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Development and Shelf-Life Assessment of Fish Sticks Using Grass Carp (*Ctenopharyngodon Idella*)

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Abstract: The study's primary objective was to evaluate the storage duration, sensory characteristics, and microbial changes of improved fish sticks made from grass carp. The fish sticks were stored at different temperatures: room temperature (28ºC), refrigerated temperature (5ºC), and frozen temperature (-18ºC). Strict adherence to good manufacturing practices was followed during the development of the fish sticks, incorporating a diverse range of food additives. Proximate composition analysis was conducted to determine the precise moisture, lipid, protein, and ash contents of the grass carp fish mince. The analysis showed that the fish mince had approximately 79.16±1.42% moisture, 3.07±0.69% lipid, 17.21±0.45% protein, and 1.71±0.19% ash. Fresh fish sticks exhibited a moisture content of 65.78±0.86%, lipid content of 6.81±0.85%, protein content of 16.37±0.34%, and ash content of 2.84±0.09%. The initial total plate count (TPC) in fresh fish sticks was meticulously measured and found to be 4.11±0.75 Log CFU/g. Throughout the storage period, it was observed that the TPC of grass carp fish sticks significantly increased at room and refrigerated temperatures. Interestingly, refrigeration slowed down the rate of microbial increase, whereas frozen storage at -18°C resulted in a substantial reduction in the initial microbial load, reaching 2.15±0.44 Log CFU/g after 8 weeks. A sensory evaluation was conducted by a panel of seven experts using a nine-point descriptive scale to assess the appearance, flavor, taste, texture, and overall acceptability of the fish sticks. Over the storage duration, the sensory properties gradually declined for fish sticks stored at room and refrigerated temperatures, with a more pronounced decrease observed at room temperature. In contrast, frozen storage showed minimal changes in sensory quality, closely resembling the sensory characteristics of fresh samples even after 8 weeks. Based on the comprehensive findings, it can be inferred that the shelf life of grass carp fish sticks is limited to 24 hours at room temperature and extends slightly to 72 hours under refrigeration. However, fish sticks stored at -18°C maintain their quality for an extended period of 8 weeks, offering a significantly prolonged shelf life compared to other storage conditions.

Keywords: Shelf Life, Fish Sticks, Grass Carp, Storage Duration, Sensory Characteristics, Microbial Changes

1. Introduction

Fish is recognized for its safety, nutritional profile, and abundance of micronutrients, essential fatty acids, and proteins [1]. However, in Bangladesh, a substantial portion of low-cost fish is traditionally underutilized, with approximately 90% being consumed directly or in dried form. The remaining fish are utilized for fish meal production or as manure [2]. Given their high nutritional value, there is significant potential for value addition and the development of human food products from these fish [3].

The consumption of fish products has been increasing in Western nations due to international recommendations to reduce dietary fat intake. Likewise, in Asian countries, consumer awareness of health issues has resulted in a growing demand for fish and fishery products. The

prevalence of fast-food consumption has risen due to rapid urbanization and the increased participation of women in the workforce. Consequently, numerous fast-food establishments have emerged in urban, suburban, and industrial areas of the country. With the modernization of society, there has been an increasing reliance on convenient foods among working individuals, students, and young people [4].

The demand for ready-to-eat and ready-to-cook products has been steadily growing due to their convenience [5]. Fish food consumption has also witnessed an upward trend among city dwellers and fast food consumers in response to the growing health consciousness. Therefore, fish and fishery products are expected to occupy a significant portion of the Bangladeshi diet in the future [5].

Additionally, the fish processing industry in Bangladesh is export-oriented, and export values have shown consistent growth year after year [6]. Furthermore, in the face of a growing population and increasing demand, expanding fish supplies to ensure food security has become a priority in Bangladesh. The utilization of low-cost fish species presents a significant opportunity to meet the escalating food demand. Value addition and diversification of fish products can cater to the ever-changing and diverse consumer demands [7-15].

In Bangladesh, low-cost fish species such as bighead carp (*Aristichthys nobilis*), common carp (*Cyprinus carpio*), grass carp (*Ctenopharyngodon idella*), silver carp (*Hypophthalmichthys molitrix*), sutchi catfish (*Pangasianodon hypophthalmus*, locally known as Thai-Pangus), and tilapia (*Tilapia niloticus*) are widely available. However, due to factors such as unattractive color, flavor, texture, small size, and high-fat content, a significant portion of these fish species remains underutilized. For instance, the presence of intramuscular bones in carp diminishes consumer preference for these species. Therefore, there is a need to develop convenient products from the meat of low-cost fish to enhance consumer acceptance [4].

These highly nutritious low-cost fish species can be utilized to produce ready-to-eat and value-added fish products such as fish balls, fish fingers, fish sticks, and fish cutlets. With this perspective and the demand for nutritionally balanced ready-to-eat fish products in mind, this study focused on the development of improved value-added fish sticks using grass carp (*Ctenopharyngodon idella*), a fast-growing aquaculture species.

The primary goals of this study were to create and refine fish sticks using grass carp to enhance their utilization, assess the proximate composition, sensory attributes, and microbiological quality of these fish sticks, and investigate their shelf life under different storage conditions.

2. Material and Method

2.1. Collection of Fish Species

Fresh grass carp fish were collected from local fish markets in the Sylhet district. Immediately after collection, the fish were iced properly with crushed ice in an insulated box and transported to the laboratory of Fisheries Technology and Quality Control, Sylhet Agricultural University. The average size of the fish was 32± 2.50 cm and 750± 0.35 gm.

2.2. Preservation of Raw Materials

After being brought to the laboratory, the fish were washed thoroughly, either minced immediately for use or packed in a polyethylene pouch, and then frozen and stored in a deep freezer (-20°C).

2.3. Preparation of the Product

The fish was weighed and then washed with clean water, beheaded, eviscerated, skinned, and washed. The skinned fish were filleted and deboned manually in iced condition. Then all the bones and connective tissues were removed from the muscles manually and mechanically (by a mechanical mincer through a 1 mm orifice diameter). All the utensils used in the experiment were cleaned with adequate washing and kept cool (5°C). A significant amount of crushed ice was made available to maintain an appropriate temperature throughout the product preparation. After mincing, the mince was kept in a small bowl that was fixed in a large plastic bowl surrounded by a substantial amount of ice.

The minced fish meat was mixed with salt, sugar, wheat flour, cumin seed powder, onion paste, garlic paste, pepper powder, and sodium tri-polyphosphate in predetermined quantities (Table 1) to form a pasty mass of hard consistency. The mixture was then shaped into slabs and placed in a freezer for 2 hours. The frozen slab was subsequently cut into sticks of uniform size. The product was then coated with batter and rolled in breadcrumbs until a consistent coating of breading material was achieved on the surface. The battering solution was prepared by combining egg white, spices, salt, and MSG (Table 2). Finally, the breaded sticks were fried in hot oil until they reached a brown color. The prepared fish sticks were then placed on kitchen paper to absorb any excess oil from the surface. All the utensils used in the experiment were cleaned with adequate washing and kept cool (5°C). The scheme for the preparation of fish sticks from grass carp fish is presented in Figure 1.

Table 1. *Ingredients and the amounts used for the preparation of fish sticks.*

Ingredients	Amount (%)
Minced fish meat	60
Common salt	As needed
Sugar	As needed
Pepper	0.3
Green chili	0.3
Coriander	As per need
Ginger	1
Garlic	1
Cumin (Jeera)	0.3
Potato	10
Beet, Carrot, Capsicum	17
Onion	10
Vinegar	2 teaspoons
Oil	As needed

Table 2. *Ingredients and the amounts used for the battering solution for fish sticks.*

Ingredients	Percentage (%)
Wheat flour	34
Salt (NaC1)	1
Monosodium glutamate	1
Spices (green pepper, ginger, garlic, cumin, onion paste, mixture of hot spices)	1
Egg	19
Vinegar	1 teaspoon
Water	44

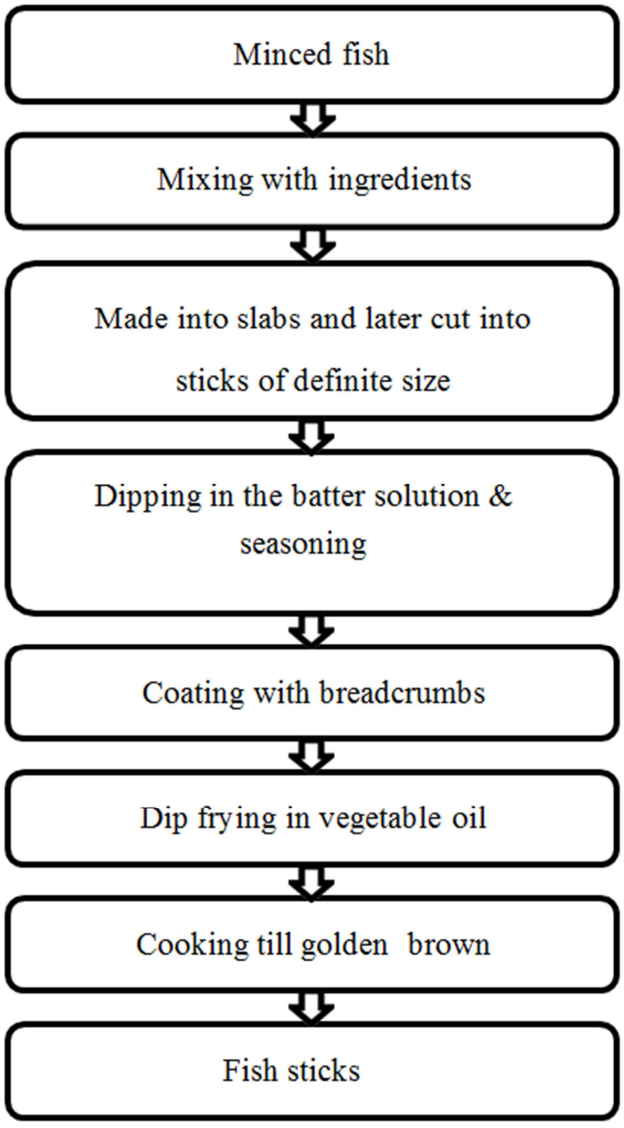

Figure 1. *Scheme for the preparation of fish sticks.*

Various local gel-enhancing ingredients and spices were used for the preparation of batter solution for fish sticks to ensure the products had a Bangladeshi known taste so that the products could attract local consumer's acceptance (Figure 2).

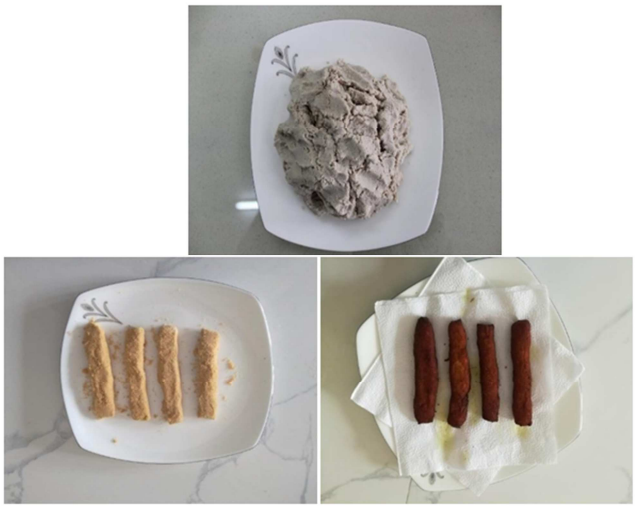

Figure 2. *Here, plate no. 01: (a) Minced fish meat, (b) Fish sticks blocks before frying; (c) Fish sticks after frying with vegetable oil.*

2.4. Quality Changes and Shelf-Life Study

Proximate composition, bacterial load, and sensory analysis were done for the study of quality changes and shelf life of the fish sticks during different storage conditions.

2.4.1. Proximate Composition Analysis

Proximate composition analysis of moisture, crude protein, crude lipid, and ash was carried out according to the methods of the Association of Analytical Chemists (AOAC, 1980) with certain modifications as described below:

(i). Determination of Moisture Content

The moisture content of the fish sticks was analyzed using a hot air oven. Initially, the empty crucibles were labeled and weighed using an electric balance, and the measurements were recorded for each sample. Next, a 2 g sample of fish sticks was carefully placed in a porcelain crucible using the same balance and subjected to a temperature of 105°C in a hot air oven for 24 hours. Afterward, the crucible containing the sample was cautiously removed and allowed to cool in a desiccator for approximately 15 minutes. The weight of the crucible with the sample was then measured again. Subsequently, the moisture content of the sample was calculated as a percentage using the following formula: Moisture content (%) = (W1 - W2) / Ws × 100, where Ws represents the weight of the sample, W1 represents the combined weight of the sample and crucible, and W2 represents the weight of the dried sample and crucible.

(ii). Determination of Lipid Content

To determine the lipid content using a Soxhlet Apparatus, the following procedure was followed. Initially, the sample was obtained and cut into small pieces. An accurately measured 2-3 g of the sample was then placed in a thimble of paper and inserted into the empty spaces of the Soxhlet Apparatus. Subsequently, 200-300 ml of acetone was poured into the round-bottom flask of the apparatus, and the flask was carefully heated between 70-90°C for approximately 2-3

hours to allow acetone evaporation at this temperature. As a result, the acetone slowly accumulated in the spaces of the Soxhlet Apparatus and was siphoned back into the round-bottom flask. The acetone collected in the flask was transferred to a pre-weighed beaker and placed in a hot air oven at 70°C for about 45-50 minutes to facilitate acetone evaporation. After cooling in a desiccator, the beaker containing the lipid residue was weighed. The lipid content was then estimated using the following formula: Lipid (%) = (W1 - W2) / Ws × 100, where W1 represents the weight of the crude lipid, W2 represents the weight of the empty beaker, and Ws represents the weight of the sample.

(iii). Crude Protein Determination

The determination of crude protein was conducted indirectly using the Kjeldahl method to analyze the protein content of the samples. Initially, the total nitrogen content of the sample was determined using the Standard Kjeldahl method. Once the percentage of nitrogen was obtained, it was multiplied by the empirical factor of 6.25 to calculate the crude protein [16]. To determine crude protein using the Kjeldahl method, the following procedure was followed. The sample was obtained and chopped into small pieces and then ground using a grinder. Approximately 0.5 g of the sample was placed in a clean Kjeldahl flask, and 1.1 g of digestion mixture, along with 10 ml of concentrated H2SO4, was added by swirling the flask. The sample was digested at 420°C for 45 minutes and then removed from the digestion unit. After cooling, the solution changed to a green color, at which point 5 ml of Na2S2O3 (33%) was added to each tube, causing the solution to turn reddish-pink. After homogenizing the solution, 30 ml of 10N NaOH was added. A conical flask containing 25 ml of 4% H3BO3 with 3 drops of the mixed indicator was positioned under the condenser, and placed against the Kjeldahl flask, to collect the distillate. Once the distillation was complete (approximately 100 ml distillate), the collected distillates were titrated with 0.2 N HCl. The endpoint was indicated by a light pinkish color. The total crude protein was calculated using the following formula: Nitrogen (%) = (Milliequivalent of nitrogen × Titrant value (ml) × strength of HCl) / Initial sample weight (g) × 100. For most routine purposes, the percentage of protein in the sample is then calculated by multiplying the percentage of nitrogen by a protein conversion factor of 6.25 for fish. Therefore, the percentage of crude protein can be determined as follows: % of crude protein = % of total N2 × 6.25.

(iv). Ash Determination

The ash content was analyzed by subjecting a 1 g sample to ignition in a muffle furnace at a temperature of 550°C for a duration of 6 hours. Subsequently, the crucibles containing the samples were cooled in a desiccator. The average percentage of the remaining material in each sample was then calculated and considered as the ash content. The following formula was utilized to determine the ash content: Ash content (%) = (W2 - W1) / Ws × 100, where W1 represents the weight of the sample plus crucible before oven drying, W2 represents the weight of the sample plus crucible after oven drying, and Ws represents the weight of the sample.

2.4.2. Bacterial Load Analysis

(i). Materials and Equipment

Glasswares and appliances used during the experiment are as follows: Test tubes (with or without Durham's fermentation tube and stopper), Petri dishes, conical flask, pipette, incubator, freeze, thermometer, sterilizing instruments, electronic balance, sterilized cotton, beaker, hand gloves, spirit lamps, match lighter, glass spreader and forceps, scissors, mortar-pestle and autoclave.

(ii). Culture Media and Reagents Preparation

The plate count agar, which served as the culture media in the experiment, was obtained from Difco. To prepare it, 23.5 g of plate count agar was suspended in 1.0 L of distilled water and heated until fully dissolved. The media was then subjected to sterilization in an autoclave at 121°C and 15 lb/sq. inch pressure for 20 minutes. After sterilization, the media was allowed to cool to 50°C and poured into sterilized Petri dishes. Incubation at 37°C overnight was performed to confirm the sterility of the dishes, which were subsequently stored in a refrigerator. For the analysis of total plate count, aseptically, 1 gram of dry fish sample was homogenized in a sterilized mortar with 10 ml of distilled water. The resulting homogenate was transferred to a sterile bottle, and 1 ml of the sample was taken and diluted with 9.0 ml of distilled water to achieve a 10^-1 dilution. Using consecutive decimal dilution techniques with spread plates, further dilutions of 10^{-2}, 10^{-3}, 10^{-4}, 10^{-5}, 10^{-6}, and so on were prepared.

(iii). Bacteria Culture and Cell Counting

Duplicate sterile Petri dishes were prepared using sterile plate count agar media. From the solution of the sample contained in various test tubes with different dilutions, a 0.1 ml portion was aseptically taken using a micropipette and transferred into the pre-prepared agar plates. This was done by lifting the upper lid sufficiently to allow the pipette tip to enter the lip of the plate. Carefully and uniformly, the samples were spread across the surface of the media using a sterile flamed L-shaped glass rod until the sample was dried. The plates were then inverted and incubated at 37°C in an incubator. After 48 hours of incubation, the colonies that had developed on the Petri dishes were counted following a standardized method. There are several methods to count the colonies, including using a bacterial colony counter, using a magnifying glass mounted above the plate while viewing through it, or marking the Petri dish over each colony with a pen to keep track of which colonies have been counted. A hand tally was used to record the number of colonies counted. In this experiment, the marking method was employed to count the colonies.

(iv). Calculating the Original Cell Concentration

The bacterial concentration in the initial samples was determined by multiplying the colony counts by the total dilution factor. Only plates containing a colony count ranging from 30 to 300 were considered for calculating the original concentration. Counts lower than 30 were deemed statistically

unreliable, while counts exceeding 300 colonies were likely to suppress the formation of colonies by certain bacteria, resulting in an underestimation of the actual bacterial numbers. In cases where two plates yielded colony counts between 30 and 300, the calculated concentrations for each plate were averaged. The formula used to calculate the colony-forming units per gram (cfu g-1) is as follows: cfu g-1 = No. of colonies on a Petri dish × 10 × dilution factor × Volume of total sample solution / Weight of fish sample (g).

2.4.3. Sensory Evaluation

The sensory attributes of the fish sticks were evaluated by a group of panel members from the Fisheries Faculty at Sylhet Agricultural University. These panel members had prior experience in assessing similar products. The evaluation was conducted using a nine-point scale, where scores ranged from '1' indicating the lowest attribute to '9' representing the highest attribute. The sensory characteristics assessed, following the descriptions by Reddy (1992), including appearance, color, flavor, taste, texture, and overall acceptability. The fish sticks were prepared by deep-frying them in refined sunflower oil until they were fully cooked before being presented to the panelists. For each sensory characteristic, scores of 9, 8, 7, 6, 5, 4, 3, 2, and 1 were assigned to represent "like extremely," "like very much," "like moderately," "like slightly," "neither like nor dislike," "dislike slightly," "dislike moderately," "dislike very much," and "dislike extremely," respectively. Samples stored under refrigerated conditions were evaluated four times within 72 hours, with a 24-hour interval between each sampling. Conversely, samples stored under frozen conditions were assessed four times over 8 weeks, with a 2-week interval between samplings. The sensory evaluations were carried out in the Laboratory of Fisheries Technology and Quality Control at Sylhet Agricultural University, Sylhet, as well as in the Fish Nutrition Laboratory of Bangladesh Agricultural University, Mymensingh, Bangladesh.

2.5. Statistical Analysis

One-way analysis of variance and the general linear model were used to analyze the data. Duncan's New Multiple Range Test (DMRT) was used to find the significant differences between storage periods.

3. Results

3.1. Assessment of Nutritional Quality

To determine the nutritional value of fish sticks made from grass carp fish mince, the proximate composition, including moisture, protein, lipid, and ash contents, was analyzed. The grass carp fish mince had moisture, lipid, protein, and ash contents of approximately 79.16±1.42%, 3.07±0.69%, 17.21±0.45%, and 1.71±0.19%, respectively (as shown in Table 3). In comparison, the fresh fish sticks had a moisture content of approximately 65.78±0.86%, lipid content of 6.81±0.85%, protein content of 16.37±0.34%, and ash content of 2.84±0.09%.

Table 3. *Proximate composition of grass carp fish sticks.*

Type of product	Proximate composition (%)			
	Moisture	Lipid	Protein	Ash
Fresh mince	79.16±1.42	3.07±0.69	17.21±0.45	1.71±0.19
Fish sticks	65.78±0.86	6.81±0.85	16.37±0.34	2.84±0.09

3.2. Shelf Life Study of Grass Carp Fish Sticks

To determine the shelf life of the fish sticks, the bacterial load was evaluated. The fish sticks, prepared from mince, were stored at two different temperatures: room temperature (28°C) and refrigerated temperature (5°C). The total plate count (TPC) was measured at 24-hour intervals to monitor the growth of bacteria. The changes in bacterial load, measured in Log CFU/g, for the fish sticks stored under both room temperature (28°C) and refrigerated temperature (5°C) are presented in Table 4. Initially, the TPC of the fresh fish sticks was determined to be approximately 4.11±0.75 Log CFU/g. As the storage period progressed, the bacterial load (Log CFU/g) of the grass carp fish sticks increased significantly under both room temperature (28°C) and refrigerated temperature (5°C) conditions ($p<0.05$).

Table 4. *Effect of the storage period on bacterial load of fish sticks in the room and refrigerated storage conditions.*

Product	Storage conditions	Storage periods (hr)	Bacterial load (Log CFU/g)
Fish sticks	Room temperature (28°C)	0	4.11±0.75d
		24	5.47±0.58c
		48	7.33±0.69b
		72	9.73±0.45a
	Refrigerated temperature (5°C)	0	4.11±0.75d
		24	4.85±0.31c
		48	5.70±0.42b
		72	6.98±0.78a

*Each value is represented as the mean ± SD of n=3; Within a column, means not sharing common superscript letters are significantly different at ($p<0.05$).

Under frozen storage conditions (-18°C), the fish sticks made from grass carp fish mince were carefully packed in transparent polyethylene packages. The polyethylene packs were securely sealed using a mechanical sealer. Once sealed, the packs were placed in a freezer at a temperature of -18°C for analysis of quality and shelf life. The variations in bacterial load (Log CFU/g) of the fish sticks at the frozen temperature of -18°C are displayed in Table 5.

Table 5. *Effect of the storage period on bacterial load (Log CFU/g) of fish sticks prepared from grass carp fish during frozen storage.*

Storage Time (week)	Bacterial Load Log CFU/g
0	4.11±0.75a
2	3.65±0.22b
4	3.19±0.58c
6	2.70±0.31d
8	2.15±0.44e

*Each value is mean ± standard deviation of triplicate determinations. Within a column, means not sharing a common superscript letters are significantly different at ($p<0.05$).

3.3. Sensory Evaluation

To investigate the shelf life of the prepared fish sticks, sensory evaluation was conducted under different storage conditions: room temperature, refrigerated, and frozen. The sensory attributes of the fish sticks noticeably decreased as the storage time increased at room temperature. However, when stored at 5°C, the fish sticks exhibited better stability, with no significant changes observed in terms of appearance, flavor, taste, texture, and overall acceptability even after 72 hours (Table 6). During frozen storage, the sensory quality of the fish sticks remained favorable, showing minimal changes even after being stored for 8 weeks (Table 7).

Table 6. *Sensory attributes changes of fish sticks stored at room and refrigerated temperatures in different storage periods.*

Sensory attributes	Storage periods	Storage condition	
		Room temperature (28°C)	Refrigerated temperature (5°C)
Appearance	0	9.00± 0.00a	9.00± 0.00a
	24	7.72±0.43b	8.85±0.18a
	48	2.78±0.47c	8.47±0.59ab
	72	1.65±0.34d	8.06±0.27b
Color	0	9.00± 0.00a	9.00± 0.00a
	24	7.12±0.38b	8.69±0.18a
	48	3.44±0.25c	8.37±0.41b
	72	1.47±0.32d	7.85±0.37b
Flavor	0	9.00± 0.00a	9.00± 0.00a
	24	8.65±0.54a	8.78±0.42a
	48	2.80±0.45b	8.64±0.29a
	72	1.49±0.15c	7.53±0.37b
Taste	0	9.00±0.00a	9.00±0.00a
	24	8.26±0.55b	8.75±0.16a
	48	2.37±0.33c	8.16±0.42b
	72	1.00±0.00d	8.02±0.29b
Texture	0	8.77±0.33a	8.77±0.33a
	24	8.40±0.21b	8.36±0.66b
	48	3.38±0.57c	6.83±0.29c
	72	1.22±0.63d	5.78±0.42d
Overall acceptability	0	8.89±0.36a	8.89±0.36a
	24	8.05±0.23b	8.70±0.22a
	48	3.10±0.55c	7.77±0.38b
	72	1.33±0.58d	7.13±0.17c

*Here, 1= Dislike extremely; 2= Dislike very much; 3 = dislike moderately; 4= dislike slightly; 5= Neither like nor dislike; 6= Like slightly; 7= Like moderately; 8= Like very much; 9= Like extremely. Each value is represented as the mean ± SD of n=7 Within a column, means not sharing common superscript letters are significantly different at ($p<0.05$).

Table 7. *Effect of the storage period on sensory quality attributes of grass carp fish sticks during frozen storage.*

Storage period (week)	Color	Flavor	Taste	Texture	Overall acceptability
0	9.00±0.00a	9.00±0.00a	9.00±0.00a	8.77±0.33a	8.89±0.36a
2	8.71±0.63a	8.72±0.29a	8.50±0.24ab	8.23±0.17b	8.57±0.21a
4	8.52±0.28ab	8.60±0.12ab	8.23±0.31b	8.19±0.21b	8.31±0.76b
6	8.19±0.41b	8.47±0.23b	8.17±0.10b	8.09±057b	8.23±0.30b
8	8.10±0.35b	8.40±0.21b	8.05±0.30b	7.98±031b	8.09±0.48b

*Each value is represented as the mean ± SD of n=7. Within a column, means not sharing a common superscript letters are significantly different at ($p<0.05$).

4. Discussion

The analysis of grass carp fish mince composition revealed the following percentages of moisture, lipid, protein, and ash at fresh conditions: 79.16±1.42%, 3.07±0.69%, 17.21±0.45%, and 1.71±0.19%, respectively. Conversely, fresh fish sticks had moisture, lipid, protein, and ash content of 65.78±0.86%, 6.81±0.85%, 16.37±0.34%, and 2.84±0.09%, respectively. Shaviklo et al. (2016) studied fish burgers with tuna protein isolate and silver carp mince, which had moisture, protein, lipid, and ash ratios of 61.32%, 19.01%, 7.025%, and 2.63%, respectively, consistent with our findings [17]. Similarly, Vanitha et al. (2013) reported moisture, protein, lipid, and ash content of 55.08%, 18.11%, 12.18%, and 2.18%, respectively, in a fish burger, supporting our results [3]. In our study, we observed a decrease in moisture content from 79.16±1.42% in fish mince to 65.78±0.86% in fish sticks, likely due to water loss during cooking. The protein content also decreased, possibly due to denaturation from excessive heat during cooking. Conversely, the lipid content increased, likely due to the absorption of vegetable oil during frying, and the ash content increased due to added spices and ingredients. The bacterial growth in fish sticks stored at room temperature increased rapidly, while refrigerated storage slowed down bacterial growth. The shelf life of fish sticks at room temperature was no more

than 24 hours, but at refrigerated temperature, it could remain in good condition for up to 72 hours. Freezing reduced bacterial count, and the frozen storage of fish sticks showed acceptable bacterial levels even after 8 weeks. Other studies also found extended shelf lives for frozen storage of similar fish-based products. The sensory attributes of fresh fish sticks decreased significantly during storage at room temperature, rendering the product unacceptable after 72 hours. At refrigerated temperature, the product exhibited better stability, with no significant changes in color, taste, or appearance even after 72 hours. Frozen storage at -18°C maintained consistent sensory quality throughout the storage period, similar to fresh samples. These findings align with previous studies on the frozen storage of fish-based products. Overall, the shelf life of fish sticks at room temperature and the refrigerated temperature was not more than 24 hours and 72 hours, respectively. Frozen storage at -18°C allowed for longer shelf life without compromising sensory quality.

5. Conclusion

Consumer preference has shifted towards fast food consumption in recent years due to rapid urbanization and an increase in the population of working women. This trend creates promising prospects for value-added products such as grass carp and fish sticks in Bangladesh. Grass carp fish, known for its abundance and affordability, can serve as an excellent source of high-quality mince. Additionally, grass carp fish sticks offer a valuable protein source for the population. The production technology for fish sticks is relatively simple, requiring less complex machinery and incurring low production costs. Furthermore, all the necessary ingredients for fish stick preparation are readily available in nearby markets. This presents a significant opportunity for both small-scale and large-scale entrepreneurs to enter a new food market and achieve economic self-dependence.

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