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Chemical properties indices for nutritional quality evaluation of Nasser Lake fish, Aswan, Egypt

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Abstract

Background: Fish is considered an important food because it includes main nutrients (proteins, fats, and ash) and micronutrients (vitamins and minerals). The assessment of fish nutritional content data may offer crucial recommendations regarding freshwater fish consumption and preserving human well-being.

Aim: Evaluate the safety and quality properties of Nasser Lake fish, Aswan, Egypt.

Methods: A total of 250 samples, 50 of each Nile tilapia, Nile perch, Zander, Catfish, and Elephant-snout, from Nasser Lake, Aswan, Egypt; beheaded, eviscerated, filleted, and minced for determination of proximate analysis, amino acid, fatty acids (FAs), minerals and heavy metal, histamine content, cholesterol content, and sensory assessment.

Results: The proximate analysis showed that all the samples examined were of good protein sources, with mean values ranging from 15.92% to 22.89%. Nile perch exhibits the highest levels of total FAs and amino acids. Heavy metal concentrations varied considerably among the analyzed samples, with a significant variance in the detection of metals among the examined fish. The findings show low histamine and cholesterol levels in the examined species, and were in accordance with those set by the National Food Safety Authority (NFSA) and the European Union Commission (EC). Accordingly, all samples are accepted based on their sensory properties.

Conclusion: Nasser Lake fish are of high nutritional value and have an excellent supply of amino and FAs.

Keywords: Freshwater fish, Quality, Histamine, Proximate analysis, Nasser Lake.

Introduction

Fish play an important role in human nutrition, being a source of biologically valuable proteins, fats, and fat-soluble vitamins (Łuczyńska *et al.,* 2023). Fish is a high-nutrient diet that helps people maintain a healthy diet. It is also regarded as an excellent source of readily digested protein, high in fats, macro- and trace elements, essential amino acids, and fat-soluble vitamins. Furthermore, fish contains a lot of valuable long-chain polyunsaturated omega-3 fatty acids (FAs), diminishing illness risks and improving human health (El-Sherbiny and Sallam, 2021). Fish is one of the best sources of protein and the consumption of fish provides polyunsaturated FAs (PUFA), liposoluble vitamins, and essential minerals for human health. It is also a desirable component of the diet due to its high nutritional value and sensory value (Solgi and Beigzadeh-Shahraki, 2019).

The texture of the flesh and the composition of fat and protein are usually among the major factors determining consumer acceptance. The lipid content and composition are also particularly important in terms of both taste and nutritional value (Łuczyńska *et al.,* 2023). The quality of fish has a substantial effect on human fitness, consumer acceptance, and global fishery trade. Globally, food safety is increasingly recognized as a crucial issue of the utmost importance; in research and development, assessing the freshness of fish has become increasingly critical (Qu *et al.,* 2015).

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As freshness is closely related to quality, ensuring it is one of the most important aims of the fish sector. Fish quality encompasses elements significant to the consumer, including nutritional value, availability and integrity, freshness, palatability, and the species' conspicuous physical characteristics, variety, and size (Abbas *et al.,* 2008). Nevertheless, chemicals, heavy metals, pollutants, and pathogenic microorganisms constitute the primary concern regarding freshwater fish consumption. In Egypt, fish are captured and gathered from aquacultures and natural sources dispersed throughout the country. However, multiple studies have been undertaken on many freshwater fish species from Egyptian aquacultures; there needs to be more data on the safety and quality of freshwater fish from other sources, such as Nasser Lake, which is an essential source for Egypt's national fisheries. The common fish types that are eaten extensively in Egypt are Nile tilapia (*Oreochromis niloticus*), Nile perch (*Lates niloticus*), Zander (*Sander lucioperca*), African catfish (*Clarias gariepinus*), and Elephant-snout (*Mormyrus kannume*). These fish are typically caught from Nasser Lake in South Egypt. Due to the scarcity of information regarding the contaminants present in these fish and their threats to the health of the general public, this investigation aimed to evaluate the safety and quality of Nasser Lake fish, Aswan, Egypt.

Material and Methods

Study area and sampling

Lake Nasser is the largest artificial lake in the world. It runs for more than 350 km inside Egyptian borders at 180 m altitude at the southern border of Aswan, Egypt (Fig. 1). It has served as the nation's primary source of fresh water since the Aswan High Dam was finished in the 1960s and is a significant fishery for Egypt (Elghazali *et al.,* 2023). Two hundred and fifty fresh fish samples (190–220 g each) include 50 of each Nile tilapia (*Oreochromis niloticus*), Nile perch (*Lates niloticus*), Zander (*Sander lucioperca*), Catfish (*Clarias gariepinus*), and Elephant-snout (*Mormyrus kannume*) collected from Nasser Lake in Aswan, Egypt, during January and March 2023. Cleaning, eviscerating, filleting, and deboning were carried out on the samples. The muscle tissues were packed individually into impermeable polyethylene bags, labeled, kept at 4°C in an ice box, and sent to the laboratory.

Proximate analysis

After the techniques of the Association of Official Analytical Chemists (AOAC, 2016), a proximate composition study was performed at the Food Science and Technology Department, Faculty of Agriculture and Natural Resources, Aswan University, to determine moisture, crude protein, crude fat, and ash. Briefly, samples were dehydrated in an oven at 65°C for 24 hours and then at 105°C for 6 hours until they reached constant weight. Crude protein was calculated using the Macro–Kjeldal method, which involved adding 25 ml of concentrated sulfuric acid and 8 g of a catalyst mixture containing 96% anhydrous sodium sulfate, 3.5% copper sulfate, and 0.5% selenium dioxide to 0.5 g of the dehydrated sample in a Kjeldal digestion flask. After being cooled and digested, the precise mixture was moved to the distillation flask and dissolved in

Fig. 1. Geographical presentation of the study area.

200 ml of tap water. 75 ml of 50% sodium hydroxide (NaOH) was incorporated into the distillation flask. The liquid was titrated up to the endpoint (faint blue or colorless) using N/10 sodium hydroxide solution. Petroleum ether was used in a Soxhlet extraction device to quantify crude lipids. The mass was burned after the furnace reached the necessary temperature, and the amount of ash was inspected by dry ashing in a muffle furnace for 6 hours at 550°C–600°C (white ash was generated). The amount that remained after deducting the sample's moisture, crude protein, fat, and ash from 100 g on a wet weight basis was used to indicate the total amount of carbohydrates. Using the Merrill and Watt (1973) equation, the energy value was computed as follows:

Gross energy value (kcal/100g) = (Protein% x 4) + (Fat% x 9) + (Carbohydrate% x 4).

Amino acid determination

Using the methodology outlined by AOAC (2012), the amino acid content of fish flesh was examined in the Food Quality Laboratory, Animal Health Research Institute, Agricultural Research Centre, Egypt. Fish flesh was digested in 6N HCl for 24 hours. 1.0 g of the sample was mixed with 5 ml H2O and 5 ml of HCl (Note: final concn. of HCl is 6 M) and then heated at 100°C for 24 hours and then filtered. Finally, 1 ml of the filtrate was injected to HPLC. The amino acids formed during acid hydrolysis reacted with phenylisothiocyanate before being separated using reverse-phase HPLC (Shimadzu). Column: Phenomenex, Luna C18, 5 micron, 250 9 4.6 mm. U.V. detector at 254 nm. The quantification occurred through multilevel internal calibration using the alpha aminobutyric acid (AABA) as an internal standard. Tryptophan could not be detected after acid hydrolysis and was not estimated in this study. The results were recorded in mg/g of dried-weight muscle.

FAs determination

Fish flesh FAs were measured at Egypt's Food Quality Laboratory, Animal Health Research Institute, and Agricultural Research Centre. Bligh and Dyer (1959) technique extracted lipids from the muscle tissues. For the FA analysis, the lipids underwent saponification and esterification via Christie (2010) technique. A gas chromatography system (Hewlett Packard 6890) fitted with a flame ionization detector (FID) was used to separate the methyl esters of FAs. Peaks were identified by comparing the obtained retention durations to a reference methyl ester (HPLC Analysis of FA Methyl Esters (FAMES) on SUPELCOSIL™ LC-18). The electronic integrator was used to measure the areas under the chromatographic peak.

Minerals and heavy metals determination

Two grams of the homogenate muscle were placed into 20 ml screw-capped tubes that had been cleaned and previously filled with a solution of 70% concentrated perchloric acid (4 ml) and 65% concentrated nitric acid (8 ml), sealed and immersed in a water bath at 53°C/12 hours to complete the digestion process, chilled to ambient temperature, diluted with deionized water and filtered into a sterile beaker through Whatman filter paper to a level of 50 ml. The diluted filtrate was transferred to clean, labeled screw-capped bottles and kept at ambient temperature until analysis. A blank digest was achieved without samples, and any residuals were removed from the outcome for analysis. The mineral and heavy metal remnants were examined using a "Buck Scientific USA 210 VGP Atomic Absorption Spectrophotometer with an oxidizing air acetylene flame" (Norwalk, CT) at the Animal Health Research Institute, Agricultural Research Center, Egypt. The mineral and heavy metal remains of all filters were inspected. For Hg, Pb, Cd, Cu, Fe, Zn, Mn, and As, the apparatus can perform at wavelengths of 253.7, 283.3, 228.8, 324.8, 248.3, 213.9, 279.5, and 193.6 nm, respectively (Pietrzak-Fie´cko *et al.,* 2022).

Histamine content determination

The quantification of histamine was conducted at the National Research Centre in Giza, Egypt, utilizing HPLC with a diode detector (Varian ProStar 330, The Netherlands), per a previously described accredited and validated procedure (Pawul-Gruba and Osek, 2021). In summary, trichloroacetic acid was employed to extract histamine from the samples, which was subsequently purified by Strata-X-AW ion-exchange SPE cartridges (Phenomenex, Torrance, CA). Chromatographic separation was done on a C18 column (Agela Technologies, Torrance, CA) with a detection wavelength of $\lambda = 215$ nm. The discovery limit was 2.1 mg/kg, the quantification limit was 3.3 mg/kg, and the range of the technique was 3.3–420 mg/kg.

Cholesterol content determination

Based on a previously published method (Azlan *et al.,* 2015), cholesterol was isolated from the lipid fraction at the National Research Centre in Giza, Egypt. In a screw-top assay tube, 0.40 g of sample was weighed with 200 ml of pyrocatechol solution as an antioxidant. After adding 5 ml of a 0.5 M KOH solution in methanol, the sample was vortexed for 20 seconds. The tubes were immersed in an 80°C water bath for 15 minutes, withdrawn every 5 minutes, and vortexed for 15 seconds. After being refrigerated in cold water, the tube was filled with 1 ml of distilled water and 5 ml of hexane. It was centrifuged for 2 minutes after quickly vortexing the mixture for one min at 425 × g. 3 ml of the upper phase was moved to a different test tube and nitrogen-dried. 3 ml of the HPLC mobile phase solution (methanol: acetonitrile: water (68: 28: 4, v/v/v) was used to dissolve the semi-solid residue (extract) once more, and the mixture was then membrane filtered (pore size 0.50 µm; Whatman, Clifton, NJ). Subsequently, a 20-l aliquot of the extract was introduced into an Agilent 1100 series HPLC system manufactured by Agilent, USA. After that, the extracts were stored at −20°C for HPLC analysis. An analytical scale (25 cm, 0.4 cm ID.), A C18 column with a particle size of 5 m (Agilent, USA) were used

for chromatographic analysis. The following were the HPLC conditions: methanol: acetonitrile: water (68: 28: 4, v/v/v), 1.4 ml/minutes flow rate, and 36°C column temperature make up the mobile phase. A diode-array detector operating at 208 nm was used for the detection process. The presence of cholesterol in the samples was determined through an assessment of the retention durations of the samples and the standards using the spiking test. The concentrations of the compounds were determined through quantification using the obtained standard calibration curves, with the results as mg/100 g of the wet sample.

Sensory assessment

Thirteen members of the Aswan University Faculty of Veterinary Medicine, Food Hygiene Department were shown the fresh samples in their entirety after they had been cleaned with potable water. They requested to evaluate the appearance, color, odor, consistency, and overall acceptability using a 9-point hedonic scale that went from dislike extremely (1) to like highly (9), and a score of <4 indicated spoiled samples (Svensson, 2012).

Statistical analysis

The results obtained were presented as the means of the measurements and standard error (SE). Significant differences were estimated using a one-way analysis of variance (ANOVA). Differences were reported as statistically significant at $p < 0.05$.

Ethical approval

Not required for this study.

Results

Table 1 reveals the mean of proximate analysis of the examined fish samples in Nile tilapia, Nile perch, Zander, Catfish, and Elephant-snout were 71.61 ± 0.68, 68.63 ± 0.43, 69.15 ± 0.62, 72.63 ± 0.51, and 73.13 ± 0.72, respectively, for moisture%, 19.61 ± 0. 18, 22.89 ± 0.23, 21.03 ± 0.18, 18.29 ± 0.15, and 15.92 ± 0.17, respectively, for protein%, 2.58 ± 0.22, 3.47 ± 0.41, 2.1 ± 0.33, 4.18 ± 0.27, and 2.79 ± 0.51, respectively, for fat%, 1.77 ± 0.07, 1.21 ± 0.3, 1.61 ± 0.06, 1.14 ± 0.11, and 2.85 ± 0.04, respectively, for ash%, 0.23 ± 0.02, 0.39 ± 01, 0.11 ± 0.01, 0.76 ± 0.01, and 1.35 ± 0.02, respectively, for carbohydrates % and 102.58 ± 0.24, 124.35 ± 0.78, 105.04 ± 0.8, 113.82 ± 1.04, and 94.19 ± 1.65, respectively, for gross energy (kcal/100 gm). There were no significant differences in all examined samples except for Nile perch in moisture and Elephant-snout in ash contents.

Table 2 shows the amino acids composition (mg/g dry weight) of Nile tilapia, Nile perch, Zander, Catfish, and Elephant-snout were 61.97, 86.06, 38.301, 28.79, and 17.83 mg/g, respectively, for essential amino acids and 87.8, 124.31, 51.44, 43.44, and 30.09 mg/g, respectively for non-essential amino acid with significant differences between the examined samples at $p \leq 0.05$. Furthermore, Table 3 reveals that the Catfish and Zander presented the highest content of saturated FAs (SFAs) (32.60 ± 1.23 and 29.94 ± 1.28 mg/g). Monounsaturated FAs (MUFAs) and PUFAs recorded 34.38 ± 1.55 and 20.75 ± 2.73 in Nile tilapia, 34.91 ± 1.93 and 32.45 ± 1.67 in Nile perch, 32.24 ± 1.46 and 27.68 ± 2.69 in Zander, 32.87 ± 2.31 and 19.76 ± 1.35, and 18.14 ± 1.58 in Catfish and 11.26 ± 1.43 in Elephant-snout with significant differences between the examined samples at $p \leq 0.05$.

Heavy metal concentrations "µg/g" in the fish species examined shows in Table 4 in which Hg, Pb, Cd, Cu, Zn, Fe, and Mn were detected in most tested samples in quantities of 0.023, 0.016, 0.014, 0.035, and 0 µg/g for Hg,0.002, 0,0, 0.003, and 0 µg/g for Pb, 0.027, 0.013, 0.018, 0.018, and 0.031 µg/g for Cd, 1.25, 0.56, 0.54, 0.53, and 0.51 µg/g for Cu, 13.1, 6, 5.53, 7.2, and 6.5 µg/g for Fe, 4.76, 5.56, 4.15, 5.64, and 1.34 µg/g for Zn and 4.3, 2.59, 2.13, 6.5, and 1.53 µg/g for Mn in Nile tilapia, Nile perch, Zander, Catfish, and Elephant-snout, respectively. Meanwhile, arsine failed to be detected in all examined samples. ANOVA indicated a significant difference ($p \leq 0.05$) between heavy metals concentrations among the fish species analyzed. At the same time, their acceptance according to the National Food Safety Authority (NFSA) (6/2022) in the different fish species examined is shown in Table 5.

Table 6 reveals the mean value of the sensory evaluations of the examined samples which ranged from 8.33 ± 0.36 in Nile tilapia, 8.28 ± 0.4 in Nile perch, 10.2 ± 0.35 in Zander, 9.4 ± 0.16 in catfish, and 9.73 ± 0.23 in

Table 1. Proximate analysis of the examined fish samples (n = 50 each).

Fish spp.	Moisture%	Protein%	Fat%	Ash%	Carbohydrates%	Gross energy kcal/100 gm
Nile tilapia	71.61 ± 0.68^{a}	19.61 ± 0.18^{b}	2.58 ± 0.22^{c}	1.77 ± 0.07^{b}	0.23 ± 0.02^{a}	102.58 ± 0.24^{b}
Nile perch	68.63 ± 0.43^{b}	22.89 ± 0.23^{a}	3.47 ± 0.41^{b}	1.14 ± 0.30^{b}	0.39 ± 0.01^{a}	124.35 ± 0.78^{a}
Zander	69.15 ± 0.62^{a}	21.03 ± 0.18^{a}	2.16 ± 0.33^{c}	1.61 ± 0.06^{b}	0.37 ± 0.01^{a}	105.04 ± 0.82^{b}
Catfish	72.63 ± 0.51^{a}	18.29 ± 0.15^{b}	4.18 ± 0.27^{a}	1.24 ± 0.11^{b}	0.76 ± 0.01^{a}	113.82 ± 1.04^{a}
Elephant-snout	73.13 ± 0.72^{a}	15.92 ± 0.17^{c}	2.79 ± 0.51^{c}	2.85 ± 0.04^{a}	1.35 ± 0.02^{a}	94.19 ± 1.65^{c}

$^{a-c}$Means with different superscripts within the same column significantly ($p \leq 0.05$) different. Values represent the mean of 3 independent replicates ± SE.

Table 2. Amino acids composition of the examined fish samples (mg/g dry weight).

Amino acids	Fish spp.				
	Nile tilapia	Nile perch	Zander	Catfish	Elephant-snout
Essential amino acids	61.97 ± 2.15[a]	86.06 ± 2.82[a]	41.30 ± 1.37[b]	28.79 ± 1.65[b]	17.83 ± 1.22[c]
Lysine	3.87 ± 0.38[b]	10.20 ± 2.45[a]	8.44 ± 1.42[a]	6.79 ± 2.06[a]	2.84 ± 0.01[b]
Histidine	5.55 ± 1.03[a]	7.78 ± 2.09[a]	5.48 ± 0.35[a]	1.62 ± 0.04[b]	1.51 ± 0.01[b]
Leucine	16.89 ± 1.33[a]	20.91 ± 1.12[a]	7.53 ± 1.72[b]	5.68 ± 1.74[b]	3.67 ± 1.27[c]
Isoleucine	3.11 ± 0.68[a]	3.97 ± 0.84[a]	4.36 ± 1.25[a]	3.72 ± 1.83[a]	2.51 ± 0.02[a]
Valine	2.83 ± 0.33[a]	3.23 ± 0.49[a]	4.831 ± 1.15[a]	3.07 ± 1.04[a]	2.67 ± 0.02[a]
Methionine	9.99 ± 2.09[b]	14.14 ± 2.66[a]	3.27 ± 1.27[c]	2.64 ± 0.02[c]	1.66 ± 0.01[c]
Phenylalanine	17.30 ± 3.19[b]	21.84 ± 1.09[a]	3.78 ± 0.49[c]	2.73 ± 0.01[c]	1.39 ± 0.02[c]
Threonine	2.43 ± 0.27[b]	3.99 ± .67[a]	3.61 ± 1.26[a]	2.54 ± 0.06[b]	1.58 ± 0.01[c]
Non-essential amino acid	87.80 ± 2.63[b]	124.31 ± 4.28[a]	51.44 ± 2.74[c]	43.44 ± 1.66[c]	30.09 ± 1.23[c]
Glycine	7.99 ± 0.92[b]	11.73 ± 0.93[a]	6.73 ± 2.13[b]	4.83 ± 1.77[c]	3.42 ± 0.74[c]
Alanine	4.54 ± 0.78[b]	10.84 ± 1.67[a]	5.62 ± 1.73[b]	4.71 ± 2.15[b]	3.28 ± 1.04[b]
Arginine	5.93 ± 0.26[b]	7.62 ± .46[a]	6.58 ± 1.42[a]	5.63 ± 1.48[b]	4.43 ± 1.32[b]
Cysteine	ND	ND	1.06 ± 0.02[a]	0.88 ± 0.01[b]	0.21 ± 0.01[b]
Serine	4.01 ± 0.57[a]	4.54 ± 0.89[a]	3.82 ± 1.25[a]	2.54 ± 0.01[a]	1.53 ± 0.01[b]
Proline	2.98 ± 0.38[b]	9.30 ± 0.25[a]	3.51 ± 1.18[b]	3.69 ± 1.08[b]	2.48 ± 0.01[b]
Tyrosine	6.01 ± 1.30[a]	6.59 ± 0.92[a]	2.26 ± 0.07[b]	2.19 ± 0.06[b]	1.81 ± 0.01[b]
Aspartic acid	9.01 ± 0.98[a]	10.55 ± 2.33[a]	8.48 ± 2.17[a]	6.87 ± 2.05[b]	4.61 ± 1.23[c]
Glutamic acid	12.66 ± 1.20[b]	16.08 ± 1.22[a]	13.38 ± 2.85[b]	12.10 ± 2.84[b]	8.32 ± 2.63[c]

[a–c]Means with different superscripts within the same row significantly ($p \leq 0.05$) different. Values represent the mean of 3 independent replicates ± SE.

Elephant-snout. Accordingly, all samples are accepted based on their sensory properties.

The results recorded in Figure 2 show the mean of histamine levels "ppm" in the examined fish samples in Nile tilapia, Nile perch, Zander, Catfish, and Elephant-snout were 48.9 ± 2.3, 23.6 ± 1.8, 80 ± 3.8, 30.7 ± 1.3, and 47.3 ± 3.1, respectively, with statistically significant differences between examines species ($p \leq 0.05$). Furthermore, all samples accepted according to NFSA (1/2022) < 200 ppm.

The mean values of cholesterol content (mg/100 g) of fish samples varied between samples as shown in Figure 3, with statistically significant differences between examined species ($p \leq 0.05$). Nile perch had the highest cholesterol content (72.6 ± 1.7), followed by Zander (57.5 ± 1.6), Nile tilapia (54.3 ± 1.6), and Catfish (48.2 ± 1.4), while Elephant-snout had the lowest cholesterol content (29.7 ± 1.07).

Discussion

Fish and fishery products are essential dietary sources for the global population due to their superior quality and proximity to composition. Fish is regarded as a superior source of fat, a well-balanced diet, and easily digestible protein; it is of considerable importance in human nourishment and its bioactive ingredients. It is critical to know the approximate composition of fish to calculate their energy value relative to commercial products (Krishna *et al.,* 2023). Table 1 displays the approximate average composition of the fish under examination, given in g/100 g of edible portion. The findings show that the Nile perch samples had the lowest moisture content (68.63% ± 0.43%) and ash content (1.14% ± 0.3%), while the highest protein content (22.89% ± 0.23%) and gross energy calories (124.35 ± 0.78 kcal/100 g) were discovered. Additionally, the samples with Elephant noses had the lowest proximal composition. Except for the Nile perch's moisture level and the Elephant nose's ash content, none of the examined samples differed significantly. Moreover, the fish under inspection had noticeably increased protein and fat concentrations. The results obtained were higher than those of Geremew *et al.* (2020) and lower than those of Shi *et al.* (2019) and Elghazali *et al.* (2023), but they matched the results of other studies (Mahboob *et al.,* 2019;). All fish species under investigation had protein contents exceeding 15.92% in this study, indicating that they were a good source of protein (Geremew *et al.,* 2020). Nile perch and catfish have higher gross energy values than the other fish

Table 3. Fatty acids content of the examined fish samples (mg/g).

Fatty acids	Carbon chain	Fish spp.				
		Nile tilapia	Nile perch	Zander	Catfish	Elephant-snout
Total fatty acids		87.73 ± 3.74[a]	90.15 ± 3.58[a]	89.86 ± 2.66[a]	80.19 ± 2.72[a]	39.26 ± 2.82[b]
Saturated FAs		32.60 ± 1.23[a]	22.79 ± 1.42[b]	29.94 ± 1.28[b]	27.14 ± 1.33[b]	9.86 ± 1.25[c]
Lauric acid	C12:0	0.37 ± 0.01[b]	0.60 ± .09[a]	0.38 ± 0.01[b]	0.42 ± 0.02[b]	0.22 ± 0.01[b]
Myristic acid	C14:0	4.00 ± 0.90[a]	2.98 ± 0.45[a]	3.37 ± 0.01[b]	2.15 ± 0.18[b]	1.13 ± 0.04[c]
Pentadecanoic acid	C15:0	3.66 ± 0.27[a]	ND	1.52 ± 0.01[b]	0.82 ± 0.07[b]	ND
Palmitic acid	C16:0	13.66 ± 0.27[b]	12.65 ± 3.20[a]	14.42 ± 2.04[b]	16.51 ± 2.30[a]	5.21 ± 1.47[c]
Heptadecanoic acid	C17:0	ND	ND	0.74 ± 0.01	ND	ND
Stearic acid	C18:0	4.01 ± 0.87[a]	2.54 ± 0.73[b]	3.32 ± 0.16[a]	2.16 ± 0.02[b]	2.16 ± 0.02[b]
Arachidic acid	C20:0	2.49 ± 0.12[a]	1.92 ± .23[b]	2.52 ± 0.71[a]	2.85 ± 0.63[a]	0.78 ± 0.06[c]
Behenic acid	C22:0	1.76 ± 0.09[a]	0.71 ± .04[b]	2.05 ± 0.01[a]	1.03 ± 0.01[a]	ND
Lignocereic acid	C24:0	2.65 ± 0.03[b]	1.39 ± .73[a]	1.62 ± 0.15[a]	1.2 ± 0.05[a]	0.36 ± 0.01[b]
Unsaturated fatty acids		55.13 ± 2.43[a]	67.36 ± 1.84[a]	59.92 ± 1.66[a]	52.63 ± 1.87[a]	29.40 ± 1.75[b]
MUFAs		34.38 ± 1.55[a]	34.91 ± 1.93[a]	32.24 ± 1.46[a]	32.87 ± 2.31[a]	18.14 ± 1.58[b]
Tridecanoic acid	C13:1	4.79 ± 0.95[b]	7.99 ± 0.11[a]	3.64 ± 1.26[c]	4.57 ± 0.53[b]	2.46 ± 0.41[c]
Myristoleic acid	C14:1	2.98 ± 0.23[a]	1.23 ± 0.88[b]	2.25 ± 1.31[a]	3.63 ± 1.02[a]	1.62 ± 0.01[b]
Cis-10-Pentadecenoic	C15:1	ND	ND	1.44 ± 0.05	ND	ND
Palmitoleic acid	C16:1	8.54 ± 2.34[a]	3.73 ± 0.97[b]	2.49 ± 0.76[b]	4.22 ± 1.06[b]	2.36 ± 1.14[b]
Palmitoleic acid	C16:1, ω7	3.81 ± 0.34[b]	6.21 ± .23[a]	2.87 ± 0.38[b]	3.66 ± 1.12[b]	1.53 ± 0.02[c]
Cis-10-Heptadecanoic acid	C17:1	ND	ND	0.63 ± 0.01	ND	ND
Oleic acid	C18:1ω9c	4.37 ± 0.98[b]	7.93 ± .98[a]	4.87 ± 1.54[b]	3.76 ± 1.05[b]	2.76 ± 1.05[b]
Oleic acid	C18:1ω9t	9.89 ± 2.73[b]	7.33 ± 1.23[c]	13.42 ± 2.72[a]	13.03 ± 3.32[a]	7.41 ± 1.63[c]
Gadoleic acid	C20:1	ND	0.49 ± 0.10[a]	0.63 ± 0.01[b]	ND	ND
PUFAs		20.75 ± 2.73[b]	32.45 ± 1.67[a]	27.68 ± 2.69[a]	19.76 ± 1.35[b]	11.26 ± 1.43[c]
Myristolinoleic	C14:2	1.83 ± 0.10[b]	8.87 ± 1.22[a]	1.47 ± 0.05[b]	1.66 ± 0.04[b]	0.62 ± 0.01[c]
Linoleic acid	C18:2ω6c	4.90 ± 1.63[b]	6.23 ± 0.84[a]	5.47 ± 2.65[b]	5.15 ± 2.36[b]	3.62 ± 1.22[b]
Linoleic acid	C18:2ω6t	3.87 ± .37[a]	2.11 ± 0.25[b]	4.17 ± 1.73[a]	3.62 ± 1.72[a]	2.81 ± 1.32[b]
α- Linolenic acid	C18:3ω3	2.77 ± 0.94[b]	4.42 ± 0.82[b]	4.72 ± 1.22[a]	2.22 ± 1.32[b]	ND
Arachidonic acid	C20:4	0.88 ± 0.05[b]	0.54 ± .02[b]	2.47 ± 0.77[a]	1.26 ± 0.01[a]	0.63 ± 0.01[b]
Eicosapentaenoic acid (EPA)	C20:5ω3	1.93 ± 0.87[a]	3.63 ± 0.26[a]	2.02 ± 0.16[a]	0.47 ± 0.01[b]	0.26 ± 0.01[b]
Docosahexaenoic acid(DHA)	C22:6ω3	4.57 ± 0.12[b]	6.65 ± 0.99[b]	7.36 ± 1.87[a]	5.38 ± 2.47[b]	3.32 ± 1.06[b]

[a–c]Means with different superscripts within the same row significantly ($p \leq 0.05$) different. Values represent the mean of 3 independent replicates ± SE. ND = Not detected.

species. This is because their fat content was noticeably higher than the others. There were notable alterations in proximate composition among the fish species under investigation. This might be brought on by their ability to consume or absorb food, convert certain nutrients from their meals or the environment around them,

Table 4. Mineral and heavy metals concentrations "µg/g" in the muscle of the different fish species examined (n = 50 of each).

Fish spp.	Hg	Pb	Cd	Cu	Fe	Zn	Mn	As
Nile tilapia	0.023 ± 0.002[a]	0.003 ± 0.001[a]	0.027 ± 0.001[a]	1.25 ± 0.02[a]	13.10 ± 1.02[a]	4.76 ± 1.02[a]	4.30 ± 0.48[b]	ND
Nile perch	0.016 ± 0.001[b]	ND	0.013 ± 0.003[b]	0.56 ± 0.003[b]	6.00 ± 0.51[c]	5.56 ± 0.82[a]	2.59 ± 0.30[c]	ND
Zander	0.014 ± 0.001[c]	ND	0.018 ± 0.002[b]	0.54 ± 0.001[b]	5.53 ± 1.01[c]	4.15 ± 0.62[a]	2.13 ± 0.71[c]	ND
Catfish	0.035 ± 0.002[c]	0.002 ± .001[a]	0.018 ± .001[b]	0.53 ± 0.002[b]	7.20 ± 1.20[b]	5.64 ± 1.02[a]	6.50 ± 1.04[a]	ND
Elephant-snout	ND	ND	0.031 ± 0.002[c]	0.51 ± 0.002[b]	6.50 ± 1.03[c]	1.34 ± 0.02[b]	1.53 ± 0.04[c]	ND

Mean ±SE bearing different superscript letters in the same column for each species are not significantly different (P≥0.05). ND: not detected.

Table 5. Comparison of mineral and heavy metal concentrations in fish muscles (µg/g wet weight) with maximum permissible limit (MPL).

Metals	MPL (µg/g)	Fish species									
		Nile tilapia		Nile perch		Zander		Catfish		Elephant-snout	
		Within MPL (%)	Above MPL (%)	Within MPL (%)	Above MPL (%)	Within MPL (%)	Above MPL (%)	Within MPL (%)	Above MPL (%)	Within MPL (%)	Above MPL (%)
Hg	0.5[a]	94	6	90	10	100	0	84	16	100	0
Pb	0.3[a]	76	24	100	0	100	0	66	34	100	0
Cd	0.05[a]	92	8	88	12	94	6	90	10	96	4
Cu	20[b]	94	6	92	8	94	6	90	10	96	4
Fe	30[b]	94	6	96	4	96	4	92	8	94	6
Zn	40[b]	100	0	100	0	100	0	96	4	100	0
Mn	2.00-9.00[b]	96	4	92	8	97	3	90	10	96	4
As	2[c]	100	0	100	0	100	0	100	0	100	0

(a): Egyptian Standards (2010); (b): FAO/WHO, (1999); (c): Food Standards Australia New Zealand (FSANZ) (2011).

Table 6. Sensory evaluations of the examined samples (n=40 each).

Sample	Sensory score*												Mean±SE
	4		5		6		7		8		9		
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	
Nile tilapia	-	-	-	-	7	14	12	24	23	46	8	16	9.23[a]±0.36
Nile perch	-	-	-	-	-	-	10	20	24	48	16	32	9.72[a]±0.35
Zander	-	-	-	-	3	6	9	18	27	54	11	22	8.48[a]±0.40
Catfish	-	-	7	14	11	22	15	30	12	24	5	10	8.20[a]±0.16
Elephant-snout	-	-	5	10	5	10	15	30	19	38	6	12	8.13[a]±0.23

*9 points hedonic scale was used for sensory evaluation where 4= Dislike slightly, 5= Neither like nor dislike, 6= Like slightly, 7= Like moderately, 8= Like very much, and 9= Like extremely. P>0.05 considered not significant by using One-way ANOVA.

the time of year they fish, their age and sex, or their reproductive status (Krishna *et al.,* 2023).

Dietary protein serves a crucial role in delivering amino acids for the biosynthesis of body proteins. Giving all essential amino acids to humans in sufficient quantities is critical for ideal protein synthesis. Fish proteins are rich in all of the essential amino acids required for a proper human diet, thereby enhancing the protein content of a food (Elshehawy *et al.,* 2016). Table 2 presents the quantified amino acids found in the fish. They were distributed in essential amino acids (lysine, histidine, leucine, isoleucine, valine, methionine, phenylalanine, and threonine) and non-essential amino acids (glycine, alanine, arginine, cysteine, serine, proline, tyrosine, aspartic acid, and glutamic acid). The results revealed the main level of essential and

nonessential amino acids (total) for Nile perch (86.06 and 124.31 mg/g) followed by Nile tilapia (61.97 and 87.8 mg/g), Zander (41.30 and 51.44 mg/g), and catfish (28.79 and 43.44 mg/g), while Elephant-snout (17.83 and 30.09 mg/g) had the lowest level, respectively, with a significant variances among the examined samples at $p \leq 0.05$. Among the essential amino acids, it was greater concentrations of leucine, phenylalanine, and lysine, while glutamic acid, aspartic acid, and alanine were among the nonessential amino acids in all inspected species. The values presented above indicate that significant variations in amino acid concentrations can be detected among various fish species and even within the same species. Such discrepancies could be caused by multiple reasons, including differences in eating, season, species, sex, maturation stage, nutritional and environmental conditions, and amino acid testing methodologies (Doğan and Ertan, 2017; Agr *et al.,* 2019).

The present study and the most recent research (Pyz-Łukasik and Paszkiewicz*,* 2018; Gauthankar *et al.,* 2021; Elghazali *et al.,* 2023) reported that the examined fish contained a substantially elevated concentration of total amino acids. The authors reaffirmed the critical function that fish can serve as a protein source in human nourishment, thereby validating the necessity to produce and record nutritious data on the diverse array of edible fish species that are accessible globally (Pyz-Łukasik and Paszkiewicz, 2018). Moreover, low findings were recorded by Elshehawy *et al.* (2016) and Sayad *et al.* (2016). Amino acids are significant biomolecules that function as intermediates in several metabolic processes and are the building blocks of proteins. They act as building blocks for creating several molecules crucial to life, such as neurotransmitters, peptide hormones, and nucleotides. Additionally, amino acids regulate gene expression, the protein phosphorylation cascade, animal cell nutrition transit, and metabolism, as well as innate and cell-mediated immunological responses. They also play significant roles in cell signaling (Bimal *et al.,* 2014).

Fish are a vital constituent of human nourishment due to the exceptional value of their lipid level, which serves as a source of PUFA that benefits health. These PUFA primarily consist of linoleic acid (LA; C18:2 ω6t), EPA (C20:5 ω3), DHA (C22:6 ω3), and arachidonic acid (ARA; C20:4 ω-6). It has been extensively documented that the ω 3 PUFAs, primarily EPA and DHA, positively affect human fitness. EPA and DHA are ubiquitous components of fetal and infant photoreceptors, cell membranes, and the developing brain (Tramice *et al.,* 2021).

FAs are critical in supporting life as they provide energy, membrane constituents, and metabolic and signaling mediators (Zhang *et al.,* 2020). Therefore, it is imperative to acquire knowledge concerning the nutritive composition of commercially substantial fish types to assess their health benefits for consumers. Table 3 summarizes the FA content of the sampled fish types and demonstrates the considerable variations in FA content observed across all fish species. SFAs ranged from 32.60 ± 1.23 in Nile tilapia to 9.86 ± 1.25 in Elephant-snout of total FAs. The highest concentration of MUFAs and PUFAs was reported in Nile perch (34.91 ± 1.93 and 32.45 ± 1.67 mg/g). Fish in various lipid classes had FA profiles that differed significantly from one another. According to earlier research, fish species were generally shown to have a high proportion of FAs (Zhang *et al.,* 2020; Tramice *et al.,* 2021).

Nonetheless, it was discovered that the FA levels in the species we studied were comparable to the previously published values (Murillo *et al.,* 2014; Shi *et al.,* 2019; Ma *et al.,* 2020; Elghazali *et al.,* 2023). It is well known that fish lipid content can vary significantly based on several circumstances, including the time of year they are caught. The type of fish food or water temperature can also influence these characteristics (Jenyffer *et al.,* 2022). The prevailing consensus is that eating SFAs raises low-density lipoprotein (LDL) cholesterol and puts one at risk for coronary heart disease (Santos *et al.,* 2013). As a result, the species under study whose lipid composition has the lowest SFAs appears to be healthier than the others and appropriate for the prevention of cardiovascular disease.

Cadmium (Cd), lead (Pb), arsenic (As), and mercury (Hg) are examples of toxic metals that pose serious health risks. Exposure of humans to these metals can result in a variety of acute and chronic harmful outcomes, including carcinogenic and neurotoxic consequences, as well as kidney and reproductive dysfunction (Bayomi *et al.,* 2019; El-Sherbiny and Sallam, 2021). Since contaminated soil and water are the main routes by which heavy metals enter the food chain, the volume of food ingested and the amount of the metal in the diet determine the hazardous threat to consumers. As a result, eating food tainted with heavy metals is becoming a more public concern (Di Bella *et al.,* 2020). Aquatic creatures obtain metals through food and water intake. Fish bioaccumulation patterns of metals are subject to various environmental factors, including age reproductive status, gender, feeding manners, trophic station, and body size. Metal enrichment is primarily impacted by environmental factors such as perseverance, quantity, mode of contact, and bioavailability. As a result, tissue-specific improvement is detected due to the various metabolic pathways through which trace metals undergo metabolism (Priyanka *et al.,* 2024).

Mineral and heavy metal concentrations (µg/g) in the fish species examined shown in Table 4 were identified in most tested species in amounts up to 0.035 µg/g for Hg, 0.003 µg/g for Pb, 0.031 µg/g for Cd, 1.25 µg/g for Cu, 13.1 µg/g for Fe, 5.64 µg/g for Zn, and 6.5 µg/g for Mn. Meanwhile, arsine failed to be identified in all the inspected samples. The heavy metal level in the studied types revealed a minimal threat of hazardous element

buildup, as previously reported in other investigations (Ong and Gan, 2017; Ariano *et al.,* 2021). Nile tilapia had the maximum Hg, Pb, Cd, Cu, and Fe residues, while catfish had the highest Zn and Mn residues. The study showed a substantial variance ($p \leq 0.05$) in the mineral and heavy metal ranks amongst the fish studied. This signifies that the contamination of the fish with metals could occur in any field of the supply chain. The researchers have been highly focused on the bioaccumulation impact of heavy metals and their related toxic impacts. Particular heavy metals are so harmless that their presence in low concentrations can potentially produce toxicity in the human body (Di Bella *et al.,* 2020). Since heavy metals are frequently ingested through food (Tramice *et al.,* 2021), regulatory bodies in numerous nations have established thresholds for the concentrations of these metals in food products. The findings presented in Table 5 suggest that ingesting the fish collected from Nasser Lake does not pose a significant risk of heavy metal exposure and follows the regulations set forth by Egyptian standards (ES, 2010). As far as the authors know, there are no recognized guidelines in Egypt concerning the Cu, Fe, Zn, Mn, and As levels in fish. Therefore, a comparison was made between the documented element levels and the standards specified by FAO/WHO (1999) and FSANZ (2011). Furthermore, Elephant-snout Nile perch and Zander produced superior results compared to Nile tilapia and Catfish. Metals are essential components of enzyme activity. They play a chief role in biological functioning, and a lack of them can result in metabolic diseases. We anticipated that low metal concentrations would not affect the lipid structure of the species under investigation, given that the metals under study have the potential to redox react with reactive oxygen species (ROS) (Tramice *et al.,* 2021).

The observations are similar to those found by other authors (Huang *et al.,* 2021; Tramice *et al.,* 2021; Yang *et al.,* 2021). Higher findings were reported in Nile tilapia and Catfish by Helmy *et al.* (2018) who recorded 1.29 and 1.62 µg/g, 0.53 and 0.67 µg/g, 0.19 and 0.25 µg/g, and Khalid *et al.* (2019) reported 0.045 and 0.017 µg/g, 0.704 and 0.64 µg/g, 0.024, 0.020 µg/g, and 0.511and 0.568 µg/g for Hg, Pb, Cd, and As. Furthermore, Elkady *et al.* (2015) recorded lower results in the flesh of Nile tilapia, and these findings were lower than those obtained by Mert *et al.* (2014) who documented the ranks of Zn, Fe, Cu, and Mn were 36.0323, 47.304, 0.5146 and 0.8655 µg/g, respectively, from the Damsa Dam Lake fish, whereas Abubakar *et al.* (2015) discovered a substantially higher iron concentration in the fish flesh examined from Nigeria (11.453 and 21.873 µg/g) and stated that these levels were over the FAO/WHO (1999) suggested safety limits. The variation in metal concentrations in muscle across various fish types can be ascribed to factors such as foraging intensity, geographic location, fish age and size, and the tendency of metals to accumulate in the foodstuff chain via bioaccumulation (YiHua *et al.,* 2014). Furthermore, the efficacy of heavy metal absorption by fish from contaminated food and water is subject to variation contingent upon ecological requirements, physiological metabolic ratio, water salinity, and temperature (Satheeshkumar and Kumar, 2011).

One of the primary significant biogenic amines in food safety is histamine (Pawul-Gruba, and Osek, 2021). Histamine, an endogenous compound found naturally in the human body, is formed through the decarboxylation of the amino acid histidine. Some meals that contain free histidine may also include histamine, which is produced by specific bacteria during the fermentation and spoiling of fish. Histamine-rich meals may cause diet bigotry in people who are sensitive to them and histamine contamination in fish (Elsherief *et al.,* 2019). The measurement of histamine is significant because it serves as a marker for fish freshness and is hazardous to humans (Pawul-Gruba, and Osek, 2021). Regarding Fig. 2, histamine was detected with the highest value (80 ± 3.8) in Zander, followed by Nile tilapia (48.9 ± 2.3) while Catfish recorded the lowest value (30.7 ± 1.3). None of them exceeded the regulatory limit (<200 ppm) according to the NFSA (2021) and the regulation of the European Union Commission (EC, 2005) (100–200 ppm) with statistically significant variances among examined species ($p \leq 0.05$). The low levels found in this survey indicate that fish were kept under good conditions till the analysis.

Research on the histamine content of fish that corresponds with the outcomes of the current investigation conducted by Park *et al.* (2022) detected histamine content in 48.7% of the samples. Meanwhile, low results of histamine content were obtained by Mamdouh *et al.* (2022) who reported 15.49 ± 2.05 and 17.18 ± 2.24 ppm in Nile tilapia and Catfish, as well as Bangieva *et al.* (2020) recorded 4.503 ± 1.133 ppm. Conflicting with our outcomes, Antonello *et al.* (2020) who reported histamine with a concentration of 110 ppm in 7.6% of all fresh inspected fish, and Pawul-Gruba and Osek (2021) recorded the amount of the amine from 3.4 to 156.4 ppm amongst the examined samples. Histamine release is most often influenced by both the effect of time and temperature (Antonello *et al.,* 2020). Regretfully, we could not accurately estimate the temperature following collection, as well as the duration and temperature of storage. Therefore, we could not assess any potential relationships with the histamine levels. Several investigations have found that improper storage and sanitary conditions increase histamine levels in fresh fish samples (Bilgin and Genccelep, 2015; Mejrhit *et al.,* 2018; Antonello *et al.,* 2020). Elevations of histamine and other biogenic amines can be avoided by following appropriate handling, distribution, storage protocols, and basic hygiene standards. Immediate chilling and rapid cooling following a fish's demise is a highly effective method

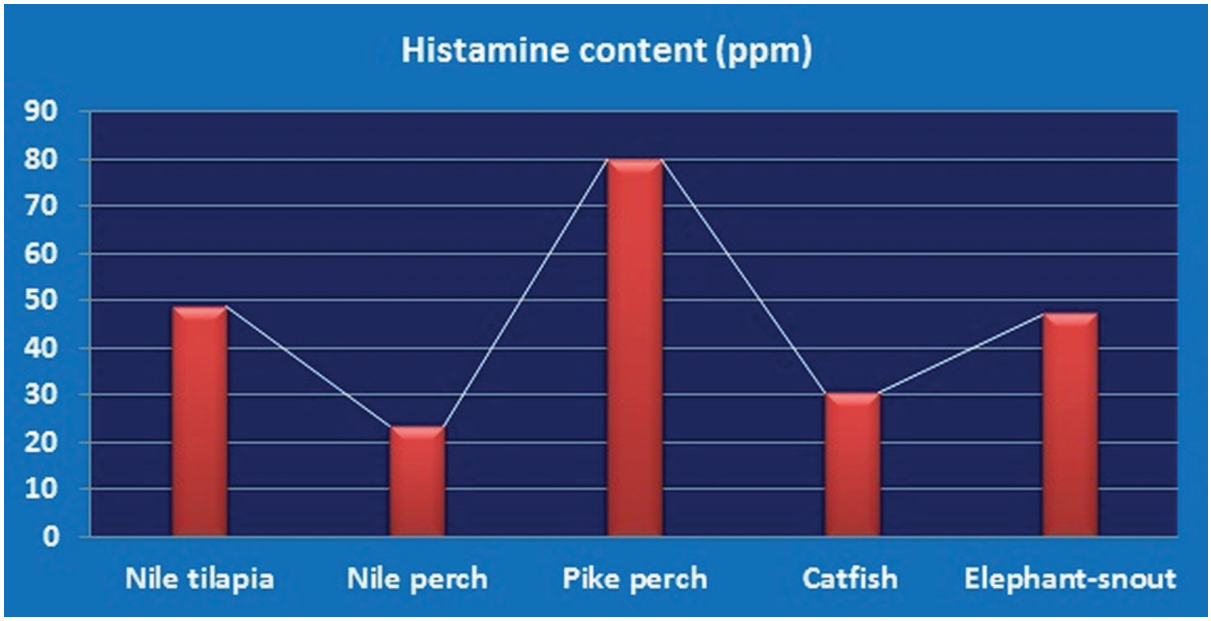

Fig. 2. Histamine concentrations "ppm" in the examined fish (n = 50 each).

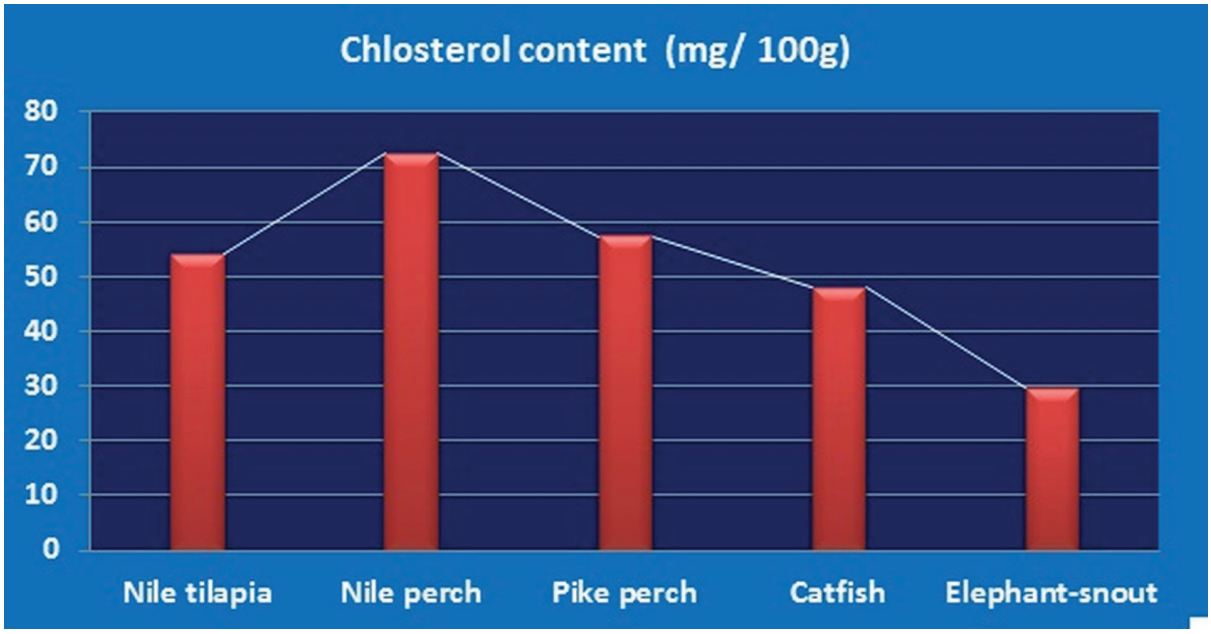

Fig. 3. Cholesterol content (mg/100 g) in the examined fish (n = 50 each).

for inhibiting the formation of histamine (Bangieva *et al.,* 2020).

Cholesterol is widely dispersed all over the animal body, with notable concentrations in the epidermis, blood, bile, brain, and nervous tissue. Exogenous cholesterol consumption is the most significant variable influencing the amount of LDL cholesterol in human blood serum (Yidam *et al.,* 2019). The total cholesterol level in fish meat varies depending on the species, age, gender, hatching cycle, collecting period, and geographic site of the lake, as cholesterol levels in fish meat can differ, even among linked species that live in similar areas and have identical eating behaviors (Karim *et al.,* 2022).

In the current study, the cholesterol content (mg/100 g) of the fish samples differed significantly among the examined species ($p \leq 0.05$) (Fig. 3). Nile perch had the highest cholesterol content (72.6 ± 1.7), followed

by Zander (57.5 ± 1.6), Nile tilapia (54.3 ± 1.6), and catfish (48.2 ± 1.4), while Elephant-snout had the lowest cholesterol content (29.7 ± 1.07). The values of cholesterol contents in the current investigation are close and correspond to those values achieved by previous research (Karim *et al.,* 2022; Mangas *et al.,* 2022). Meanwhile, lower results by Danielli *et al.* (2019) and Saei-Dehkordi *et al.* (2021) reported cholesterol levels of 4.20 to 19.61 mg/100 g in the investigated species. But Azrina *et al.* (2015) indicated that the cholesterol content in fish samples is up to 353.97 mg/100 g, and Menezes *et al.* (2009) recorded 188.00 and 187.52 mg/100 g cholesterol values in examined fish, which were regarded as excessive compared to the current investigation's quantities. The findings of the present investigation did not reveal any discernible correlation pattern among cholesterol and lipid levels. This implies that an elevation in total fat content cannot fundamentally result in an elevation in cholesterol levels. Cholesterol is an indispensable component of the majority of biological systems. It is a necessary component of animal cellular membranes and the building block of significant endogenous compounds. Humans can get cholesterol from two different sources: food consumption and endogenous synthesis. However, high, low-density lipoprotein cholesterol levels constitute an important cardiovascular risk factor. An increase in dietary cholesterol consumption raises plasma cholesterol levels, which raises the risk of atherosclerosis and cardiovascular disease (Albuquerque *et al.,* 2016). The World Health Organization (WHO, 2007) issued a guideline suggesting that healthy individuals restrict their dietary cholesterol consumption to 300 mg daily. However, in recent years, there has been a shift in the notion of the ideal daily cholesterol intake, which no longer specifies an exact quantity. As a result, the species analyzed are below the acceptable limit set by these organizations.

Sensory attributes serve as the primary determinants of fish quality and the primary factors that influence consumers' decisions to purchase raw fish. Sensory characteristics of fish include its appearance, color, meat flexibility or texture, odor, and taste. Based on these criteria, numerous sensory qualities could be utilized to categorize fish freshness. Additionally, all chemical and analytical instrument usage must follow the sensory evaluation findings (Zhang *et al.,* 2022). Client audacity was correlated with the sensory evaluation of fish as it is more efficient than other methods for handling seafood freshness and other quality issues and it does not require laboratory expertise. Despite the apparent palatability of the fish's sensory attributes when marketed to consumers, its suitability for ingestion may be compromised by substantial degradation in these quality parameters (Abdelrahman *et al.,* 2021).

From the summarized results given in Table 6, it is clear that all analyzed samples met the 9-point hedonic scale requirements for organoleptic acceptance, where the mean values of the scores of all groups were nearly similar with no substantial variance ($p \geq 0.05$), and none of the samples were regarded as spoiled. The findings of this investigation are generally consistent with earlier reports (Abdelrahman *et al.,* 2021; Zhang *et al.,* 2022). The sensory examination of fish yields a precise assessment of the apparent qualities and offers comprehensive information that aids in a better comprehension of the responses from customers (Abdelrahman *et al.,* 2021). As a result, fish sensory evaluation continues to be among the most reliable methods for determining variations in the quality of fish. In this regard, the study provides an assessment of the sensory quality of fish from Nasser Lake to ascertain the freshness of the fish quickly and, as a result, calculate the financial loss resulting from the consignments of rejected and condemned fish.

Conclusion

The finding provides crucial and beneficial information for Egyptian society regarding the selection of high-quality fish that are rich in nutrients. According to the current study, fish provide an alternate supply of protein and fat, as well as acceptable levels of histamine and cholesterol, and, to a greater extent, appropriate levels of heavy metals, making them safe for public consumption Furthermore, strict regulations are required to prevent the pollution of fish in this region and maintain levels below legal limits, in addition to proper hygiene and safety measures when handling fish. Further research is recommended continuously to ensure the maintenance safety and quality of Lake Nasser fish.

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Authors' contributions

Nady Elbarbary and Reda Gomaa: investigation, methodology, supervision, writing—review and editing. Alaa Eldin Morshdy: supervision, and visualization. Marwa Ali and Maha Abdelhaseib: methodology, conceptualization, and validation. Nermeen Malak and Ali Ghania: data curation, formal analysis, visualization, and writing—original draft. All authors read and approved the final manuscript.

Conflict of interest

The authors claim no conflicts of interest in publishing this research.

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Data availability

All data supporting the findings of this study are available within the manuscript.

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