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Quality And Shelf-Life Analysis Of Canned Hilsa (*Tenualosa Ilisha*) Under Eco-Friendly Thermal Processing: A Sustainable Approach To Bangladesh's Blue Economy

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Abstract

Hilsa (Tenualosa ilisha), a commercially important fish known as the "King of Fish" in Asian countries, was processed using a small-scale canning procedure that included high-pressure sterilization to increase shelf life. This study compared the physiological, nutritional, biochemical, and microbiological aspects of the canned Hilsa (CH) products to ram fish. Sensory qualities were evaluated on a 9-point hedonic scale, with CH maintaining satisfactory scores over the 365-day storage period. Proximate composition was determined using AOAC methods, and fatty acid (FA) profiles, particularly omega-3 and omega-6, were assessed using GC-MS. Significant changes ($P < 0.05$) were found in FA categories between raw fish and CH after storage, with a decreasing trend of MUFA > PUFA > SFA in CH canned with sunflower oil. Acid hydrolysis-derived amino acid profiles demonstrated the presence of critical amino acids, with the essential/non-essential amino acid ratio (0.60) shifting significantly during storage. Clostridium botulinum was not detected in any CH samples, indicating that the sterilization process was effective. This study shows that small-scale canning with high-pressure sterilization can preserve the quality and safety of Hilsa while extending its shelf life.

Keywords: *Thermal processing, canned hilsa, fatty acids, amino acids, sterilization*

1. INTRODUCTION

Fish and fish-based value-added products are essential part of human diet regarding their nutritional quality such as surfeit of proteins, essential fatty acids (EFA), essential amino acids (EAA), vitamins and minerals, that elevate their worth compared to all terrestrial foods (Rana et al., 2021). Fish and fish products serve as the primary and preferable source of animal protein in underdeveloped nations, such as Bangladesh (Shamsuzzaman et al., 2020). Fisheries and aquaculture play a crucial role in food security, supplying around 20% of animal protein to over 3 billion people globally (FAO, 2020). Fish processing technology comprises the various methods and procedures involved in the post-harvest processing, handling, and marketing of aquatic products, starting from the initial phase of harvesting to final consumption (Keerthana et al., 2022). Fish undergo various processing methods to enhance their shelf life, maintain their nutritional quality, flavor, texture, and visual appeal, facilitate handling and further processing, and reduce post-harvest losses (Mustapha et al., 2014). These efforts contribute to the consistent availability of affordable animal protein for consumers.

Canning is a process of preserving fish in sterile, airtight containers without the use of artificial preservatives (Topuz, 2025). When properly prepared, tightly sealed, and stored in a cool, dry place, unopened canned food remains safe to eat for at least a year without refrigeration. The canning process is comprised of precooking the food, packaging it with filling material, and sealing and sterilizing the cans. The filling medium distributes heat from the retort to the fish muscle, acts as a preservative, and raises acidity (Rabiepour et al., 2024). Nonetheless, the filling medium has the potential to dilute and extract certain components, thereby modifying their concentrations in the final product (Aubourg, 2001; Naseri et al., 2011)

Interactions with fish lipids affect the fatty acid profile of the filling medium (Gómez-Limia et al., 2020). The fish canning industry uses vegetable oils (olive, sunflower etc.) as a filling media. Hilsa is a national fish of Bangladesh generally called as "king of fish" due to its unique flavour and taste. Bangladesh is 1st in hilsa production and more than 80% of world catch produces here (Alam et al., 2021). During the peak harvesting season huge amount

of hilsa caught by the fishermen in different rivers, coast and in the sea. Huge supply leads to fall the market prices and fishermen's suffering serious problem that hampered their livelihood (Haque et al., 2024; Owusu, 2025). The dishonest businessmen's take the benefits they buy huge amount of hilsa fishes from the fishermen and prepared salted fish products which will be sold year-round and get profit. In Bangladesh there no especial type of cold store for preserving the hilsa fish, that's why in peak season price fall, on the other hand hilsa is a highly fatty fish which can't be preserved by drying (Khatun et al., 2021). Canning would be the best solution for preserving the hilsa fish. Canned fish products are popular globally, but canned hilsa is a novel concept, particularly in Bangladesh. Currently, Bangladesh imports all canned fish products, as no domestic production exists. Promoting optimized household canning technologies at the community level will popularize value-added canned fish, especially hilsa, and foster the development of a domestic canned fish industry. These advancements will add value to the market chain and contribute to the country's blue economy. This study investigates the physiological, nutritional, and microbiological changes in canned hilsa following high-pressure heat treatment and their implications for shelf life.

2. MATERIALS AND METHODS

2.1. Collection and preparation of raw materials

Hilsa fish weighing about 800-900g were purchased from Chandpur Fishery Ghat, Chandpur, Bangladesh and transported under iced (chilled) conditions to the processing plant laboratory. We selected hilsa from the Padma River because, in terms of flavor and other characteristics, the fish from this river are better than those from other sources in Bangladesh. The fishes were dressed (scaling, finning, gutting, bleeding) properly, washed with portable water and chunked into small sizes of an equal weight of 60-70g each. Before canning, the prepared Hilsa chunks were kept at a temperature of 4°C. The study was conducted according to the standard animal ethical guidelines of Bangladesh.

2.2. Collection and Storing of Can

The cans, particularly the ones with a double layer and zinc oxide coating to prevent the reaction between the can's materials and content, were collected from Hebei Well Bollte Co., Ltd. in China. The can measured 83×46 mm. After being collected, we kept the cans in the lab for later use. The cans were transported under safe conditions to prevent any shrinkage.

2.3. Development of Recipe for Canning

We developed three unique recipes for canning hilsa: Sorisha (Rapeseed) Hilsa (T1), featuring a mustard seed base; Tomato Hilsa (T2); and a simple Plain Hilsa (T3). See the **Table (1)** below for the complete recipes.

Table 1. Development of Recipe for Canning

Treatment -1 (T_1)		Treatment -2 (T_2)		Treatment -3 (T_3)	
Ingredients	**Amount**	**Ingredients**	**Amount**	**Ingredients**	**Amount**
Salt	1.6%	Salt	1.6%	Salt	1.6%
Sorisha Paste*	10.5%	Tomato Sauce*	11.5%	Turmeric Powder	0.52%
Cumin Powder	0.8%	Ginger Paste	2.5%	Chili powder	0.77%
Turmeric Powder	0.52%	Turmeric Powder	0.52%	Onion Paste	7.08%
Chili powder	0.77%	Chili powder	0.77%	Vegetable oil (Sunflower)	2.5%
Onion Paste	7.08%	Onion Paste	7.08%	-	-
Vegetable oil (Sunflower)	26.8%	Vegetable oil (Sunflower)	27.5%	-	-

*Variation in flavor

2.4. Processing of canned Fish

The process of canning Hilsa fish begins with the sterilization of empty cans, a critical step in ensuring food safety. This is accomplished using an autoclave set to 121°C and a pressure of 15 psi for 30 minutes. This high-temperature environment effectively eliminates any microorganisms, making the cans safe for food storage (Pais-Costa et al., 2025). After sterilization, chunks of Hilsa fish are carefully placed inside each can. The handling of the fish is done with precision to preserve its delicate texture and flavor. Next, specific filling ingredients, chosen to enhance the taste and act as preservatives, are added according to a prescribed method. This careful combination is essential for achieving the desired flavor profile. Once the cans are filled, they are sealed tightly using a specialized sealer (Model no: TDFJ-160, Zhejiang Youlian Machinery Co., China). This

sealing step creates an airtight environment, preventing contamination and preserving the fish's quality. Following sealing, the cans undergo further processing in the autoclave (Model; no: WT280A, Wincom Company Ltd., China), where they are treated again at 121°C and 15 psi for 45 minutes. This additional heat treatment ensures that the contents are thoroughly sterilized, enhancing the safety and longevity of the canned Hilsa. The entire Hilsa canning process, from sterilization to final treatment, is designed to maintain the fish's quality while ensuring it remains safe for consumption over time. A diagram **(Figure 1)** accompanying this explanation illustrates each step of the process, providing a clear visual representation of the meticulous methods involved in canning Hilsa.

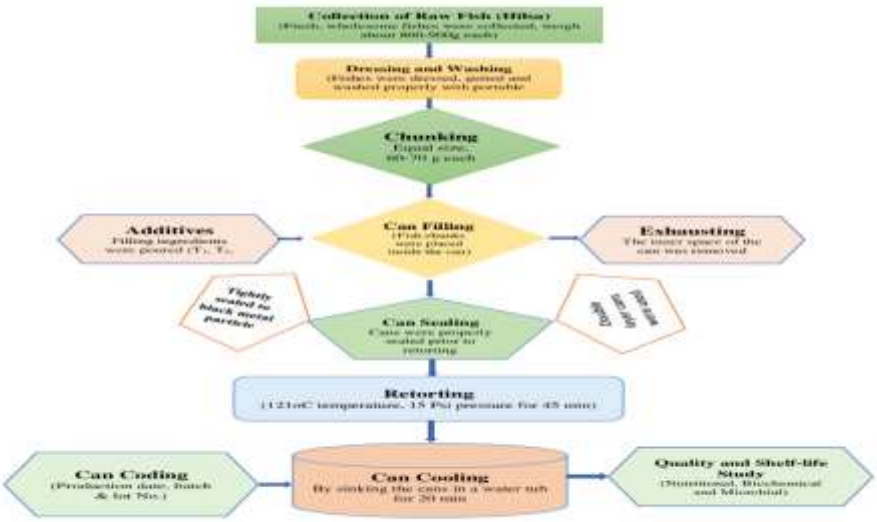

Figure 1. Schematically showing the canning protocol of Hilsa Fish.

2.5. Identification of Most Effective Treatment by Expert Panel

We were chosen as the top treatment out of three options because our products had the finest sensory quality and flavor, according to a ten-person expert team that had received extensive training in this area. We looked at the newly processed products' color, flavor, texture, taste, and overall look to see which one was the best. An evaluation of quality was carried out during the sensory evaluation using a 9-point hedonic scale, with 1 being a strong dislike and 9 an intense liking. The cutoff point was set at 5, and anything below that was deemed unacceptable (Li et al., 2013). The best canned hilsa were put away so that they could be tested for microbiology, shelf

Figure 2. Echo-friendly thermal processing of hilsa life, and nutrition **(Figure 2)**.

2.6. Evaluation of Proximate Composition

We followed the approach of (AOAC, 2000) at the Traditional Microorganism Resources Center in Daegu, South Korea, to assess the proximate composition of raw and finished canned products. This includes protein, fat, ash, and moisture. The water content of fish muscle was determined by oven drying method at 105 °C for

24 h. Total nitrogen was used to calculate the protein values using the Kjeldahl method, and total nitrogen was multiplied by 6.25 times to determine the protein content. Lipid content was measured using the Soxhlet system. Total ash content was obtained by using the muffle furnace at 550°C. Sample, when turned into white in color, it was taken out and the ash content was measured.

2.7. Determination of micronutrients

Micronutrients play a crucial role in assessing the quality of canned fish, as they contribute to the nutritional value and overall health benefits of the product. In our analysis, we focused on key micronutrients, including calcium, iron, and phosphorus, which are essential for various bodily functions. To accurately determine the levels of these micronutrients, we employed the (International, 2000) method, a widely recognized and standardized approach for food analysis.

2.8. Determination of Fatty acid Composition

The saponification of lipids was carried out by refluxing them in a 2 M KOH/EtOH solution for two hours. The resulting fatty acids were subsequently converted into methyl esters through a 45-minute reflux reaction with 3% methanolic hydrogen chloride, followed by dissolution in hexane. The purification of these methyl esters was achieved using either thin-layer chromatography (TLC) with the same eluent or silica gel column chromatography with a hexane/diethyl ether mixture.

N-acyl pyrrolidines were synthesized by directly reacting methyl esters with a pyrrolidine/acetic acid mixture (10:1, v/v) under reflux for two hours (Haque et al., 2024). The reaction product was then purified using TLC on a 0.5 mm silica gel layer, with hexane/diethyl ether (1:2, v/v) as the developing solvent. Gas chromatography-mass spectrometry (GC/MS) analysis of the methyl esters and N-acyl pyrrolidines was performed using a Hewlett-Packard HP-5890 gas chromatograph and a 5989A mass spectrometer, both connected to an HP 9000/345 integrator. The GC column used was a DB1 (30 m × 0.32 mm × 0.25 μm). The column temperature was programmed to increase from 170 °C to 300 °C at a rate of 3 °C/min. Helium was used as the carrier gas, while the injector and detector temperatures were maintained at 250 °C.

2.9. Determination of Amino acid Profile

The amino acid composition was assessed using a slightly modified version of the Moore and Stein technique (Moore and Stein, 1951). At first, a 25 mL acidic hydrolysis solution containing 1 g dried biomass of each microalga was heated to 110 ± 2.0C for 24 hours. The solution had been previously prepared with 6 M HCl and 0.1% phenol. Sample dilution buffer (SDB/Na) was used to stabilize the samples after they cooled. After that, a basic neutralization agent was used to bring the sample pH down to a range of 2.1 to 2.3. After that, the hydrolysates were filtered and then diluted with SDB/Na before being transferred to the injection vials.

A UV detector was included in the SYKAM S433 amino acid analyzer for the analysis. The procedure had a 3% repeatability, and it employed nitrogen gas as the carrier gas while keeping the flow rate at 0.5 mL/minute at 60 °C. The amino acid concentration was determined using the AA-S-18 standard wease, which is manufactured by Sigma-Aldrich in Germany. The amino acid contents were calculated in mg/kg and subsequently converted into a percentage of the total amino acids.

2.10. Determination of Peroxide Value

The peroxide value of the dried fish was determined using the (International, 2000) method. A total of 0.5 g of extracted lipids was combined with a 3:2 (v/v) mixture of glacial acetic acid and chloroform in a conical flask. The mixture was then allowed to react for 10 minutes in darkness following the addition of 0.5 mL of saturated potassium iodide. Subsequently, 0.5 mL of a 1% starch solution and 30 mL of distilled water were introduced, and the solution was thoroughly mixed. Finally, titration was carried out using 0.01 mol/L sodium thiosulfate, with the results expressed in milliequivalents per kilogram (meq/kg) of lipid.

2.11. Determination TVB-N Content

A modified version of the method described by (Rana et al., 2020) was used for the determination of total volatile basic nitrogen (TVB-N) content of fish muscle. This procedure involved immersing about 10 g of fish sample into 90 mL of a 6% $HClO_4$ solution and homogenizing for two minutes before cooling the mixture. A total of 100 mL of the extract was mixed with six drops of the phenolphthalein indicator solution in a Kjeldahl flask for titration and steam distillation. Finally, 20 mL of 20% NaOH was put into the flask with several glass beads and placed on a distillation apparatus. A drop of a composite indicator was used, and the distillate was collected in a conical flask of 50 mL of 3% boric acid (H_3BO_3).

The color changed from violet to green, and distillation was carried out at 70 °C until the product was obtained. When the mixed indicator reverted to its violet color, the endpoint was determined. The distillate was finally titrated with 0.01 N HCl and TVB-N content was calculated according to the following formula:

$$\text{TVB N (mg / 100g)} = \frac{\text{ml of acid titrant} \times \text{milli equivalent of N (0.014)} \times \text{normality of acid titrated (0.01)}}{\text{Sample weight}} \times 100$$

2.12. Measurement of PH content

In this experiment, a 5-g sample homogenized with 25 mL of distilled water for 2 min was then pH measured using a pH meter (pH meter CL 46 Deluxe, TOSHCON-TOSHNIWAL Pvt. LTD., India) by passing a pH probe into the sample homogenate.

2.13. Microbiological Quality Analysis

2.13.1. Canned fish sample preparation

The samples of canned fish were aseptically opened, 10g of fish flesh transferred to 90ml of sterile water. To dilute by 1:10, the suspension was manually shaken for 5 minutes. Further analysis was performed for all the samples by plating them in triplicate as necessary and preparation of additional serial dilutions if needed.

2.13.2. Total viable bacterial count (TVBC)

The total microbial load of fish was assessed by Plate Count Agar (PCA), utilizing a slightly modified version of the methodology described by (Rana et al., 2020). Firstly, 1 ml of the serially diluted (10^{-1} to 10^{-4}) sample was taken from the homogenate and placed into test tubes in 9 ml of sterile peptone water by using separate sterile pipettes.

A vortex mixer was used to mix the dilutions, and 1 ml of the appropriate dilution was placed into duplicate Petri dishes previously marked and sterilized. Following the original dilution, 15 minutes were given for PCA to cool to 45±1°C and 15-20 ml of the medium was added to each plate. Subsequently, the agar medium and sample dilutions were thoroughly and uniformly mixed using the method of back-and-forth rotation and plate movement on a level surface. The Petri dish was quickly rotated and incubated for 48±2 hours at 35°C after the agar had chance to solidify for 15 minutes. Finally, the total colonies forming units per gram of sample were determined by counting the colonies and multiplying the resultant number by the dilution factor. The total bacterial count (TBC) and coliform count (CC) were determined using the methodologies outlined by (Ahmedou et al., 2025), and (Anderson et al., 2024) respectively. The counts of *Clostridium botulinum* were determined using the methodology of (Andersen, 1951).

2.14. Statistical Analysis

The data was collected, documented, and structured in Microsoft Excel 2019 and statistical programming R software. Statistical analyses, particularly one-way analysis of variance (ANOVA) and Tukey's multiple range tests have been conducted by using SPSS software version 25 to determine the statistical significance of differences among Treatments. The analyses were conducted with a significant level of $P < 0.05$.

3. RESULTS

3.1. Proximate and chemical composition

The proximate compositions of hilsa canned in three treatments are shown in **Table 2**. The moisture content for the different treatments ranged from 45.86% to 47.6%. The highest moisture content (47.86%) was observed in treatment 3 and the lowest (45.6%) in T_1. The highest (19.87%) and lowest (18.93%) values were found in T_1 and T_2, respectively. The fat content was observed to fluctuate within the range of 20.42% to 23.3% in three sampling treatments. The highest value (23.3%) was found in T_1 while the lowest value (20.42%) in T_3.

Table 2. Proximate and chemical composition of canned hilsa in different treatment

Item	Experimental groups		
	T_1	T_2	T_3
Moisture%	45.6 ± 0.01	46.74±0.04	47.86±0.12
Protein%	19.87 ±0.2	18.93±0.12	19.05±0.21
Fat%	23.5 ±0.78	21.3±0.01	20.42±0.78
Ash%	1.66 ±0.23	1.73±0.40	1.94±0.10
Calcium (mg/100g)	245.7 ±0.05	258.3±0.17	278.2±0.06
Iron(mg/100g)	3.8±0.12	3.5±0.01	3.2±0.84
Phosphorus(mg/100g)	198.65±0.08	188.5±0.23	212.67±0.21
pH	5.3±0.14	5.8±0.01	5.1±0.16
Salt (%)	3.75±0.23	2.88±0.04	3.4±0.65
TVB-N (mg/100g)	5.45±0.059	7.66±0.02	6.93±0.84

The calcium (mg/100g) content across the various treatments varied between 245.7 mg/100g to 278.2 mg/100g. T_1 exhibited the lowest Calcium content at 245.7 mg/100g, while T_3 recorded the highest at 278.2 mg/100g. The Iron(mg/100g) content varied between 3.2 mg/100g and 3.8 mg/100g across three sampling treatments. T_1 exhibited the highest value at 3.8 mg/100g, whereas T_3 recorded the lowest value at 3.2 mg/100g. A significant difference in phosphorus (mg/100g) content was observed (P>0.05) among treatments with a fluctuation of 188.5 to 212.67 mg/100g. Out of the three treatments, T_3 recorded the maximum Phosphorus(mg/100g) content at 212.67 mg/100g and T2 was the minimum at 188.5 mg/100g. Three unique recipes for canning hilsa: Sorisha (Rapeseed) Hilsa (T1), featuring a mustard seed base; Tomato Hilsa (T2); and a simple Plain Hilsa (T3).

3.2. Sensory properties of canned hilsa sample in different treatments

The canned fish samples were presented to panelists for sensory evaluation (color, flavor, texture, general appearance, and taste) and the results are shown in **Table 3**. The average scores of sensory properties of canned hilsa samples were higher in T_1 than those of other canned samples. As for the color of canned hilsa, it scored 8.33 in T_1, 7.13 in T_2, and 7.36 in T_3. With the exception of general appearance, a similar pattern was observed in flavor (8.55, 7.23 and 7.71), texture (8.40, 7.39 and 7.49) and taste (8.53, 7.17 and 7.52). The highest value of general appearance was found in T_1 (8.53), then followed by T_2 (7.57) and T_3 (7.5). Therefore, there were significant differences ($p > 0.01$) among the three treatments of canned hilsa sensory characteristics. Furthermore, no significant differences ($p < 0.01$) were observed between T_2 and T_3 of canned hilsa.

Table 3. Sensory properties of canned hilsa sample in different treatments

Sensory properties	Experimental groups		
	T_1	T_2	T_3
Color	8.33±0.02	7.36±0.71	7.13±0.01
Flavor	8.55±0.01	7.23±0.03	7.71±0.3
Texture	8.4±0.40	7.39±0.01	7.49±0.01
General Appearance	8.38±0.25	7.57±0.10	7.5±0.02
Taste	8.53±0.32	7.17±0.05	7.52±0.65

Three unique recipes for canning hilsa: Sorisha (Rapeseed) Hilsa (T1), featuring a mustard seed base; Tomato Hilsa (T2); and a simple Plain Hilsa (T3).

3.3. Sensory Properties of canned hilsa in different storage periods

The results of the sensory evaluation of the canned hilsa (color, flavor, texture and taste) by panelists are shown in **Figure 3.** The initial sensory properties were observed in color (8.33±0.04), flavor (8.55±0.1), texture (8.40 ±0.02) and taste (8.53±0.1) during storage at 0 days, which steadily declined over time and reached in value of color (7.0±0.01), flavor (6.8±0.04), texture (6.8 ±0.2) and taste (6.78±0.27) on the 365 days. Hilsa canned samples were rated as very good to good in terms of color. Additionally, canned hilsa scored very good to acceptable in terms of flavor and taste. Research suggests that fish muscle texture is influenced by elements such as fibres density and fat concentration.

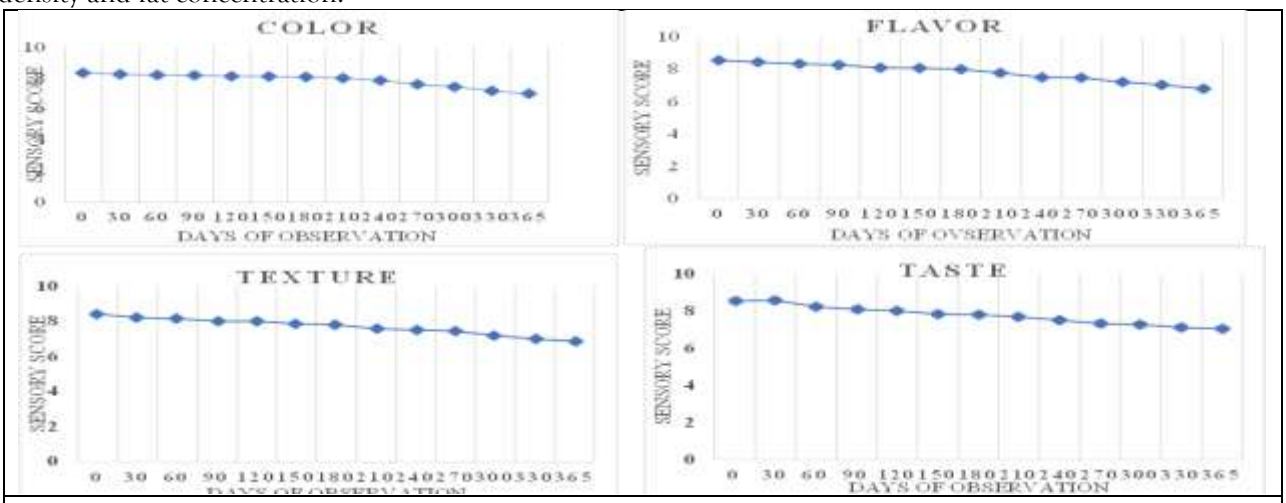

Figure 3: Changes in physiological characteristics of canned Hilsa during storage (assessed by panelist); a. color, flavor, c. texture and d. taste.

3.4. Fatty acid composition of canned sorisha hilsa

The fatty acid compositions of raw and canned hilsa sampled during a 12-month storage period and packaged in sorisha paste, shown as percentages of the total fatty acids (**Table 4** and **Figure 4**). In raw hilsa fish, saturated fatty acids (SFAs) comprised most of the fatty acids (48.70%), followed by polyunsaturated fatty acids (PUFAs) (40.51%) and monounsaturated fatty acids (MUFAs) (32.49 %). Each FA group, SFA, MUFA, and PUFA, revealed values in the 32-48% range. The main fatty acids were Palmitic acid (C 16:0) (27.86%), Linoleic acid (C 18:2) (ω-6) (22.41%), Oleic acid (C 18:1, c9) (18.81%), Palmitoleic acid (C16:1) (9.28%), Eicosapentaenoic acid (C20:5) (ω-3) (8.72%), Myristic acid (C14:0) (8.56%), Stearic acid (C 18:0) (8.33%), Docosahexaenoic acid (C22:6) (4.58%), Docosapentaenoic acid (C22:5) (2.64%) and Vaccenic acid (C 18:1, c11) (2.37%). A large amount of ω-3 polyunsaturated fatty acids (PUFA) was composed of Eicosapentaenoic acid (C20:5, EPA), Docosahexaenoic acid (C22:6, DHA), Docosapentaenoic acid (C22:5, DPA), Eicosatrienic acid (C20:3, c8,11,14,17) and Linolenic acid (C18:3), whereas ω-6 PUFAs was constituted of Linoleic acid (C18:2) and Eicosatrienic acid (C20:3, c8,11,14). The n-6/n-3 ratio has been suggested as a valuable measure in assessing the nutritional quality of dietary fat, which holds significant importance for humans. In the present study, the mean n-6/n-3 ratio in raw hilsa was found at 1.26. Consequently, this species may be regarded as a source of high-quality lipids.

Table 4. Fatty acid compositions of canned hilsa throughout storage period (shown as % of total fatty acids).

	% of composition	
Fatty acids	**Raw Hilsa**	**Canned Hilsa**
Lauric acid (C12:0)	0.32	0.1
Myristic acid (C14:0)	8.56	5.42
Pentadecanoic acid (C15:0)	0.41	0.3
Palmitic acid (C 16:0)	27.86	21.02
Palmitoliec acid (C 16:1)	9.28	7.49
Margaric acid (C 17:0)	0.56	0.17
Stearic acid (C 18:0)	8.33	6.76
Elaidic acid (C 18:1, t9)	0.31	0.11
Oleic acid (C 18:1, c9)	18.81	17.57
Vaccenic acid (C 18:1, c11)	2.37	1.64
Linoleic acid (C 18:2) (ω-6)	22.41	19.55
Linolenic acid (C 18:3) (ω-3)	0.81	0.2
Arachidic acid (C 20:0)	0.56	0.39
Eicosenic acid (C 20:1)	0.85	0.34
Eicosatrienic acid (C 20:3 c8,11,14) (ω-6)	0.14	0.06
Eicosatrienic acid (C 20:3 c8,11,14, 17) (ω-3)	1.2	0.79
Behenic acid (C 22:0)	1.08	0.45
Eicosapentaenoic acid (C20:5) (ω-3)	8.72	5.13
Lignoceric acid (C24:0)	1.02	0.48
Nervonic acid (C24:1)	0.87	0.11
Docosapentaenoic acid (C22:5) (ω-3)	2.64	1.31
Docosahexaenoic acid (C22:6) (ω-3)	4.58	3.16
Unknown	9.86	7.45
∑ ω 3	**17.95**	**10.59**
∑ ω 6	**22.55**	**19.61**
∑ ω 6/∑ ω 3	**1.26**	**1.85**
∑SFA	**48.70**	**35.09**
∑MUFA	**32.49**	**27.26**
∑PUFA	**40.51**	**30.2**

SFA: Saturated Fatty Acids; MUFA: Monounsaturated Fatty Acids; PUFA: Polyunsaturated Fatty Acids.

In this study, an order of decreasing fatty acids (FA) composition of sorisha paste combined with sunflower oil was MUFA > PUFA > SFA. During a 12-month storage, significant differences in values of FA group between raw fish and canned fish processed with sorisha paste ($p < 0.05$). Processing lowered the SFA content with decreasing amounts of C12:0, C14:0, C15:0, C16:0, C17:0, C18:0, C20:0, C22:0 and C24:0. Moreover, the

sorisha paste with sunflower oil reduced completely ($p > 0.05$) eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) during the canning time. The ω-3 and ω-6 fatty acid contents of the hilsa packed in sorisha paste decreased during storage, attributed to the reductions in the C20:3, c8,11,14,17, C20:5, C22:5, C22:6 and C 18:2, C 20:3 c8,11,14 contents respectively. The filler medium could affect the final product's fatty acid composition in addition to transferring heat from the retort to the fish muscle.

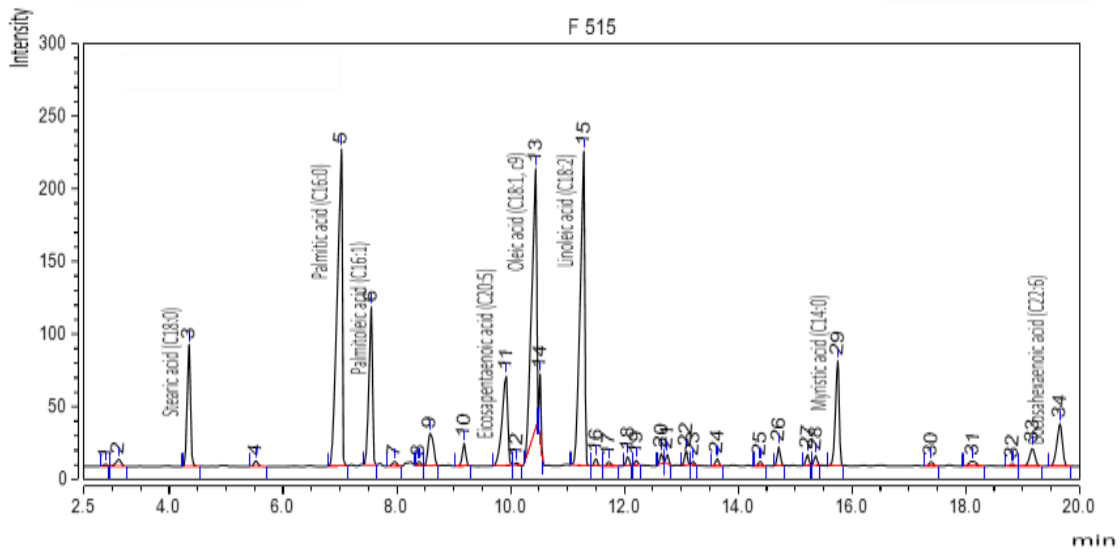

Figure 4. GC-MS chromatogram of injected Fatty Acid Methyl Easters (FAMEs) from CH samples with major fatty acids peaks.

3.5. Amino Acid Composition of canned Hilsa

The amino acid contents (mg/ g sample) of raw and canned hilsa packed with sorisha paste throughout a 12-month storage period presented in **Table 5.** The analysis revealed that glutamic acid (30.19 mg/g) was the most prevalent non-essential amino acid in raw fish, followed by aspartic acid (17.23 mg/g) and alanine (10.73 mg/g), collectively comprising 36.08% of the total amino acid content. In hilsa fish, lysine (13.62 mg/g) was identified as the primary essential amino acid, followed by leucine (11.43 mg/g) and threonine (7.12 mg/g), which together constituted 19.96% of the total amino acids. Additionally, other notable amino acids detected in raw hilsa fish included serine (8.61 mg/g), cystine (6.78 mg/g), phenylalanine (6.41 mg/g), histidine (6.38 mg/g), proline (6.87 mg/g), and isoleucine (5.17 mg/g). These amino acids collectively accounted for approximately 24.95% of the total amino acid content. However, certain amino acids, including methionine, valine, and tyrosine, were found in relatively lower concentrations. Among them, valine was the least abundant amino acid in raw fish, with a concentration of 4.29 mg/g. The essential amino acid to non-essential amino acid (EAA/NEAA) ratio serves as an indicator of protein quality, with higher ratios signifying superior protein content. In this study, the EAA/NEAA ratio was determined to be 0.62 in raw fish. Furthermore, the total essential amino acids (58.75 mg/g), total semi-essential amino acids (7.79 mg/g), and total non-essential amino acids (94.65 mg/g) accounted for 36.45%, 4.83%, and 58.72% of the total amino acid content (161.19 mg/g), respectively.

Table 5. Total amino acid profiles (g/100 g) of raw and canned Hilsa packed with sorisha paste throughout a 12-month storage period.

Name of Amino Acid	Composition (mg/g)	
	Raw	Storage 12 months
EAA		
Threonine	7.12	6.03
Methionine	4.33	3.91
Valine	4.29	3.82

Isoleucine	5.17	5.12
Leucine	11.43	11.32
Phenylalanine	6.41	5.34
Histidine	6.38	6.25
Lysine	13.62	12.85
SEAA		
Arginine	7.79	7.57
NEAA		
Aspartic acid	17.23	16.15
Serine	8.61	8.48
Glutamic acid	30.19	29.08
Glycine	9.67	8.54
Alanine	10.73	10.61
Cystine	6.78	6.67
Tyrosine	4.57	4.48
Proline	6.87	6.98
Total EAA	58.75	54.64
Total SEAA	7.79	7.57
Total NEAA	94.65	90.99
EAA/NEAA	0.621	0.60
Total AA	161.19	153.2

EAA: Essential amino acids; SEAA: Semi-essential amino acids; NEAA: Non-essential amino acids.

During storage period, there were significant changes ($p < 0.05$) in the total amino acids, non-essential amino acids, and total essential amino acids of canned hilsa packed in sorisha paste with sunflower oil. In hilsa packed in sunflower oil with sorisha paste, the levels of threonine, methionine, valine, leucine, phenylalanine, lysine, aspartic acid, glutamic acid, and glycine decreased throughout the sterilization process. However, the amount of proline in canned hilsa fish increased during sterilization, which suggests that other steps may also be responsible. The rising trend in proline levels might indicate that collagen was breaking down over time. The essential/non-essential (EAA/NEAA) ratio varies significantly after 365 days of storage.

3.6. Microbiological profile of canned hilsa

The changes observed in the microbiological profile during a 12-month storage period, focusing on Total Viable Count (TVC), total Coliform, *E. coli, Salmonella* spp., and *Clostridium* spp of canned hilsa have been shown in **Table 6.** The results found significant differences in total viable count (TVC) during the storage period, with a significance level ($p<0.05$). The TVC values were found to range from 1.9×10^2 Cfu/g (at 180 days) to 7.2×10^2Cfu/g (at 330 days). The initial TVC for the 0-day canned was found to be 2.5×10^2 Cfu/g and after storage of 360 days, it increased to 6.38×10^2Cfu/g. However, *Salmonella* spp. and *Clostridium* spp. we're not identified, while total Coliform and *E. coli* frequently remained below detection limits (<0.3 MPN/g) throughout the storage period (**Table 6**). The results of the research aligned with the HACCP principle that fish products should not include any harmful microorganisms.

Table 6. Microbiological profile of canned hilsa throughout the storage

Storage Period	TVC (Total Viable Count) Cfu/g	Total coliform (MPN/g)	*E. coli* (MPN/g)	*Salmonella sp.* (Cfu/g)	*Clostridium sp* (Cfu/g)
0 Day	2.5×10^2	<0.3	<0.3	ND	ND
30 Day	4.7×10^2	<0.3	<0.3	ND	ND
60 Day	2.3×10^2	<0.3	<0.3	ND	ND
90 Day	6.8×10^2	<0.3	<0.3	ND	ND
120 Day	7.1×10^2	<0.3	<0.3	ND	ND
150 Day	3.7×10^2	<0.3	<0.3	ND	ND
180 Day	1.9×10^2	<0.3	<0.3	ND	ND
210 Day	5.4×10^2	<0.3	<0.3	ND	ND
240 Day	4.7×10^2	<0.3	<0.3	ND	ND
270 Day	2.86×10^2	<0.3	<0.3	ND	ND
300 Day	3.28×10^2	<0.3	<0.3	ND	ND
330 Day	7.2×10^2	<0.3	<0.3	ND	ND
365 Day	6.38×10^2	<0.3	<0.3	ND	ND

[As per the MPN (most probable number) chart, MPN <0.3 indicates an absence of test organism in 1 g; ND=Not Detected]

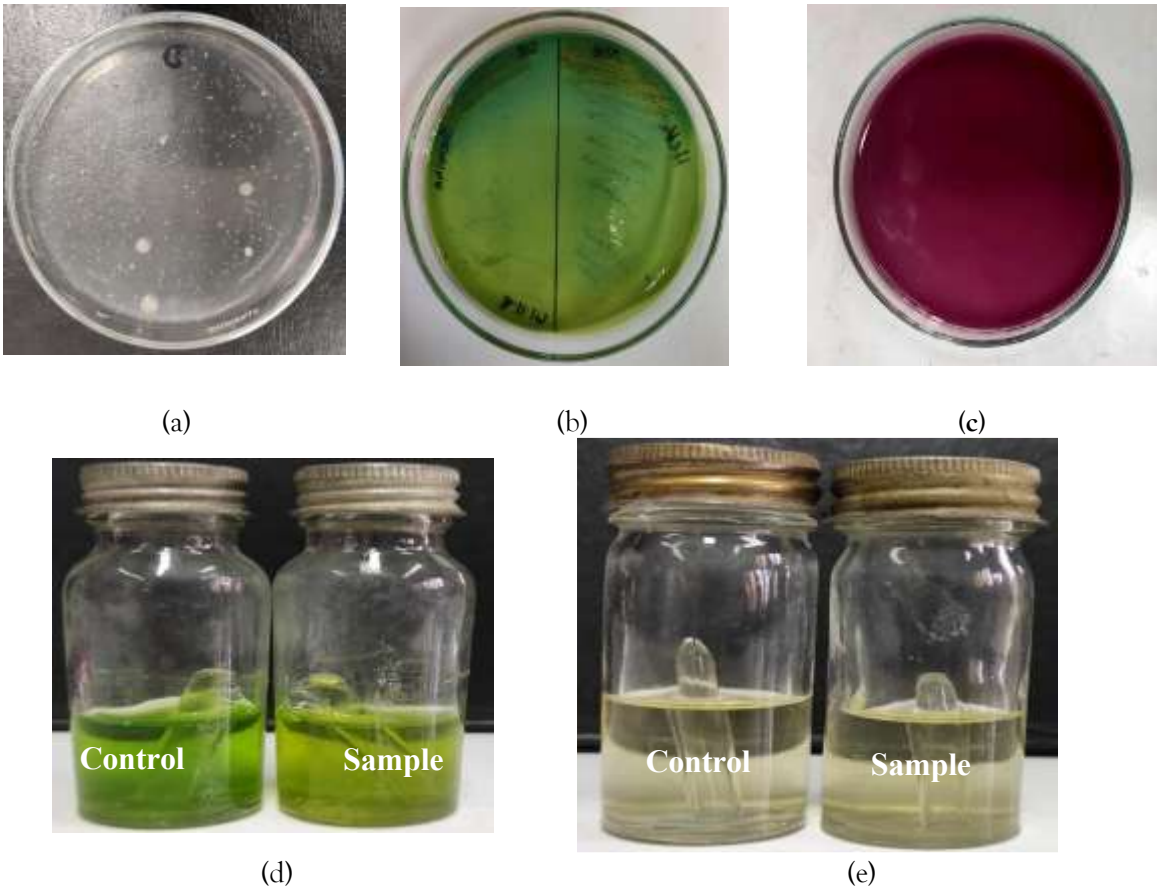

Figure 5. Results of microbiological analysis; (a)Total viable count on Plate Count Agar media; (b)Test of *Salmonella* spp. on Hektoen Agar; (c) Test of *Clostridium* spp. on Reinforced Clostridium media; (d)Test of Coliform occurrence in sample and (e) Test of E. coli occurrence in sample.

3.7. Changes in TVB-N and Peroxide value of canned hilsa

The TVB-N values of the canned hilsa showed an increasing pattern throughout the storage period (Figure 5). The initial TVB-N value of canned hilsa was 13.76±0.01 mg/100 g during storage at 0 days, which increased continuously throughout the time and reached 28.13±0.06 mg/100g on the 365 days.

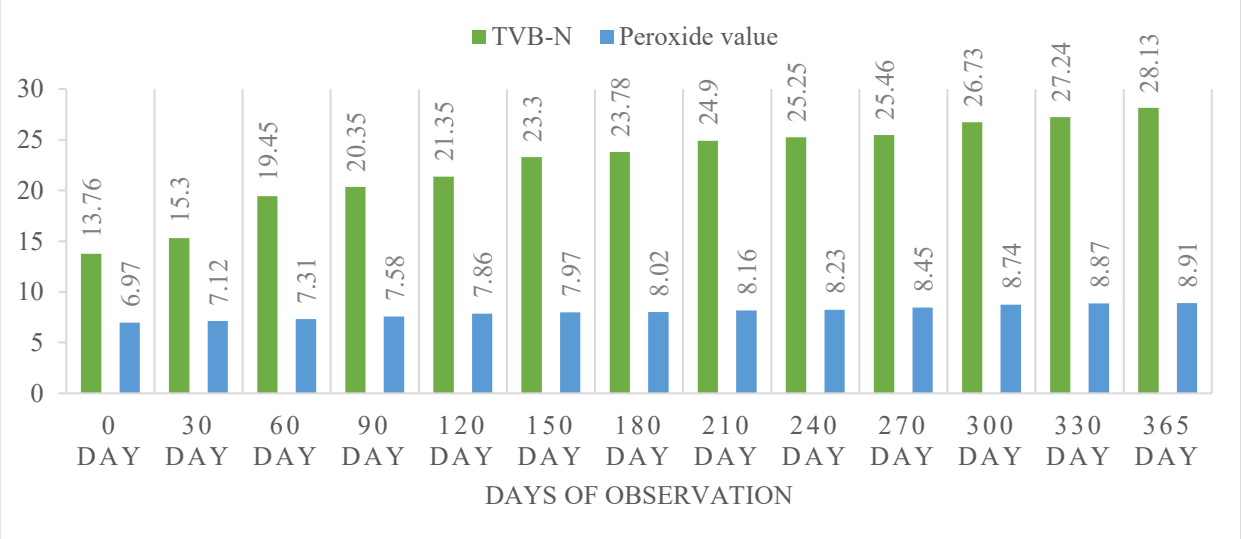

Figure 5. Changes in TVB-N and Peroxide value of canned Hilsa.

The peroxide value of canned hilsa was recorded at 6.97±0.10 meq/kg of oil at the beginning of storage, which exhibited a gradual increase throughout the storage period. After a duration of 365 days stored at ambient temperature, the peroxide value exhibited an increase to 8.91±0.10 meq/kg of oil.

4. DISCUSSIONS

The implication of this research is that there is an opportunity for the creation of new hilsa recipes in canned products that retain the nutritional and organoleptic attributes. The analysis of sensory results also proves that T_1 remains the most effective as it dominated in all parameters, including color, taste, and texture. This is consistent with the studies that have shown that the ingredient combinations affect the sensory attributes of the product. The continual decrease in sensory scores is an indication of the problems of storage, however, the product was still acceptable up to one year. These findings are in conformity with the results by (ElShehawy and Farag, 2019) on the effect of canning on the shelf life of fish products. Sensory assessments indicate that canning increases hardness and decreases cohesivity as heat degrades connective tissue, causing cell blocks to split (Rodríguez et al., 2010). The proximate composition analysis indicated differences between treatments and T_1 (*sorisha hilsa*) had the highest protein and fat content as reported in earlier studies which stated that with reduced moisture, there is increased nutrient density (Aberoumand and Baesi, 2024). This goes to support the best practices of canning methods since nutritional density is an important consideration for consumers and market value of hilsa. The fat content was observed to fluctuate within the range of 20.42% to 23.3% in three sampling treatments.

The amount of fat in fish has been great dependent on the time of year when the fish is caught (Luzia et al., 2003). The highest value (23.3%) was found in T_1 while the lowest value (20.42%) in T_3. Potentially because of the reduction of water after sterilization, the canned samples had significant protein and fat concentrations (Aberoumand and Baesi, 2024). Omega-3 fatty acids such as, EPA & DHA were also fairly well retained in canned sorisha hilsa, although there was some decline during the sterilization process. These findings are not far from (Stephen et al., 2010) who observed similar reductions in tuna after thermal treatment. However, sorisha paste usage seems to prevent the oxidation breakdown as indicated by the antioxidant component of spices by (Sampels, 2013) and (Cardoso-Ugarte and Sosa-Morales, 2022). This suggests that there is a potential for the modification of canned fish products to achieve moderate preservation while enhancing nutritional value. Similar findings were reported by (Gómez-Limia et al., 2020)for raw European eels (32.5–55.77%) and (Prego et al., 2022) for mackerel fish muscle (30–36%). The n-3 and n-6 PUFAs are the most significant fatty acid sources for human nutrition and health (Zárate et al., 2017). The n-6/n-3 ratio has been suggested as a valuable measure in assessing the nutritional quality of dietary fat, which holds significant importance for humans. Various research has supported a low n-6/n-3 ratio and proposed an ideal n-6/n-3 ratio for enhancing human health (Simopoulos, 2002; 2008; 2016). The recommended range for the n-6:/n-3 ratio is 3:1 to 1:1 (Kim et al., 2007).

Glutamic acid (30.19 mg/g) was the most prevalent non-essential amino acid in raw fish, followed by aspartic acid (17.23 mg/g) and alanine (10.73 mg/g), collectively comprising 36.08% of the total amino acid content. Glutamic acid and aspartic acid are also predominant amino acids in various raw fish species, such as herring (Oluwaniyi et al., 2010), Atlantic bonito (Ormanci and Colakoglu, 2015), cod (Teixeira and Mendes, 2020), and swordfish (Cobas et al., 2022). In Hilsha fish, lysine (13.62 mg/g) was identified as the primary essential amino acid, followed by leucine (11.43 mg/g) and threonine (7.12 mg/g), which together constituted 19.96% of the total amino acids. Similar findings were observed by (Cobas et al., 2022), who reported that leucine, making up approximately 8.7% of total amino acids, is the dominant essential amino acid in swordfish muscle.

The pH value was found to significantly ($P< 0.05$) fluctuate ranging from 5.1 to 5.8. The highest value (5.8) and lowest (5.1) values were reported in T_2 and T_3, respectively. It was discovered that heat processing caused the samples' pH to drop (Biji et al., 2015). The TVB-N value (mg/100g) varied between 5.45 mg/100g and 7.66 mg/100g across three sampling treatments. The TVB-N concentration indicates how much proteins in aquatic goods are degraded to amines and ammonia by microorganisms and endogenous enzymes (Luo et al., 2021). T_2 exhibited the highest value at 7.66 mg/100g, whereas T_1 recorded the lowest value at 5.45 mg/100g. Results of salt content (%) and TVB-N mg/100g showed statistically significant differences ($P< 0.05$) among treatments in the present study. Reduced TVB-N content was linked to lower microbial population and putrefying metabolic activity, resulting in less ammonia nitrogen production (Kumar et al., 2019).

TVC value of processed CH was increased from 2.5×10^2 Cfu/g to 6.38×10^2Cfu/g during storage (365 days), however, *Salmonella* spp. and *Clostridium* spp. were not detected while total Coliform and *E. coli* remained below detection limits (<0.3 MPN/g). These findings were consistent with several previous works. El-Dengawy et al,

2012 reported that total *Coliform* and *Clostridium* spp. we're not detected in canned tuna, mackerel, and common carp. The results of the research are aligned with the HACCP principle that fish products should not include any harmful microorganisms. This study's findings show fish products do not contain *salmonella* germs in agreement with those of (Mansour, 2023). It also agrees with the Egyptian General Authority for Standardization and Metrology's findings on the microbiology of canned tuna and sardines and the absence of *Escherichia coli* in brine-canned fish (Saleh et al., 2021).

The present work revealed that all treatments were safe throughout the storage period as evidenced by the lack of detection of *Salmonella* and *Clostridium* spp., in agreement with HACCP guidelines. The rising trend of TVC values is consistent with earlier research that has associated storage duration with microbial growth (Ruiz-Capillas and Moral, 2001). However, the values did not go beyond the allowable range at any one time to guarantee that products manufactured are safe and of good quality. However, the following limitations of the study have to be noted. The losses of the essential amino acids in the canned foods indicate that sterilization has taken place at the expense of nutrient content. Furthermore, the study failed to look at the consumer preference in different economic status groups, which is very important in market penetration. Further studies should be directed at improving the formulation of the ingredients in order to contain as little nutrient loss as possible and at carrying out extensive consumer research in order to develop products to suit the needs of every consumer. Canned hilsa is a shelf-stable product which meets the trends of the contemporary consumers and maintains the nutritional and organoleptic attributes. The research has valuable implications for the fish processing industry in Bangladesh and presents a strategy for increasing the economic value of hilsa while supporting food security in the country.

CONCLUSIONS

This study highlights the potential of canned hilsa as a value-added product that addresses preservation challenges while meeting modern consumer demands. Among the tested treatments, sorisha hilsa demonstrated superior nutritional, sensory, and microbiological qualities, confirming its viability for commercial production. Despite minor nutrient losses during processing, the canned products retained acceptable quality over a year of storage. The findings contribute to the sustainable utilization of hilsa and underscore its role in enhancing food security and economic growth in Bangladesh. Future research should optimize recipes and explore broader consumer preferences to maximize market acceptance.

Declarations

Animal Ethics: The study was conducted according to the standard animal ethical guidelines of Bangladesh.
Consent for publication: Not applicable
Availability of data and material: All data are presented in the tables and figures. Data may be obtained from the corresponding authors upon reasonable request.
Competing interests: The authors declare that they have no financial or non-financial conflicts of interest related to this work.
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Conflicts of Interest : The authors declare no conflicts of interest.

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