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ORIGINAL ARTICLE

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Enhancing Freshwater Fish Consumption in Algeria: A Study on the Nutritional and Sensory Attributes of Common Carp Sticks

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ABSTRACT

Background: To enhance the level of fish consumption in Algeria, it is crucial to promote the utilization of freshwater and farmed fish. The common carp, being the most produced species, often exhibits an undesirable odor attributed to its feeding behavior. This characteristic leads many consumers to prefer wild fish over farmed alternatives. Furthermore, there is a notable scarcity of research on fish products within Algeria.

Aims: The aim of this study was to propose common carp sticks as an alternative product form to increase freshwater fish consumption, and to rigorously evaluate their nutritional value and sensory properties.

Material and Methods: In this regard, the flesh of common carp was initially marinated in two distinct types of organic acids and various condiments. Following a 12-hour marination period at 4°C, steam cooking was performed to yield fish flakes. These flakes were subsequently combined with dry ingredients, including potato flakes, salt, spices, corn oil, and skimmed milk powder. Water was then added to form a smooth and homogeneous dough, which was shaped into sticks. The sticks were coated in flour, eggs, and breadcrumbs before being deep-fried in vegetable oil. The prepared sticks from both types of marinated flesh were then evaluated for their microbiological, nutritional, and sensory attributes. (Analyses on raw common carp were conducted prior to this study).

Results: No significant differences were observed between the two types of sticks, regardless of whether they were marinated with vinegar or lemon. An antimicrobial effect of the lemon was noted, leading to a reduction in the microbial load of the sticks. Both groups of sticks demonstrated appreciated nutritional value. Additionally, panelists showed strong appreciation for the fish sticks from both groups, rating those marinated with lemon juice at 7.61 ± 0.99 and those with vinegar at 7.68 ± 1.14.

Conclusions: These findings suggest that freshwater fish, when presented in this processed form, are acceptable to consumers for inclusion in their diet. This approach could positively impact the national economy and contribute to food security in Algeria.

Keywords: Fish consumption, Freshwater fish, Sticks, Nutritional quality, Sensory profile.

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1 INTRODUCTION

Fish is widely recognized as a high-quality food for human consumption, primarily due to its rich content of easily digestible protein, which provides various essential amino acids. Furthermore, fish meat is abundant in various vitamins and minerals. However, its most notable nutritional feature is its high concentration of unsaturated fatty acids, which play a crucial role in maintaining human health and well-being (Izci, 2010).

Despite its nutritional benefits, the average fish consumption rate in Algeria stands at a mere 2.39 kg per capita per year, which is significantly lower than the global average of 20.5 kg per capita per year (Naji *et al.*, 2023). To address this disparity and enhance national fish consumption, it is essential to promote the utilization of freshwater and farmed fish species. These varieties offer the comparable nutritional benefits to marine fish but are typically available at considerably lower prices and with greater accessibility (Sabba *et al.*, 2023).

Among freshwater species, carp is among the most widely distributed fish globally, largely attributed to its resilience to diverse environmental conditions and its minimal vital requirements (Öz & Uçak, 2023). In Algeria, the common carp (*Cyprinus carpio*) is the most produced species (Naji *et al.*, 2023). However, it is often associated with an undesirable odor, primarily due to its benthic feeding behavior (Elyasi *et al.*, 2010). Currently, almost all aquaculture fish in Algeria is sold fresh, with only limited and experimental processing initiatives undertaken by some producers. Consumers who have not regularly consumed aquaculture products frequently cite poor taste as their primary deterrent, with a strong preference for wild fish over farmed fish in terms of flavor, perceived safety, nutritional content, and health benefits (Naji *et al.*, 2023).

Recognizing the challenges posed by these perceptions, there is a clear demand from carp producers to develop alternative products aimed at enhancing carp consumption Tokur *et al.* (2006). Such initiatives focus on employing various additives and processing techniques to remove undesirable flavors and odors. Freshwater fish products, including fish sticks, surimi, and fish burgers, represent promising avenues for offering a range of healthy food options to boost fish consumption rates.

Common carp species are inherently bony, and those harvested from certain wetland environments frequently exhibit an earthy or muddy odor. In some regions, a traditional practice involves marinating fish meat with lemon juice and salt to enhance the palatability of carp. This marinated fish is then then often frozen for later consumption and has proven to be well-received by consumers (Öz & Uçak, 2023).

The marinating process itself is widely technique for preserving fish and improving its sensory attributes. A typical marinade consists of a mixture of salt dissolved in water, organic acids (such as acetic acid from vinegar, lactic acid, and citric acid from lemon), and various spices. The effectiveness of the marinating process and the resulting product quality are influenced by numerous factors, including the concentration of salt, the specific type of organic acid used, the choice of spices, the material of the container, and the preliminary processing steps applied to the fish (Bilgin *et al.*, 2011; Topuz, 2016).

The objective of the present study was to marinate common carp meat to effectively eliminate its muddy odor, subsequently fabricate value-added fish sticks to enhance human consumption, and evaluate their nutritional, microbial, and sensory quality.

2 Material and Methods

2.1 Preparation of Fish Sticks

Common carp (*Cyprinus carpio*) from semi-intensive farming systems (Achour Ali agricultural farm, Jijel province, Algeria) were utilized for the preparation of the fish sticks. Following cleaning and evisceration, the fish were divided into two distinct groups, each of which was marinated using a different organic acid to eliminate the characteristic muddy odor. Two food-grade acids were employed for this purpose: lemon juice and vinegar (dark cider vinegar, with an acetic acid content of 5% v/v).

Marinating solutions were prepared by combining either lemon juice or vinegar at a concentration of 100 ML per liter of water. To these solutions, sodium chloride (3% w/w, relative to fish flesh) and a blend of spices were added, including black pepper (3%), cumin (3%), ginger (6%), and garlic (6%). The marinating process was conducted for 12 hours at 4°C. Following the marination of the raw flesh, the

Figure 1. Common carp used in the study (A), marinating process (B), cooking processed carp (C), and sensory analysis (D)

treated fish were steamed to obtain flakes, which were then used in the formulation of the fish sticks (Figure 1).

The fish sticks were prepared by mixing common carp flakes (40%), potato flakes (25%), table salt (0.95%), spices (0.95%) comprising black pepper, garlic powder, cumin, coriander, ginger, and onion powder, corn oil (2.38%), skim milk powder (1.43%), and water (29.29%) to form a homogeneous dough.

Twenty-gram portions were taken from the prepared dough and manually shaped into sticks. These sticks were then breaded (coated with flour, dipped in eggs, and then coated with breadcrumbs). The prepared fish sticks were placed on parchment-lined trays and frozen overnight at -18°C. Prior to sensory evaluation, the fish sticks were deep-fried in vegetable oil until golden brown, drained on absorbent paper, and then presented to tasters. A portion of the fresh, unfried samples was stored in a freezer bag at -18°C for subsequent proximate analysis.

2.2 Microbial Analysis

To evaluate microbiological quality of the samples, 25 g aliquots was initially diluted with 225 mL of sterile peptone water and homogenized using a stomacher. From the 10^{-1} dilution, serial decimal dilutions were prepared (10^{-2} to 10^{-7}).

- **Total Plate Count (TPC)** was determined using Plate Count Agar (PCA) in accordance with ISO 4833: 2013. Plates were incubated at 30°C for 24–48 hours.

- **Fecal coliform bacteria** were enumerated using the NF V 08-060 (AFNOR, 1996) method with Violet Red Bile Lactose (VRBL) agar. Plates were incubated at 44°C for 24 hours.
- For *Salmonella* **enumeration**, a 25 sample was initially mixed with 225 mL of buffered peptone water for pre-enrichment, followed by incubation at 37°C for 18–24 hours. For selective enrichment, 1 mL of the pre-enrichment culture was inoculated into three tubes of selenite cystine broth (SFB) were and incubated at 37°C for 18–24 hours. Isolation was performed by surface inoculation onto Hektoen enteric agar supplemented with specified additives, with subsequent incubation of plates at 37°C for 24 hours.
- For *Staphylococcus* **enumeration**, five drops of the primary dilution were surface-inoculated on Chapman agar, followed by incubation at 37°C for 48 hours.

Colonies were counted on plates exhibiting 30–300 colonies for the total plate count. All microbial counts were reported as colony-forming units per gram (CFU/g).

2.3 Proximate Composition Analysis

Proximate composition, including moisture and ash content, was determined according to the methods of the Association of Official Analytical Chemists (AOAC, 2006). Moisture content was ascertained by oven-drying samples at 105°C until a constant weight was achieved (3–4 hours). Ash content was determined by incineration at 550°C in a muffle furnace for 4–6 hours. Protein content was measured by the Kjeldahl method (Kjeldahl, 1883). Nitrogen content was determined through three sequential phases: acid digestion, steam distillation, and titration with 0.1 N Hydrochloric acid (HCl). The crude protein concentration was then quantified using a nitrogen conversion factor (6.25).

Lipid content was extracted using the method Folch *et al.* (1957) Briefly, 1 g of the sticks was homogenized with 20 mL of a chloroform:methanol solution (2:1, v/v). The homogenate was then filtered through filter paper. A 0.58% homogenate was then filtered through filter was added to the filtrate to facilitate phase separation. After allowing the phases to separate, the upper methanol/water phase was discarded, and the lower phase chloroform/lipids was recovered. the solvent was subsequently evaporated and the remaining lipid residue was weighed using an analytical balance.

Fiber content was determined according to AOAC Method 978.10 (AOAC, 1978). Total carbohydrate content was calculated by difference using the following equation:

- Total Carbohydrates % = 100% − (Moisture % + Protein % + Lipid % + Ash % + Fiber %)

The energy value of the prepared fish sticks was calculated in kilocalories (kcal) using the following equation:

- Energy Value (kcal) = (Lipids (g) × 9) + (Proteins (g) × 4) + (Carbohydrates (g) × 4)

Fatty Acid Methyl Esters (FAMEs) were separated using a Hewlett Packard Agilent 6890 Plus Gas Chromatograph (GC) equipped with an HP-5 Mass Spectrometer (MS) capillary column (30 m, 0.25 mm i.d., 0.25 µm film thickness, 5% phenyl and 95% dimethylpolysiloxane). FAMEs were then using a Hewlett Packard Agilent 5973 MS.

2.4 Sensory Analysis

Sensory analysis was conducted to evaluate the organoleptic properties of the two formulations of common carp fish sticks using a hedonic test. A consumer panel comprising 100 naïve subjects (70 women, 30 men; aged 17–70 years) participated in the evaluation. The two fish stick formulations were presented on numbered plates and served to the panelists, who rated them on a 9-point hedonic scale (e.g., 1 = "dislike extremely" to 9 = "like extremely") based on attributes including appearance, color, aroma, taste, and texture. Ultimately, an overall score was assigned to each product based on perceived satisfaction.

2.5 Statistical Analysis

All data were expressed as means ± standard deviations (SD). Statistical comparison of means was performed using one-way Analysis of Variance ANOVA (XLSTAT 2014), followed by Tukey's post hoc test for multiple comparisons. Differences were considered statistically significant at $p < 0.05$).

3 Results and Discussion

3.1 Microbiological analyses

The results of the microbiological enumeration conducted on the raw common carp flesh and the prepared fish stick formulations are summarized in Table 1. Interpretation of these findings was performed in accordance with the Food Microbiology Standard outlined in the Official Journal of the Algerian Republic (O.J.A.R. No. 39/2017). The enumeration of bacteria serves as a crucial indicator for assessing contamination levels and predicting shelf-life following fish processing (Aktaruzzaman *et al.*, 2022).

Microbiological analyses of the common carp flesh used for stick production revealed the presence of total mesophilic aerobic flora, but crucially, demonstrated the absence of key

Table 1. Comparison of the results from our microbiological analyses of the flesh of common carp and the formulations prepared from this fish with the permissible limit values (CFU/g) as per O.J.A.R. No. 39/2017.

Aerobic Bacteria	Aerobic Bacteria	Heat-Tolerant Coliforms	*Salmonella*	Coagulase + Staphylococci
Raw Fish	$2.17x10^4 \pm 3.21x10^3$	Absence	Absence	Absence
Algerian Standards	10^7	10^2	Absence in 25g	10^3
Sticks 1 (Lemon	$1.25x10^{5a} \pm 8.5x10^3$	Absence [a]	Absence in 25g	$3.36x10^{2a} \pm 0.00$
Sticks 2 (Vinegar	$1.2x10^{5a} \pm 5.21x10^4$	$6.2x10^{2b} \pm 70.71$	Absence in 25g	$5x10^{2a} \pm 60$
Algerian Standards /	/	$5x10^4$	Absence in 25g	$5x10^2$

pathogenic microorganisms, such as fecal coliforms, coagulase-positive, *Staphylococci* and *Salmonella*.

These results are identical to those found by Degnon *et al.* (2013), that noticed an absence of pathogenic germs but with a load of highly higher aerobic microorganisms (9.4 x 10^6 CFU/g) in horse mackerel in Morocco, our values of the FTAM are similar to those obtained by Itongwa *et al.* (2019) in Congo (5.4 x 10^2 to 1.5 x 10^4 CFU/g), who observed a satisfactory microbiological quality on tilapia and Nile perch as also noted by Dergal *et al.* (2013) (10^3 CFU/g) on Nile tilapia samples in Algeria. As for fecal coliforms, our results contrast with those of Itongwa *et al.* (2019) where the microbiological quality of the analyzed samples was not satisfactory. Similarly, the absence of *Staphylococcus* contamination in our study contrasts with the findings of Itongwa *et al.* (2019), who reported counts of 10^2 to 10^3 CFU/g, albeit still within acceptable limits for satisfactory microbiological quality. No *Salmonella* germs were detected in our raw samples, which is consistent with the research by Itongwa *et al.* (2019) and Degnon *et al.* (2013). Based on comparisons with Algerian standards (O.J.A.R. No. 39/2017), the raw common carp utilized in this study was confirmed to be of satisfactory hygienic quality.

The prepared fish sticks exhibited an increase in total mesophilic flora. Fecal coliforms were exclusively detected in the vinegar-marinated sticks, while coagulase-positive *Staphylococci* were present in both stick formulations, though at a comparatively lower level in the lemon-marinated sticks. *Salmonella* remained consistently absent in all prepared formulations. Despite the observed increase in microbial load during processing, these findings comply with the standards outlined by Algerian regulations (O.J.A.R. No. 39/2017). This indicates that the prepared fish stick products maintain a satisfactory hygienic quality and are deemed safe for human consumption.

The FTAM results obtained for our fish sticks are comparable to those reported by Tokur *et al.* (2006) for sticks produced from mirror carp (8 x 10^4 to 2 x 10^5 CFU/g), İZci (2010) for *Atherina hepsetus* chips (10^4 CFU/g), and Cakli *et al.* (2005) for sticks prepared from sardine, tuna, whiting, and pike perch (10^4 to 10^5 CFU/g. However, it is noteworthy that none of these comparative studies identified the presence of coliforms or staphylococcal bacteria in their processed products.

Conversely, our FTAM values were considerably higher than those reported in several other studies conducted on fried fish-based products, which observed significantly lower counts. For instance, Elyasi *et al.* (2010) reported values ranging from 3.33 to 26.66 CFU/g for common carp sticks made from minced meat and surimi, with an absence of coliforms. Similarly, lower FTAM values were documented by Aktaruzzaman *et al.*, (2022) on tilapia sticks (10^3 CFU/g). The observed increase in bacterial load in the prepared sticks compared to that in fresh fish, as well as its higher level compared to literature values, along with the presence of indicator bacteria (fecal coliforms and coagulase-positive *Staphylococci*), despite still complying with the standards, can be attributed to one or more of the following factors:

- Potential contamination of the added raw materials, such as potato flakes and water, which may have overcome the inhibitory effects of antimicrobial ingredients (e.g., salt, garlic, and black pepper) and the bacterial reduction typically achieved during the frying process (Khanipour *et al.*, 2014; Elyasi *et al.*, 2010).
- Unsatisfactory hygienic conditions during preparation.
- Potential cross-contamination during enumeration processes.

Comparing the higher bacterial loads observed in vinegar sticks to the lower loads in lemon-marinated sticks this disparity strongly suggests an antimicrobial effect of lemon, as demonstrated in the study conducted by Öz & Ucak (2023).

3.2 Nutritional Characterization of Stick Products

The nutritional composition of sticks fabricated from common carp flesh, alongside the raw material (fish meat), and reference nutritional values derived from the CIQUAL food composition table (2020) are presented in Table 2.

Table 2. Nutritional composition of fish sticks and comparison with results obtained from raw material (common carp flesh) and values provided by the CIQUAL food composition table)

Sample	Moisture	Mineral Matter	Proteins	Fats	Fibers	Carbohydrates	Energy Value
Lemon Sticks	$46.05^a \pm 5.12$	$1.00^a \pm 0.006$	$11.08^a \pm 1.01$	$8.11^b \pm 2.31$	$0.17^b \pm 0.03$	$33.59^a \pm 6.47$	$243.31^a \pm 22.52$
Vinegary Sticks	$51.35^a \pm 2.71$	$1.00^a \pm 0.025$	$10.79^a \pm 0.50$	$7.8^b \pm 2.86$	$0.06^a \pm 0.03$	$28.99^a \pm 5.03$	$229.08^a \pm 12.78$
Common Carp Fresh	$78.53^b \pm 5.19$	$0.94^a \pm 0.09$	$10.63^a \pm 1.56$	$1.23^a \pm 0.4$	/	/	/
Sticks (CIQUAL, 2020	72.5	2.15	8.31	4.92	<0.33	11.8	125

Note: The results are presented as mean ± standard deviation (n = 3). Results are denoted in g/100g of wet product, with energy values expressed in Kcal/100g. Values in the same column with different superscript letters are significantly different ($p < 0.05$).

No discernible distinction was observed between the sticks prepared from lemon-marinated common carp and those from vinegar-marinated common carp, which was corroborated by statistical analyses demonstrating no significant difference between the two formulations ($p > 0.05$).

The moisture content of the sticks has been reduced compared to that of fresh fish, likely attributed to the inclusion of preparation ingredients such as potato flakes and the effects of frying. This observation aligns with findings reported by Elyasi *et al.* (2010) (reduction from 76.65% to 66.1% for common carp sticks and from 83.76% to 70.08% for similar preparations), Aktaruzzaman *et al.*, (2022) (reduction from 77% to 56.23% for tilapia fish sticks), Tokur *et al.* (2006) (reduction from 70.23% to 68.5% for mirror carp sticks), and Cakli *et al.* (2005), who reported analogous outcomes. The moisture content observed in this study is notably lower than the values reported in the CIQUAL food composition table and also lower than those reported in many previous studies. This difference could potentially be attributed to the pre-cooking of fish meat and its subsequent use as crumbles in the preparation process. In contrast, other studies have typically utilized minced fish meat directly in formulation.

The ash content of the final product was slightly higher than that of fresh fish meat but remained significantly lower than the values reported in the CIQUAL table and those observed in previous studies. Elyasi *et al.* (2010) reported an increase from 1.82% to 4.47%, Aktaruzzaman *et al.*, (2022) from 2.25% to 2.93%, and Tokur *et al.* (2006) from 2.14% to 2.2%. These studies, conducted on various fish species, consistently observed a substantial increase in ash content following the addition of ingredients in the preparation process.

A marginal elevation in protein content, likely attributable to the dipping of the sticks in eggs, was observed. Comparable increases were reported by Aktaruzzaman *et al.*, (2022), ranging from 19.28% to 26.01%.

Aktaruzzaman *et al.*, (2022) reported an inverse relationship between moisture content and lipid content. Consistent with these findings, an increase in lipid content was observed in our study, concomitant with a decrease in moisture. This lipid increase is attributed to the absorption of frying oil by the sticks during the deep-frying process. Similar outcomes were documented by Elyasi *et al.* (2010) (increase from 1.98% to 4.01% and from 4.58% to 5.58%), Aktaruzzaman *et al.*, (2022) (increase from 2.74% to 7.62%), and İzci (2010) (increase from 4.63% to 10.51%) on the various formulations resulting from the processing of different fish species, which underwent frying.

In general, fish muscles typically contain low levels of carbohydrates. The elevated carbohydrate percentage observed in this study can be attributed to the inclusion of potato flakes at a 25% proportion in the formulation, along with coating materials such as flour and breadcrumbs. Comparable findings have been corroborated by Elyasi *et al.* (2010) (increase from 1.48% to 5.25%), Cakli *et al.* (2005) (from 7.49% to 14.8%), and Tokur *et al.* (2006) (from 7.76% to 15.05%). These values have been associated with the presence of coating materials, despite the exclusive use of minced fish in their formulations.

When comparing our findings of lipid, protein, and carbohydrate content with the data from the CIQUAL food composition table, our values significantly exceeded those reported in the table. Consequently, the energy value of our products is correspondingly higher.

The proportions of fatty acids (expressed as a percentage of the total fatty acids) for the sticks prepared with common carp flesh are detailed in Table 3.

The fatty acid compositions of the prepared sticks exhibited alterations compared to the flesh of the common carp utilized in their preparation. Notably, C16:0 within saturated fatty acids, C18:1 ω-9 within monounsaturated fatty acids, and C18:2 ω-6 within polyunsaturated fatty acids emerged as the predominant fatty acids.

A significant decrease ($p < 0.05$) was observed in fatty acids such as C16:0, C16:1, and C18:3 ω-6 in the sticks. However, a significant increase ($p < 0.05$) in the quantity of

Table 3. Fatty Acid Compositions (% of the Total Fatty Acids) of the sticks prepared using common carp flesh and comparison with results obtained from common carp flesh

Fatty acids	Common Carp Flesh	Lemon Sticks	Vinegary Sticks
	SFA		
C8:0	0.64 ± 0.00		
C12:0	0.27 ± 0.00[b]	0.117 ± 0.00[a]	0.37 ± 0.00[c]
C13:0	ND	0.388 ± 0.16	ND
C14:0	3.64 ± 0.00[b]	0.52 ± 0.00[a]	ND
C15:0	2.58 ± 2.18[b]	ND	0.85 ± 0.00[a]
C16:0	22.48 ± 4.23[b]	13.56 ± 0.55[a]	13.86 ± 0.18[a]
C17:0	5.02 ± 0.00	ND	ND
C18:0	5.38 ± 1.58[a]	5.66 ± 0.42[a]	5.41 ± 0.41[a]
C19:0	1.31 ± 1.44	ND	ND
C20:0	0.62 ± 0.00[b]	0.48 ± 0.00[a]	0.4 ± 0.00[a]
C22:0	0.44 ± 0.00[a]	0.55 ± 0.03[a]	0.54 ± 0.00[a]
C23:0	0.57 ± 0.00	ND	ND
C24:0	0.21 ± 0.00[a]	0.32 ± 0.08[a]	ND
	MUFA		
C16:1 ω-7	10.33±2.19[b]	0.6 ± 0.09[a]	ND
C18:1 ω-9	19.41±1.13[a]	28.35 ± 0.73[b]	30.76 ± 0.97[b]
C20:1 ω-9	0.55±0.00[b]	0.42 ± 0.00[a]	0.61 ± 0.00[c]
	PUFA		
C18 :2 ω-6	9.5±3.08[a]	48.26 ± 1.66[b]	48.75 ± 2.07[b]
C20 :2 ω-6	ND	0.15 ± 0.00	ND
C16 :3 ω-7	0.35±0.00	ND	ND
C18:3 ω-3	1.97±0.23[a]	0.63 ± 0.00[a]	ND
C22:3 ω-9	3.01±0.00	ND	ND
C20:4 ω-6	6.34±0.00	ND	ND
C20:5 ω-3 (EPA	0.78±0.00	ND	ND
C22:6 ω-3 (DHA	4.6±0.00	ND	ND
Σ SFA	43.16	21.59	20.49
Σ MUFA	30.29	29.37	30.76
Σ PUFA	26.55	49.04	48.75
Σ ω-3	7.35	0.63	0
Σ ω-6	15.84	48.41	48.75
EPA + DHA	5.38	0	0
Σ ω-3/ ω-6	0.46	0.01	0

Note: The results are presented as mean ± standard deviation (n=3), with significant differences denoted by dissimilar superscript letters on the same line ($p < 0.05$). SFA: Saturated fatty acids, MUFA: Monounsaturated fatty acids, PUFA: Polyunsaturated fatty acids, EPA: Eicosapentaenoic fatty acid, DHA: Docosahexaenoic fatty acid, ND: Not defined.

unsaturated fatty acids (C18:1 ω-9 and C18:2 ω-6) was evident. Certain polyunsaturated fatty acids, including C22:3 ω-9, C20:4 ω-6, C20:5 ω-3 (EPA), and C22:6 ω-3 (DHA), were entirely absent from the sticks. Our findings align with those reported by İzci (2010) for sticks prepared from Prussian carp.

The increased concentration of linoleic acid (18:2 ω-6) detected is probably a consequence of the frying method applied during the preparation of the sticks, leading to the uptake of frying oil. This proposition is substantiated by the research conducted by Tokur *et al.* (2006) on sticks derived from mirror carp flesh.

The disappearance of certain polyunsaturated fatty acids may be ascribed to their inherent susceptibility to oxidation, particularly in fish. Fish inherently possesses elevated levels of unsaturated fatty acids, thus expediting the oxidation process during marination and frying. Bilgin *et al.* (2011) similarly noted a reduction in these polyunsaturated fatty acids subsequent to marinating sand smelt in solution comprising vinegar and saltwater.

3.3 Sensory characterization of sticks

The results of the sensory analysis for the sticks prepared from common carp marinated in lemon water and vinegar water are depicted in Figure 2. Various attributes including shape, color, aroma, taste, texture, and overall acceptability have been evaluated and presented.

There was no significant difference observed between the two types of fish sticks in terms of all attributes, including overall acceptability. Both shape and color are regarded as crucial quality parameters influencing product acceptability among consumers (Idah & Nwankwo, 2013). The shape of the lemon sticks received a score of 7.97 ± 0.88, while the shape of the vinegar sticks was rated at 7.89 ± 0.93. The evaluators provided scores of 8.18 ± 0.95 and 8.10 ± 0.99 for the color of the lemon sticks and vinegar sticks, respectively. These scores indicate good acceptability among the panelists for both color and shape. The favorable color of the sticks may be attributed to the Maillard reaction.

Concerning aroma, the lemon-marinated sticks received an evaluation score of 7.73 ± 1.23, while vinegar sticks received a score of 7.78 ± 1.36. The judicious use of spices and condiments in the preparation may have contributed to achieving these high scores.

High scores were also obtained for the taste and texture of both lemon sticks and vinegar-marinated sticks, ranging from 7.68 ± 1.23 to 7.69 ± 1.37 and 7.39 ± 1.25 to 7.41 ± 1.37 for texture, respectively. This positive perception may be attributed to the coating process, which enhances the sensory quality of the processed products by improving

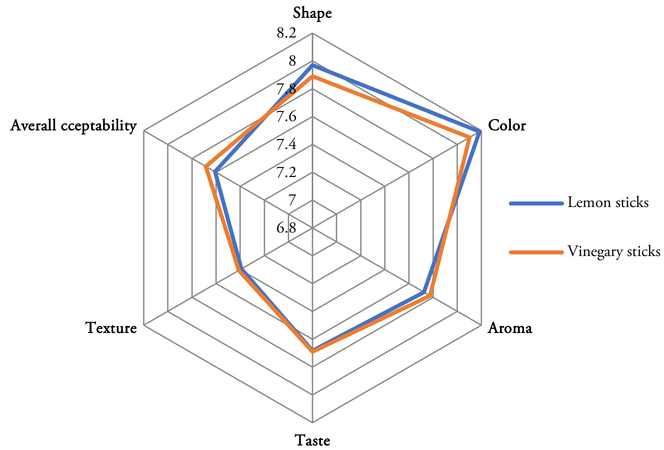

Figure 2. Sensory evaluation of sticks prepared from common carp marinated in lemon water and vinegar water

flavor, texture, and appearance, ultimately yielding a product that is moist on the inside and crispy on the outside (Khanipour *et al.*, 2014). Additionally, these favorable attributes may be due to the presence of lemon and vinegar, which effectively eliminate the off-flavors associated with common carp. Öz & Ucak (2023) similarly noted that lemon juice positively influenced the flavor of carp meat, with panelists highly appreciating the taste of the fish.

The sensory findings obtained in this study were consistent with those documented by Tokur *et al.* (2006), Öz & Ucak (2023), and other previously reviewed studies. Regarding overall acceptability, the lemon-marinated sticks achieved a score of 7.61 ± 0.99, and the vinegar-marinated sticks received a score of 7.68 ± 1.14, indicating their high quality and consumer appeal. The sensory evaluation results from this study suggest that the incorporation of lemon and vinegar, along with other ingredients, the specific processing method of carp meat, the coating process, and the cooking technique, all contribute effectively to eliminating the muddy odor and taste from common carp flesh, resulting in a delicious and high-quality value-added product.

4 CONCLUSIONS

The two formulations of common carp fish sticks demonstrated notable nutritional value. No significant differences were observed in either the proximate nutritional composition or the sensory attributes (including aroma, taste, color, texture, and overall acceptability) between the vinegar-marinated and lemon-marinated fish sticks. However, a distinct antimicrobial effect of lemon was identified, as evidenced by a reduction in the microbial load of the lemon-treated fish sticks.

Based on these results, it is evident that freshwater fish, particularly common carp, can achieve high consumer acceptability when incorporated into the human diet in this processed and palatable form. This successful valorization of common carp holds significant potential to positively impact the economy and enhance food security within Algeria.

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