioned in a vial for infusion.

Operational condition of GC–MS

The desired analytes were evaluated using a Shimadzu gas chromatograph with a mass selective detector (GC-MS QP 2010 Ultra, Japan) and the analytical column, Restek (Bellefonte, PA) Rxi-5 MS with fused silica (30m long 0.25mm internal diameter 1.0m flim thickness). The operating mode was split, (ratio 10.0); the injection port temperature was 250°C; the sampling time was 1min, helium was used as a carrier gas with a flow rate of 0.75 ml/min; linear velocity was flow of control mode, 124.6kPa pressure, 19.5ml/min overall flow, 1.5ml/min column flow, 46cm/s linear velocity, 3ml/min purge flow, and the injection volume was 1 l. The temperature was increased from 120°C to 200°C at 45°C for 3min, then to 240°C at 5°C for 10min, and finally to 310°C at 10°C for 3min, the total time of which was 34min. The analysis was performed in selected ion monitoring (SIM) mode to trace all analytes, with a minimum of four ions regarded for each pesticide. Standard solutions of various pesticide concentrations were prepared and injected with appropriate instrument parameters prior to the injection of the sample extract. The samples' retention time and peak area were calibrated using a matrix-

matched calibration standard for the pesticide's five-point calibration curve. The coefficient of determination (r^2) in the matrix-matched calibration curve was 0.99, the limits of detection (LoD) ranged from 0.002 to 0.004mg/kg, and the limits of quantification (LoQ) were 0.01mg/kg for all the pesticide measurements.

Statistical analysis

The statistical package for social science (SPSS) software version 23.0 (SPSS Inc., Chicago, Illinois, USA) was used to conduct all analyses. The differences between means were examined using the least significant difference method (LSD, ANOVA), and all data were reported as mean ± SE (standard error). A Games-Howell nonparametric post hoc analytic approach was also used for performing multiple comparisons. Values with a significance level of $P < 0.05$ were considered substantially different.

RESULTS AND DISSCUSION

Sensory characteristics of dried fishery products

Changes in sensory characteristics among four major fish drying center of sun-dried shark (S. *sorrakowah)* are presented in Table (3). No significant differences ($P< 0.05$) were detected among the sampling stations despite the excellent quality characteristics, except the color attributes. The color of the species was ash and natural dried shark color, which indicates excellent quality of the by-products. Dublarchar fishermen dried shark fish are of a high quality, compared to the other locations. Based on the odor, Chattogram fishermen produced fish with a natural fishy odor, which differed significantly ($P< 0.05$) from the other drying yards. Texture of the sun- dried shark species was firm and flexibile. On the other hand, the Dublarchar samples differed significantly ($P < 0.05$) among the other locations' samples. The dried fish produced by the local fishermen was excellent in quality according to the insect infestation properties.

Table 3. Sensory characteristics of sun- dried shark (*S. sorrakowah)* fish products

Parameter	Kutubdiapara	Chattogram	Kuakata	Dublarchar	*P*-value
Color	2.30^{a}±0.03	1.30^{ad}±0.06	1.60^{acd}±0.12	1.40^{ab}±0.06	<0.0001
Odor	1.30^{b}±0.10	1.50^{abc}±0.10	1.60^{abc}±0.15	1.70^{a}±0.12	0.184
Texture	1.60^{a}±0.15	1.10^{d}±0.06	1.40^{abcd}±0.10	1.50^{ab}±0.06	0.036
Insect	4.00^{b}±0.00	3.67^{bd}±0.33	5.00^{ab}±0.58	4.33^{bc}±0.33	0.150
Overall	2.00^{b}±0.00	2.00^{c}±0.00	2.33^{a}±0.33	2.00^{d}±0.00	0.441

Note: Values are mean ± SE of triplicate (n = 3) samples. In a row, values with different alphabetical superscripts differ significantly at ($P< 0.05$).

According to **Paul *et al.* (2018),** dried fishery products were judged to be of poor to fairly acceptable quality, based on sensorial attributes such as color, odor, texture, and insect infestation. Non-enzymatic browning reaction in dried fish may be attributed to color changes that continuously occurred during the storage period **(Koizumi *et al.*,**

1992), which is inconsistent with the current study. It has been proposed that a lower sensory score of dried fishery products indicates higher acceptance rate and vice versa **(Roy *et. al.,* 2014)**. Our findings indicate that both dried fishery products produced by fishermen were of high quality, which is in contrast to the findings of **Rahman *et al.* (2012)** and **Rasul *et al.* (2018)**.

Microbiological quality of sun- dried shark fish products

Table (4) summarizes the findings of microbiological analysis of sun- dried shark fish products from various major fish drying locations. The APC for all collected produced in the respective fish drying yards exceed the regulatory limit of 1×10^5cfu/g, except for Dublarchar fish drying yard ($9.6\pm0.09\times10^4$cfu/g). There were significant differences ($P < 0.05$) between locations. This assumes the consideration of the low water content and water activity of dried shark fishery products. The total plate count of bacteria in dried shark may be kept low by drying the fish to the optimum moisture content and water activity **(Al-Ghabshi *et al.,* 2012)**. This is in line with the findings of **Nur *et al.* (2020)** who discovered that, raw and sun- dried fishes from Kawran bazar, Dhaka, Bangladesh, may host a dangerous pathogen. In contrast to the current study, the most common dried fishes, such as ribbon fish and Bombay duck, have low bacterial counts and remain below the permissible limits found in the study of **Paul *et al.* (2018)**. The fungal count was found at a reasonable state and significantly ($P< 0.05$) different among the four major fish drying yards. The highest fungal was observed at Chattogram fish drying yard ($1.78\pm0.03\times10^3$cfu/g), where the lowest value was found at Dublarchar counterpart ($1.08\pm0.03\times10^3$cfu/g) (Table 4). Pathogenic bacteria such as *Coliforms* spp. and *E. coli* were found both in Chattogram and Kutubdiapara, and the value were 110MPN/g, 110MPN/g, respectively. On the contrary, Dublarchar products contained negligible amount of pathogenic bacteria and the ranged of *Coliforms* spp. and *E. coli* were 8MPN/g and 4MPN/g, respectively (Table 4). The other pathogenic bacteria such as *Salmonella* spp., *Vibrio cholera*, *Vibrio parahaemolyticus* and *Listeria monocytogens* were not found in all collected samples.

In addition, all samples taken from the four main fish drying centers in Bangladesh's coastal region did not contain total *Salmonella* spp. count (TSC), total *Vibrio* spp. count (TViC), and *Listeria monocytogens.* **Aliya *et al.* (2018)** demonstrated that some dry fish products contained coliforms and pathogenic bacteria at levels above the recommended limits, which is consistent with the current findings. Although there is a close relationship observed between the high bacterial load and the corresponding high level of NPN content **(Ravishankar & Jamuna, 2014)**, the samples did pick up some moisture content before any microbial attack was possible when the initial moisture content was close to 20% or below. According to **Sen *et al.* (1961)**, bacterial action ceased when the water content of the fish went below 25% of the wet weight, and mold ceased to grow when the water content was further lowered to 15%. In this situation, **Mithun *et al.* (2021)** found that the viable plate count (APC) of traditionally (7.72×10^7cfu/g) produced sun- dried

fishery products may be higher than that of the improved (4.32×10^4cfu/g) dried fishery products. Additionally, **Frazier and Westhoff (1979)** denied the capability of any microorganism (yeast, mold or bacteria) to grow in a fish product with less than 14% moisture content. This suggested that a moisture level of 20% was insufficient for bacterial development and proliferation. All samples tested with minimum amount of coliform, showing that there was more or less contamination from sewage or a buildup of hygiene practices among the country's traditional dry fish processors. Furthermore, microbial quantity and quality variations in the results may occur due to differences in location, processing/pre-processing, and personnel hygiene between the studies **(Mithun *et al.*, 2021)**. Furthermore, the human factor plays a significant role in bacterial contamination of fish during processing **(Chakma *et al.*, 2020)**. However, there is still potential for improvement in the quality of these highly delightful food products by using high-quality raw materials to produce dried products of a desired quality **(Azam *et al.*, 2003)**.

Table 4. Microbial quality of sun- dried shark fishery product from major drying centers

Parameter	Kutubdiapara	Chattogram	Kuakata	Dublarchar	*P*-value
APC	9.5 ± 0.02 $(\times10^5)^b$	$1.5\pm0.01(\times10^6)^d$	8.3 ± 0.03 $(\times10^5)^c$	$9.6\pm0.09(\times10^4)^a$	<0.0001
TFC	$1.4\pm0.03(\times10^3)^b$	$1.78\pm0.03(\times10^3)^a$	$1.21\pm0.02(\times10^3)^c$	$1.08\pm0.03(\times10^3)^d$	<0.0001
Coliforms spp.	110	110	21	8	
E. coli	110	110	21	4	
Vibrio Cholerae	ND*	ND*	ND*	ND*	
Vibrio Parahaemolyticus	ND*	ND*	ND*	ND*	
***Salmonella* spp.**	ND*	ND*	ND*	ND*	
Listeria monocytogens	ND*	ND*	ND*	ND*	

Note: ND* = Not Detected; APC= Aerobic Plate Count; TFC= Total Fungal Count; MPN= Most Probable Number; Values are mean ± SE of triplicate (n = 3) samples. In a row, values with different alphabetical superscripts differ significantly at ($P < 0.05$).

Biochemical compositions of dried shark fishery products

The biochemical compositions of dried shark (*S. sorrakowah*) from the four major fish drying centers in Bangladesh's southern regions are presented in Table (5). Dried fish is a great source of animal protein. **Glover-Amengor *et al.* (2012)** proposed that dried fish substances could be excellent sources of protein and iron for low-income people with protein levels ranging from 44.83% to 72.29% in some dried underutilized fish species. The present study revealed that, the protein content of dried shark (*S. sorrakowah*) fish products varied significantly ($P< 0.05$) among all collected samples. The highest protein contained was found in Kutubdiapara (58.49g/100g) drying center; whereas, lowest amount of protein was observed in Chattogram (56.56g/100g) drying center (Table 5).

The protein content of dried shark fish products was compatible with the findings of **Azam *et al.* (2003)** and **Aliya *et al.* (2018)** who conducted a biochemical investigation of dried shark fish products (58.35%). However, the protein content of the other most common dried fishes, such as Chinese pomfret (*Stromateus chinensis*), ribbon fish (*Lepturacanthus savala*), and Bombay duck (*Harpodon nehereus*), collected from Cox'sbazar and Chattogram, was 60.03%, 58.33%, and 71.90%, respectively **(Siddique & Aktar, 2011; Pravakar *et al.*, 2013)**. It was deduced that the protein content of fish varies depending on species due to factors, such as the seasonal changes, the influence of breeding season and migration, food availability etc… **(Effiong & Tafa, 2005)**.

Lipids are water-insoluble macro-biomolecules that are soluble in organic solvents and serve a variety of biological functions, including fuel molecules, energy stores, and membrane components **(Mohanty *et al.*, 2019).** The lipid/fat content of dried shark differed significantly ($P < 0.05$) from all collected samples, with the highest value (7.83g/100g) observed in the Kuakata drying center (Table 5). The lipid content of sun dried shark fish products was found to be consistent with the findings of **Azam *et al.* (2003)**, who conducted a biochemical evaluation on dried shark fish products (7.84%). According to **Aliya *et al.* (2018)**, the lipid content of dried shark comprised a significant amount of fats (12.4%), which was higher than in the current study. Fresh fish has high water content; drying eliminates the water and reduces the water activity, allowing the water inaccessible to pathogens and extending the shelf life of dried items **(Nowsad, 2007).** The ash and moisture content of dried shark fish products ranged from 11.17 to 11.31g/100g and from 22.14 to 24.04g/100g, respectively (Table 5). In the case of ash, there was no significant variation ($P > 0.05$) within all obtained samples, although the quantity of moisture varied significantly ($P < 0.05$) taken from the major fish drying center in southern Bangladesh. According to **Aliya *et al.* (2018); Azam *et al.* (2003)**, the ash and moisture content found to be consistent with the research study's findings. This also extends the shelf life of the dried product while increasing the amount of other nutrients that are beneficial to human health.

Table 5. Biochemical compositions (g/100g) of sun dried shark fish products at different fish drying centers.

Parameters	Kutubdiapara	Chattogram	Kuakata	Dublarchar	p-value
Protein	$58.49^{a}\pm0.17$	$56.56^{d}\pm0.24$	$58.16^{ab}\pm0.12$	$57.48^{c}\pm0.15$	<0.0001
Lipid	$7.59^{c}\pm0.05$	$7.36^{d}\pm0.04$	$7.83^{a}\pm0.07$	$7.78^{ab}\pm0.08$	0.003
Ash	$11.17^{a}\pm0.05$	$11.22^{a}\pm0.05$	$11.31^{a}\pm0.03$	$11.25^{a}\pm0.04$	0.259
Moisture	$22.14^{d}\pm0.10$	$24.04^{a}\pm0.02$	$22.30^{cd}\pm0.03$	$22.79^{b}\pm0.04$	<0.0001
TVB-N	$59.77^{d}\pm0.16$	$62.05^{a}\pm0.13$	$60.76^{bc}\pm0.20$	$60.46^{c}\pm0.15$	<0.0001
TMA-N	$42.09^{d}\pm0.17$	$44.78^{a}\pm0.15$	$44.09^{b}\pm0.06$	$43.60^{c}\pm0.17$	<0.0001
pH	$8.05^{a}\pm0.02$	$7.85^{c}\pm0.03$	$7.49^{d}\pm0.01$	$7.90^{bc}\pm0.02$	<0.0001

Note: Values are mean ± SE of triplicate (n = 3) samples. In a row, values with different alphabetical superscripts differ significantly at ($P < 0.05$).

The other biochemical compositions like total volatile base-nitrogen (TVB-N), tri-methyl amine-nitrogen (TMA-N) and pH also contained a considerable amount of quantity. TVB-N is a protein breakdown product produced by microorganisms in raw fish that is commonly used as a quality indicator. Despite the fact that, these volatile bases may liberate during the drying, this factor was used to evaluate the degree of microbial spoilage of the dried products **(Reza *et al.*, 2009; Majumdar *et al.*, 2005).** The TVB-N values of dried shark fish samples ranged from 59.77 to 62.05mg N/100g and differed significantly ($P < 0.05$) among drying centers (Table 5). For most practical applications, values of 100-200mg N/100g are commonly regarded as the upper limit beyond which salt and dried fish can be considered spoiled **(Nowsad, 2007; Connell, 1976).** In the current study, the amount of TVB-N and TMA-N in all products was found to be lower, which is considered an acceptable condition for human consumption. However, slight variations in TVB-N compound in fishes varied by intra-species, fishing time, area, age, and sex **(Sadok *et al.*, 1996).** According to **Connell (1976)**, TMA-N is utilized as a spoilage index in aquatic species, according to the TMA-N level of the investigated samples ranged from 42.09 to 44.78 mg/N 100g, with statistically significant ($P < 0.05$) differences amongst the major fish drying locations (Table 5). **Azam *et al.* (2003)** reported TMA-N values that were similar to this study. The present findings indicate that the pH value for dried shark fish products differed statistically significantly ($P < 0.05$), with the highest value found in the Kutubdiapara (8.05) fish drying center and the lowest value found in the Kuakata (7.49) fish drying center (Table 5). The pH concentration in dried fish is typically remained within acceptable limits for human consumption. Albeit, changes in muscle pH in fish largely depend on fish species and other biological factors **(Chakma *et al.*, 2020).** Furthermore, the pH concentration is not only a significant factor but can also be used as a fish measure of quality **(Ruiz-Capillas and Moral, 2001; Huss, 1988).**

Pesticides contents of sun dried shark fishery products

The organochlorine pesticides (DDT and heptachlor) were evaluated in sun dried shark samples (n=9) collected from four major fish drying centers in Bangladesh's southern area. Table 6 shows that no dried fish samples contained organochlorine insecticides (DDT and heptachlor), which are invariably harmful to human health. In view of the fact that, DDT and heptachlor were not found in any of the dried fish samples from the sampling areas, so there is no health risk associated with DDT and heptachlor residues for consumers in Bangladesh's coastal areas. Despite the fact that none of the investigated samples contained DDT or heptachlor residues (Table 6), numerous other studies determined different organochlorine pesticide residues, with DDT being frequently reported in most other dried fish from Bangladeshi fish drying areas **(Kar *et al.*, 2020; Rasul *et al.*, 2020; Begum *et al.*, 2017; Bhuiyan *et al.*, 2009; Prodhan *et al.*, 2009).** DDT and heptachlor, both organochlorines, were frequently found in dried fish

(Sarker *et al.*, 2021). The differences in results between this study and others could be attributed to differences in fish samples, size of the sample, sampling sites, and seasonal changes **(Siddique and Akter, 2012).**

Table 6. Pesticide contents of sun dried shark fishery products from major drying centers.

Samples	Pesticides	Kutubdiapara	Chattogram	Kuakata	Dublarchar
Shark	DDT	ND^*	ND^*	ND^*	ND^*
	Heptachlor	ND^*	ND^*	ND^*	ND^*

Note: ND^* = Not Detected; N= No found. Values are mean ± SE of triplicate (n = 3) samples. In a row, values with different alphabetical superscripts differ significantly at ($P < 0.05$).

CONCLUSION

Shark fishing is not a target fishery and has recently been banned in Bangladesh for a variety of reasons. These species are not used as raw food because of their lower market value, religious beliefs, and consumer preferences. Due to sun drying, traditionally produced dried products do not maintain quality and safety aspects, particularly hygienic condition, low quality, excess contaminated salt, improper procedure, elevated sun exposure during processing in the fish drying center. The sun dried shark fishery products were of highly acceptable and fit for human consumption in terms of sensorial quality. Although microbial loads of sun dried shark products were exceeded regulatory limits but no pathogenic microorganisms were found among the analyzed samples. This dried fish products contained high quality protein-based food items (56.56 to 58.49g/100g), as well as a significant amount of other proximate compositions (lipids, ash and moisture). The other biological factors (TVB-N, TMA-N, and pH) remained within regulatory limits, indicating that they might be safe for human consumption. Besides, no amounts of selected organochlorine (DDT and Heptachlor) pesticide residues were observed and dried fish exhibited no health hazard from pesticides collected from the major drying center. It is noteworthy that sun dried shark fishery products are of high quality fishery items in terms of organoleptics, microbiology, and nutrition. These products might be useful for creating emerging export-oriented fishery items and increasing public awareness of health issues in locally and globally.

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