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The Effect of Frozen Storage on the Chemical, Functional, And Sensory Properties of Fish Burgers

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ABSTRACT
The goal of the study was to utilize common carp (Cyprinus carpio) to produce fish burgers with desirable sensory and chemical properties by incorporating spices, fillers, and salt into the production process. The sensory characteristics of the fish burgers remained stable throughout the storage life, especially in terms of textural characteristics. No significant differences were found in chewiness and shape ratings between the burgers in their respective groups. Significant differences were noted in color, texture, and flavor attributes accepted by the consumers and evaluators. The chemically analyzed burgers also showed good quality indicators during storage, including peroxide value, thiobarbituric acid (TBA) value, and total volatile nitrogen (TVN). At the end of storage, the burgers also had good free fatty acid values. Those values included malondialdehyde 1.70 mg/kg, nitrogen 8.85 mg/100g, and malondialdehyde/nitrogen (0.22%). All values were within the permitted limits, with only small changes observed at the end of the storage time. Therefore, the low-cost fish species can be used to produce nutritional, high-protein fish burgers and other sensory products with acceptable sensory and chemical quality.
Keywords: *Fish burger, Common carp* (Cyprinus carpio)*, Fish products, Chemical indicators of fish products, Sensory properties of fish products.*

INTRODUCTION

Fishes are easily distinguished by their nutritional excellence, which is marked by the presence of highly digestible proteins, lipids that are free of cholesterol, and an abundant supply of vitamins and minerals. According to Salman et al. (2023), fish are arguably the most diverse source of food and are widely collected and sold in the market. Fish also comes in numerous tastes and is appealing to many consumers. Typically, fish contain between 17% and 20% protein, which is recognized as a protein source rather than a source of essential amino acids. The body cannot produce these essential amino acids; therefore, they should be consumed to enhance functional performance (Mahmed et al., 2021). Fish are authorities that represent not just high-quality protein, but they are also among the highest consumers of lipids, vitamins, and minerals. In addition, fish flesh will always contain complete tissues, which contain considerable amounts of long-chain polyunsaturated fatty acids, where most of these are omega-3 fatty monoglycerides. Hence, nutritionists recommend consuming fish two to three times a week to maintain a healthy lifestyle (Mititelu et al., 2024). The common carp (Cyprinus carpio), a member of the family Cyprinidae, is the most commonly farmed fish species in Iraq, having been introduced to the country in 1956. It is found in nutrient-rich waters and is considered one of the important fish species to the Iraqi economy (Rose, 2024). It should be in oligohaline environments, deep lakes, or stagnant low-salinity water. Evidence has shown that this fish can adapt and tolerate many environmental factors (Moniruzzaman et al., 2021). The preparation of the product is usually less complicated than preparing a whole fish. Over time, consumers' purchasing habits have changed when presented with convenient and frequently processed fish product options, such as fish burgers. Processing fish products is a labor-intensive and repetitive endeavor. Fish processing requires multiple steps carried out by seven different units or people, each performing a specific task involved in the production of a fish product. The processing of fish begins after capture and includes grading and sorting. Other processing steps include beheading, eviscerating, cutting, and processing fish products, followed by packaging (Liu et al., 2022). Minced meat products such as fish patties and fish burgers are experiencing rapid growth for several reasons. They are recognized for their convenience, nutritional benefits, and palatability. With this growing consumer interest, fish burgers made from other species of meat have emerged (Alrubeii and Al-Hadedee 2025), which will also create opportunities for innovative fish burgers in further product development. One study found that fish burgers could be manufactured from minced fish meat or surimi and are made using starch, spices, and other flavors. These products are designed to be easy and quick to prepare. Similarly, Oppong et al. (2022) reported that sugar, vegetables, starch, and salt were added, mixed, and hand-formed into round patties (burgers), and then fried until golden brown. In their study, Sen et al. (2022) examined the feasibility of using various fish species to get fish burgers, balls, and sausages. The process involved washing the fish meat first and then mincing it to modify the texture. The mincing of fish products has the specific advantage of concealing the species of fish and likely increasing acceptability versus whole fish. The current study aims to utilize common carp (Cyprinus carpio) to create fish burgers, which involve mincing the fish meat, fillings, salt, and spices. The study also examined changes in chemical, chemical quality indicators, and sensory characteristics over an eight-week storage period.

MATERIALS AND METHODS

Live common carp (Cyprinus carpio) were purchased from local markets in Baghdad (weighing 2.5–3 kg) and thoroughly washed, descaled, and eviscerated. The edible flesh was treated separately. The chemical composition of the fresh fish flesh was analysed for the amount of moisture, ash, protein, fat, and pH. The fresh fish flesh was then minced and rinsed with cold distilled water (with a ratio of 2:1 (minced fish: water)). The samples were mixed (stirred) for five minutes to remove the lipids from the upper surface layer. The rinsing and defatting process was performed twice on each.

After washing the fish mince, a sodium chloride (NaCl) solution was added at a concentration of 0.2 g per 100 g of the mince mixture. Next, the excess water was removed through a filtration system, whereby the mixture was passed through a muslin cloth. The minced meat was then well mixed for 10 minutes. The next ingredients were added and thoroughly mixed, following the methods of Satam et al. (2004), with some modifications, as described in Table 1. The mixture was kneaded for 15 minutes and shaped into discs, which were assembled into fish burgers. The discs were packed into polyethylene bags separated by wax paper (butter paper) and stored at -18 °C. The chemical composition, chemical indicators, and sensory characteristics of the patties were evaluated throughout storage at intervals of 0, 2, 4, 6, and 8 weeks. For sensory evaluation, the burger discs were cooked on a hot plate (Hot Plate).

Table (1): Ingredients used to prepare the fish burger recipe

Ingredient	% value	Ingredient	% value	Ingredient	% value
Fish meat	100	Bread crumbs	8.5	Starch	3
Garlic powder	1	Onion powder	0.5	Clove	0.1
Coriander	0.2	Table salt	3	Black pepper	0.1

*(expressed as percentages % of the total weight)

CHEMICAL COMPOSITION DETERMINATION

The chemical composition (moisture, protein, fat, ash) was determined according to the method of the Association of Official Analytical Chemists (A.O.A.C., 2010) following all detailed protocols, including sample weight, sample handling, and temperature. According to Farshidy (2019), use a pH. A one-gram sample was homogenised with 10 mL distilled water using an electric blender, filtered through compressed cotton, and the pH of the filtrate was recorded.

DETERMINATION of chemical indicators

The Peroxide Value (P.V.) was estimated using the method described by A.O.A.C. (2010). Free Fatty Acids (FFA) and Total Volatile Nitrogen (TVN) were determined according to Ali et al. (2023, December). The Thiobarbituric Acid (T.B.A) value was estimated using the method proposed by Abed and Khairy (2023).

SENSORY EVALUATION

Sensory attributes were evaluated using a specially prepared form designed for this purpose, based on the method developed by Świąder and Marczewska (2021).

STATISTICAL ANALYSIS

The data were analyzed with the Statistical Analysis System (SAS, 2018) to evaluate the impact of various storage durations on the parameters in this study. A Completely Randomized Design (CRD) was utilized, and means were compared for asses differences using Least Significant Differences (LSD).

RESULTS AND DISCUSSION:

The values presented in Table 2 indicate the chemical composition and pH value for the flesh of fresh common carp fish. In terms of chemical composition, it has a high moisture content of 72.80% ± 2.67, a good protein content of 21.62% ± 1.07, a fat content of 4.15% ± 0.32, and an ash content of 1.33% ± 0.08. The pH value was 6.3. These results are consistent with the findings of Ponnampalam et al. (2024) regarding the composition of fresh common carp and similar to the values of Mwape et al. (2023) concerning the muscle properties of silver carp. The pH value is nearly identical to that of Pulfer et al. (2022), who found a pH of 6.15, which was lower than the neutral point of 6.5 reported by Leung et al. (2024).

Table (2): Chemical composition and pH value of fresh common carp fish meat

Fish type	Moisture %	Protein %	Fat %	Ash %	pH
Common carp	72.80 ± 2.67	21.62 ± 1.07	4.15 ± 0.32	1.33 ± 0.08	6.3 ± 0.35

Table 3 illustrates the effect of frozen storage on the chemical composition of fish burgers. It is noted from the table that the moisture, initially at 70.91%, slightly and insignificantly decreased with continued storage up to 8 weeks. This reduction may be attributed to water loss during processing. These results were consistent with Majumdar et al. (2016), who showed that moisture content decreased with storage time in processed fish burgers, reaching 68.95%.

Also observed in the table is a good protein content, which was 18.70%, decreasing slightly and insignificantly with extended storage duration up to 8 weeks. This decrease may result from washing processes applied to the minced fish meat before processing. These findings are consistent with Zangana (2016), who reported a significant decrease in protein content during storage. The decline in protein could also be due to protein degradation and the release of nitrogenous bases that may be lost with the separated liquid. The proportions of these components can vary depending on the spices added, as confirmed by Majumdar et al. (2016), who studied protein content in minced Pangasius sutchi fish meat and noted a decrease from 23.01% to 20.98% after storage.

Table (3): Effect of frozen storage on the chemical composition of fish burger

Chemical content %	Storage duration (weeks)					LSD value
	0	2	4	6	8	
Moisture	70.91 ±2.56	70.63 ±2.19	70.39 ±1.96	70.15 ±1.88	69.90 ±2.03	3.61 NS
Protein	18.70 ±0.79	18.41 ±0.85	18.33 ±0.77	18.11 ±0.69	17.88 ±0.68	1.79 NS
Ash	2.02 ±0.13 b	2.29 ±0.17 ab	2.53 ±0.23 ab	2.70 ±0.26 a	2.82 ±0.22 a	0.661 *
Fat	2.11 ±0.07 a	1.93 ±0.10 ab	1.80 ±0.09 ab	1.66 ±0.05 b	1.60 ±0.07 b	0.431 *
Carbohydrates	6.26 ±0.33 b	6.74 ±0.42 ab	6.95 ±0.37 ab	7.38 ±0.41 ab	7.80 ±0.54 a	1.457 *
Acid value (pH)	6.24 ±0.28	6.27 ±0.35	6.31 ±0.29	6.35 ±0.27	6.39 ±0.41	0.368 NS
*Means carrying different letters within the same column differ significantly at P ≤ 0.05.						

The ash content was 2.02% at the start, and climbed gradually over storage time to 2.82% at 8 weeks. This is plausible due to the requirement of adding additional ingredients during processing, which caused reductions in moisture, which could have influenced the ash upper-bound. Those values were approximately equal to, and in agreement with, Aljabeili et al. (2016), and quite similar to Kotsou et al. (2023). The carbohydrate content increased slightly with storage time, similarly to the ash and fiber contents, but remained relatively low at about 4% of the content after the maximum 8-week period, increasing from 6.26% to 7.80%, which aligns with the values reported by Hematyar et al. (2018) for surimi and fish burgers. pH showed a slight increase from 6.24 to 6.3, possibly due to metabolic products from bacteria on the proteins and amino acids. These increases in pH values are consistent with the study by Mehatiyar et al. (2018), fish balls with curry, and with the article by Siol et al. (2025), which analyzed refrigerated Nematalosa nasus patties. The fat content decreased slightly over 8 weeks of storage, possibly representing a redirection of fat content to the washing process before processing. This decrease can also be modified by the chemical composition of fat, with the action of lipase and phospholipase enzymes, and lipolysis, which provides the rupture of free fatty acids. These results are in agreement with Bavitha et al. (2016) and a similar study by Kotsou et al. (2023), which indicates differences in fat content for stored fish products.

Table 4 presents a comparison of the chemical indexes of fish burgers, where the values did not exceed acceptable limits. The free fatty acid (FFA) content was 0.05% at day zero and did not significantly increase with storage time up to 8 weeks (0.22%). This could be attributed to the low fat content in fish meat from repeated washing (therefore also a small amount of unsaturated fatty acids) that can lead to oxidation and lipolytic activity. It is also worthwhile to mention that the spices added to the mixture while manufacturing may have protected the product from oxidation due to their antioxidant compounds. The results agreed with Duman and Peksezer (2016), who evaluated chemical changes in fish balls during 6 months of frozen storage and observed only a slight increase in FFA due to enzymatic fat degradation during frozen fish. Suárez-Medina et al. (2024) also agreed in reporting that the factor responsible for the increment of FFA in frozen fish meat is due to the activation of psychrotrophic lipolytic bacteria during storage.

Peroxide values (PV) were also within permissible ranges, starting at 0.10 meq/kg oil and increasing gradually but insignificantly to 2.18 meq/kg oil after 8 weeks. The low initial value is likely due to the absence of fat oxidation at the beginning, as oxidative enzymes and bacteria, these findings agree with Verma (2021), who reported that the increase in PV is due to oxidative enzymes like lipoxygenase and peroxidase, along with chemical pro-oxidants such as hemoproteins and metal ions. The slight high in PV with storage is attributed to the use of spice blends in all prepared samples, consistent with Sikorski and Ghirmai.(2022) .

The thiobarbituric acid (TBA) value was 0.30 mg malondialdehyde/kg meat, rising slightly but insignificantly to 1.70 mg malondialdehyde/kg meat after 8 weeks, which is within acceptable limits. This stability is likely due to the antioxidant activity of spices, proteins, and fats. These results concur with karpińska-tymoszczyk (2012), who produced fish balls from carp meat and manufactured fish fingers from common carp meat.

Table (4): Effect of frozen storage on the chemical indices of fish burger

Chemical indices	Storage duration (weeks)					LSD value
	0	2	4	6	8	
% FFA	0.05 ±0.01	0.10 ±0.03	0.16 ±0.03	0.19 ±0.05	0.22 ±0.04	0.078 *
PV (meq/kg oil)	0.10 ±0.02	0.63 ±0.08	1.33 ±0.11	1.97 ±0.14	2.18 ±0.12	0.549 *
TBA mg Malonaldehyde/kg meat	0.30 ±0.04	0.40 ±0.06	0.70 ±0.06	1.15 ±0.09 ab	1.70 ±0.14 a	0.668 *
TVN mg nitrogen/100 gm	5.01 ±0.32	6.11 ±0.37	7.09 ±0.43 b	8.00 ±0.39 ab	8.85 ±0.52 a	1.604 *
*Means with different letters within a column are significantly different (P≤0.05)						

Finally, the table indicates the value of Total Volatile Nitrogen (TVN) when storing samples up to 8 weeks, where it is observed that the TVN recorded 5.01 mg nitrogen/100g at day zero. A slight, non-significant increase was observed throughout the storage, in 8.85 mg nitrogen/100g. This value also remains within the permissible limits. Therefore, it can be concluded that the fish burger can be preserved for up to 8 weeks without significant changes occurring. This may be attributed to the use of spices to preserve the product due to their content of biologically active compounds, by limiting the changes in proteins and fats. These findings are consistent with the results of Duman and Peksezer (2016), who studied the chemical changes in prepared and frozen fish balls stored at -18°C for six months. The slight increase in TVN was expected due to proteolytic degradation of minced fish meat and the activity of protease enzymes secreted by microorganisms. The mincing process increases the surface area of the meat, which increases the protein breakdown. As for Table 5, it illustrates the effect of freezing on the sensory attributes of fish burgers. According to the table, the prepared burgers retained good sensory properties throughout the 8-week storage period, with only slight variations in color, texture, and flavor. Scores for these attributes were 25.0, 19.5, and 24.0, respectively, at day zero, and 20.0, 18.0, and 19.5, respectively, at week eight — still considered very acceptable. For chewiness and shape uniformity, scores were 9.5 and 20.0 at day zero and 9.5 and 19.3 at week eight. These attributes showed no significant changes throughout the study. It is worth noting that the product maintained excellent quality in terms of sensory attributes and other indicators, as sensory changes tend to appear earlier than chemical changes during freezing. The slight decrease in burger acceptability after storage was not significant, and the sensory characteristics remained stable during the entire storage period. These results are consistent with the findings of Mahmoud and Al-Khshali (2022), who studied the sensory properties of fish burgers made from Deep flounder and Brushtooth lizardfish stored at -18°C for five months.

Table (5): Effect of Freezing Storage on Sensory Characteristics of Fish Burger

sensory qualities	Storage duration (weeks)					LSD value
	0	2	4	6	8	
Color	25.0 ±1.26 a	24.1 ±1.67 ab	24.0 ±1.62 ab	22.0 ±1.25 bc	20.0 ±0.87 c	2.360 *
Texture	19.5 ±1.07 a	19.1 ±0.87 ab	19.0 ±0.74 ab	18.6 ±0.64 ab	18.0 ±0.76 b	1.398 *
Flavor	24.0 ±1.54 a	23.0 ±1.26 a	22.0 ±1.35 ab	20.0 ±1.08 bc	19.5 ±0.91 c	2.873 *
Chewiness	9.5 ±0.59	9.6 ±0.78	9.8 ±0.68	9.6 ±0.62	9.5 ±0.65	0.802 NS
Shape Uniformity	20.0 ±0.84	19.8 ±1.02	19.7 ±0.82	19.5	19.3 ±0.86	1.024 NS
*Means with different letters in the same row are significantly different ($P \leq 0.05$)						

In general, the prepared animal burger maintained good texture and shape uniformity, such as fish, beef, and chicken burgers. This could be attributed to several factors, most notably the use of spices (Abdulrahem et al., 2022; Alrubeii and Alalaq, 2018). who conducted a sensory evaluation of fish burgers prepared from silver carp.

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