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Evaluation of Fatty Acid and the Composition of Six Different Species of Freshwater Fish in the North of Algeria

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HIGHLIGHTS

- The examined freshwater fish species appeared to have a good nutritional value.
- The studied freshwater fish species are a good source of important fatty acids with positive effects on consumer health.
- The common carp was a rich resource of eicosapentaenoic acid and docosahexaenoic acid.
- The highest concentration of ω-3 was recorded in crusian carp.
- It is important to provide diets rich in fatty acids, in particular polyunsaturated fatty acids to these freshwater fish.

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Acronyms and abbreviations
DHA=Docosahexaenoic acid
EPA=Eicosapentaenoic acid
FAME=Fatty Acids Methy Ester
MS=Mass spectrometer
MUFA=Monounsaturated fatty acid
PUFA=Polyunsaturated fatty acid
SFA=Saturated fatty acid

ABSTRACT

Background: Few studies have been published about the quality of freshwater fish in Algeria. This study determined the chemical composition and the fatty acid of six species of freshwater fish cultivated in the North region of Algeria (Nile tilapia, red tilapia, common carp, Algerian barb, crucian carp, and mirror carp) as well as the nutritional quality of the lipids in these freshwater fish species.

Methods: One hundred and ten freshwater fish were randomly caught in the spring of 2021 from Achor Ali farm (Jijel), Beni-Haroun Dam (Mila), and EL-Agrem Dam (Jijel) from Algeria. Moisture, ash, protein, lipid, and fatty acids were measured according to standard laboratory procedures and protocols of previous studies. Statistical analysis was performed using ANOVA (XLSTAT 2014), and the pair wise comparison of the means was done by Tukeys test at the 5% significance level (p<0.05).

Results: Regarding freshwater fish species, fatty acid profiles were discovered to have 38.94 to 57.75% Saturated Fatty Acids (SFAs), 29.35 to 46.63% Monounsaturated Fatty Acids (MUFAs), and 6.79 to 26.55% Polyunsaturated Fatty Acids (PUFAs). Common carp was a rich resource of Eicosapentaenoic Acid and Docosahexaenoic Acid (EPA+DHA) (5.38%); the highest concentration of ω-3 was recorded in crusian carp (10.63%); and Nile tilapia contained significant levels of ω-6 PUFA. Results demonstrated that the examined freshwater fish species appeared to have a good nutritional value and be a source of important fatty acids with positive effects on consumer health. On the other hand, results revealed low levels of PUFAs.

Conclusion: The examined freshwater fish species appeared to have a good nutritional value, but, it is important to provide diets rich in fatty acids, in particular PUFAs, to these freshwater fish to improve the nutritional quality of their lipids.

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Introduction

Fish is regarded a good source of high-quality protein which contains essential amino acids and a good supply of vitamins and minerals, occupying the major part of the human diet (Elsherief et al., 2019; Jabeen and Chaudhry, 2011; Salifou et al., 2018). It contains a significant amount of n-3 Polyunsaturated Fatty Acids (PUFA), particularly Eicosapentaenoic Acid (EPA, 20:5n-3) and Docosahexaenoic Acid (DHA, 22:6n-3), which are crucial to human health; the effects of these fatty acids on autoimmune diseases, hypertension, inflammation, coronary heart disease, and weight reduction are beneficial (Chen et al., 2022; Li et al., 2011; Linhartová et al., 2018). Additionally, they shield the body from conditions such as high cholesterol, cardiovascular diseases, certain allergies, rheumatic fever, depression, heart attacks, adult diabetes, and some types of cancer (Citil et al., 2014; Raymond et al., 2020). Therefore, as a source of essential fatty acids, freshwater fish can be compared to marine fish species (Raymond et al., 2020).

As a result, more focus should be paid to lipid and fatty acid composition of various freshwater fish species.

The annual fish consumption for an Algerian citizen is 4.06 kg per capita/year; this average is much lower than the minimum consumption recommended by the World Health Organization (WHO) which is 6.2 kg per capita./year (FAO, 2016).

To overcome the problem, it will be necessary to promote the consumption of freshwater fish and farmed fish, which offer the same nutritional benefits whose prices are much lower.

According to the majority of customers, wild fish is preferable to farmed fish in terms of flavor, safety, nutritional content, and health benefits. It was also shown that older generations had a more positive attitude about eating fish. People with higher levels of education and a better grasp of the nutrients in fish also tended to favor eating fish as part of a healthy diet (Jaya-Ram et al., 2018).

Kara et al. (2016) reported that few studies were conducted on the quality of freshwater fish and farmed fish in Algeria. Consequently, the purpose of this study is to characterize six species of freshwater and farmed fish (Nile tilapia, red tilapia, common carp, common barb, crucian carp, and mirror carp) regarding their composition and fatty acid to educate the community about the nutritional value of freshwater and farmed fish and encourage them to include it in their diet.

This study can open future perspectives for new research fields because understanding chemical and fatty acid profile of freshwater fish and farmed fish species is essential for the development of these products and their application in different technological processes of conservation and transformation. As a result, consumers' acceptability of these products increases.

Materials and methods

Sample collection and preparation

In this experimental study, 110 freshwater fish were captured in the spring of 2021 (March to June), all the fish were randomly collected from Achor Ali farm (Jijel), Beni-Haroun Dam (Mila), and EL-Agrem Dam (Jijel) from the North of Algeria, and the water characteristics of the fishing sites were measured (the temperature ranged from 18 to 25 °C, the average pH of the water was 8,45, and oxygen's concentration varied between 7.88 and 10.25 mg/l). The fish samples are shown in Table 1 with information about fish species, culture system, average size and weight, and the number of obtained fish.

The fish samples were kept in ice boxes and transported immediately to the laboratory. Then, the body weight and total length of fishes were measured, and ten specimens (n=10) were randomly selected; each individual sample was cleaned, beheaded, eviscerated, deboned, skinned, filleted, minced, and homogenized in a food blender, and immediately was packaged in polypropylene and kept at -18 °C for later analysis.

Proximate composition analysis

-pH measurement

pH value was measured according to Durmuş et al.'s method (2017); the fish flesh was homogenized 1:10 (w/v) in distilled water, and the pH was assessed using a pH meter (OHAUS, Germany) after calibration with buffer solutions.

-Moisture

To determine the moisture level, a portion of the fish sample was dried at 105 °C for 3 to 4 h to constant weight in a hot air oven (Memmert, Germany) (Horwitz and Latimer, 2006).

-Ash

The amount of ash was measured by burning the residue resulting from moisture analysis at 550 °C for 4 to 6 h in the muffle furnace (Thermolyne, France) (Horwitz and Latimer, 2006).

-Protein

Using Kjeldahl machine (Gerhardt, Germany), the nitrogen content was determined by three phases: acid digestion, steam distillation, and titration with 0.1 N Hydrochloric acid (HCl) (Honeywell, Germany). The crude protein concentration was then quantified using a nitrogen conversion factor (6.25) (AOAC, 1995)

-Lipid

According to Folch et al.'s technique (1957), fat was

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extracted by homogenizing 1 g of fish with 20 ml of chloroform (Sigma, Germany) and methanol (Sigma, Germany) solution (2/1; v/v). Filter paper was used to filter the homogenate. A saline solution (sodium chloride 0.58%) (VWR, France) was added to the filtrate for better separation of the phases, and the mixture was left for the phases to be separated. The upper phase (methanol/water) was rejected and the lower phase (chloroform/lipids) was recovered, the solvent was then distilled off and the remainder was weighed with analytical balance (Kern, Germany).

-Fatty acid composition

Fatty acids were methylated according to Nasopoulou et al.'s method (2012), 35 mg of lipid was saponified using 4 ml of 0.5 N potassium hydroxide (EMSURE, Germany) in methanol (Sigma, Germany) and extracted with 5 ml n-hexane (CHEMLAB, Belgium). After 5 min at room temperature, the reaction was finished, and the upper phase, which included methyl esters, was collected with a micropipette (Scilogex, USA).

A Hewlett Packard Agilent 6,890 plus gas chromatograph (GC) equipped with an HP-5 mass spectrometer (MS) capillary column (30 m, 0.25 mm i.d, and 0.25 µm film thickness, 5% Phenyl and 95% dimethylpolysiloxane) was used to separate the Fatty Acids Methyl Esters (FAMEs). Then, the FAMEs were analyzed with a Hewlett Packard Agilent 5,973 MS. The carrier gas was helium at 0.5 ml/min. The oven was preheated to 70 °C for 5 min, then raised to 130 °C at 10 °C/min, kept at this temperature for 2 min, then heated to 220 °C at 3 °C/min, held for 4 min, then raised to 280 °C at 10 °C/min, held for 7 min, for a total run duration of 60 min.

One µl was the injection volume (splitless injection). The injector and detector had respective temperatures of 250 and 280 °C. The MS parameters were: 280 °C for the transfer line, 230 °C for the ion source, 70 eV for the collision energy, and 30-550 for the entire scan.

The retention time and the areas of the peaks of FAME were determined by contrasting them with those found in the National Institute of Standards and Technology database (NIST 0.2 L), then, each fatty acid was represented as a proportion of all the fatty acids.

Statistical analysis

All data were described as means±standard deviations (SD). Statistical analysis was performed using ANOVA (XLSTAT 2014), and the pair wise comparison of the means were done by the Tukeys test at the 5% significance level (p<0.05).

Results

Proximate composition of the fish species

Table 2 shows the proximate composition results of the freshwater fish species represented by percentage of the contents (g/100 g of wet weight).

-pH

The obtained results varied from 6.5 (Nile and red tilapia) to 6.89 (crucian carp), the differences between species were significant. All pH values were lower than 7.

-Moisture and ash

The lowest mean value of the moisture (71.21%) was shown by Nile tilapia fish species and differed significantly from those of the other freshwater fishes studied with values ranging from 78.1 to 78.93%.

The mean ash of the fish under study was not changed significantly (p<0.05) (varied from 0.94 to 0.99%).

-Protein

The mean protein content differed significantly (p<0.05) among the six freshwater species investigated, from 10.63 to 15.4%. The protein found in the tilapia species varied from 13.12 to 15.4%, and the carp species protein ranged from 10.63 to 14.52%.

-Lipid

Lipid levels in the current study varied from 1.23 to 4.32%, and statistically significant mean differences (p<0.05) were detected, however, overall values were less than 5%.

The values obtained with tilapia species of this study were 1.46 and 3.18%, the lipid level of the carp species in this investigation ranged from 1.23 to 4.32%.

-Fatty acid profile

The percentages of the 28 total fatty acids for freshwater fish species under study are shown in Table 3. The percentage of fatty acids ranged from 38.94 to 57.75% (Saturated Fatty Acid (SFA)), 29.35 to 46.63% (Monounsaturated Fatty Acids (MUFAs)), and 6.79 to 26.55% (PUFAs). Among them, the fatty acids with the highest proportions were myristic acid (C14:0, 0.55 to 11.77%), pentadecanoic acid (C15:0, 1.31 to 21.50%), palmitic acid (C16:0, 18.29 to 29.02%), heptadecanoic acid (C17:0, 1.00 to 7.10%), stearic acid (C18:0, 3.40 to 8.41%) as SFAs, palmitoleic acid (C16:1, 2.90 to 14.12%), and oleic acid (C18:1 n9, 13.59 to 41.02%) as MUFAs, where oleic acid was the primary. The principal fatty acids identified as PUFAs were linoleic acid (C18:2 ω-6) (3.66 to 9.5%), linolenic acid (C18:3 ω-3) (0.69 to 7.68%), arachidonic acid (C20:4 ω-6) (0.45 to 6.34%), EPA (C20:5 ω-3) (0.25 to 1.92%), and DHA (C22:6 ω-3) (0.29 to 4.6%).

Mirror carp recorded the highest SFA (57.75%); the C16:0 was the dominant SFA in the muscle of six fish

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because of its high percentage, except Algerian barb where C15:0 was dominated with 21.50% opposite 18.69% of C16:0; high amounts of MUFA were found in each of the other five fish species (30.29 to 46.63%). In this study, low values of PUFA ranging from 6.79 to 26.55 % were found where the highest level was related to the muscle of common carp, and the lowest PUFA content was found to be in Nile tilapia's muscle.

The greatest amount of EPA and DHA combined was found in the common carp (5.38%). As a result, it was a good source of EPA and DHA, followed by Algerian barb, crusian, and mirror carp (3.5, 2.95 and 2.67%, respectively), then the red tilapia and Nile tilapia (1.42 and 0.54%) were registered with the lowest value. The highest proportion of ω-3 was found in crusian carp (10.63%), red tilapia, and common carp (8.21 and 7.35%, respectively). Other fish species varied from 0.54 to 4.19%. Nile tilapia showed the lowest amount.

The study revealed that crusian carp had a high ω-3/ω-6 ratio (12.08) and more ω-3 fatty acids (10.63%) than ω-6 fatty acids (0.88%). The Algerian barb had the same proportion of ω-3 and ω-6 (4.19 and 4.27%), and its ω-3/ω-6 ratio was 0.98, in contrast to all other fish species examined, which were characterized by low levels of ω-3 and low ω-3/ω-6 ratios, and high levels of ω-6 fatty acids.

Table 1: List of six freshwater fish species (with common and scientific name) cultured in Algeria with major information about culture type, site, average size (cm), average weight (g), and the total number of fish caught.

Common name of fish	scientific name	Type of culture	site	Average size (cm)	Average weight (g)	Total number of fish
Nile tilapia	*Oreochromis niloticus*	Semi-intensive	Achor Ali farm (Jijel)	18±1.01 ^{b}	115.15±14.31 ^{a}	20
Red tilapia	*Oreochromis Spp.*	Semi-intensive	Achor Ali farm (Jijel)	13.21±1.11 ^{a}	37.57±10.17 ^{a}	12
Common carp	*Cyprinus carpio*	Semi-intensive	Achor Ali farm (Jijel)	18.41±0.87 ^{b}	107.28±13.19 ^{a}	20
Algerian Barb	*Luciobarbus callensis*	extensive	Beni-Haroun dam Lake (Mila)	32.23±6.68 ^{d}	473.08±230.59 ^{c}	13
Crucian carp	*Carassius carassius*	extensive	Beni-Haroun dam Lake (Mila)	25.04±2.43 ^{c}	298.36±76.39 ^{b}	22
Mirror carp	*Cyprinus carpio carpio*	extensive	EL-Agrem dam Lake (Jijel)	31.11±1.96 ^{d}	420.39±69.11 ^{c}	23
***p*-value**				<0.0001	<0.0001	

Size and weight results are presented as mean±SD. The difference between values in the same column with various letters (a, b, c, d) is significant ($p \leq 0.05$).

Table 2: pH, moisture, ash, protein, and fat content (as a percentage of wet weight) of freshwater fish species studied.

Species	pH	Moisture (%)	Ash (%)	Protein (%)	Lipid (%)
Nile tilapia *Oreochromis niloticus*	6.5±0.06 ^{a}	71.21±4.68 ^{a}	0.94±0.08 ^{a}	13.12±2.63 ^{ab}	1.46±1.05 ^{ab}
Red tilapia *Oreochromis Spp.*	6.5±0.09 ^{a}	78.93±1.11 ^{b}	0.99±0.01 ^{a}	15.4±2.4 ^{b}	3.18±1.45 ^{bc}
Common carp *Cyprinus carpio*	6.77±0.27 ^{ab}	78.53±5.19 ^{b}	0.94±0.09 ^{a}	10.63±1.56 ^{a}	1.23±0.4 ^{a}
Algerian Barb *Luciobarbus callensis*	6.66±0.3 ^{a}	78.10±1.83 ^{b}	0.98±0.02 ^{a}	13.95±1.12 ^{b}	2.85±1.19 ^{abc}
Crucian carp *Carassius carassius*	6.89±0.16 ^{b}	78.10±1.95 ^{b}	0.99±0.01 ^{a}	14.52±1.71 ^{b}	4.32±2.24 ^{c}
Mirror carp *Cyprinus carpio carpio*	6.66±0.28 ^{ab}	78.41±1.84 ^{b}	0.97±0.01 ^{a}	13.56±1.87 ^{b}	2.25±0.8 ^{ab}
***p*-value**	0.0005	<0.0001	0.0877	<0.0001	<0.0001

Results are presented as mean±SD (n=10). The difference between values in the same column with various letters (a, b, c) is significant ($p \leq 0.05$): values in the same column that do not share a similar superscript letter (a, b, c) are significantly different ($p<0.05$) .

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Table 3: Fatty acid compositions of the six species of freshwater fish analyzed (% of total fatty acids).

Fatty acid	Nile Tilapia	Red Tilapia	Common carp	Algerian Barb	Crusian carp	Mirror carp	*p*-value
			SFA				
C8:0	1.08±0.00 [b]	ND	0.64± 0.00 [a]	ND	ND	ND	0.435
C11:0	ND	0.98±0.00	ND	ND	ND	ND	
C12:0	1.12±0.00 [a]	2.52±0.00 [a]	0.27±0.00 [a]	ND	0.33±0.22 [a]	0.48±0.00 [a]	0.1701
C13:0	ND	1.77±0.00 [b]	ND	0.70±0.17 [ab]	0.23±0.23 [a]	ND	0.0494
C14:0	4.08±0.78 [ab]	3.90±2.32 [ab]	3.64±0.00 [ab]	0.55±0.07 [a]	3.90±0.00 [ab]	11.77±0.00 [b]	0.0552
C15:0	1.31±1.25 [a]	1.62±0.66 [a]	2.58±2.18 [a]	21.50±2.89 [b]	1.64±0.93 [a]	4.41±1.29 [a]	<0.0001
C16:0	27.03±3.05 [b]	18.29±2.78 [a]	22.48 ± 4.23 [ab]	18.69±3.27 [a]	22.95±7.41 [ab]	29.02±7.28 [b]	0.0012
C17:0	7.10±0.21 [c]	1.00±0.47 [a]	5.02 ± 0.00 [bc]	1.14±0.91 [a]	6.87±0.00[c]	2.25±1.02 [ab]	<0.0001
C18:0	4.52±2.43 [ab]	8.41±2.06 [c]	5.38±1.58 [abc]	3.40±0.56 [a]	6.26±0.59 [abc]	7.17±1.71 [bc]	0.0002
C19:0	ND	ND	1.31±1.44	ND	ND	ND	
C20:0	0.27±0.00 [a]	ND	0.62±0.00 [a]	ND	1.06±0.15 [a]	1.46±1.01 [a]	0.6411
C22:0	0.06±0.00 [a]	0.45±0.00 [a]	0.44±0.00 [a]	ND	0.31±0.00 [a]	0.23±0.01 [a]	0.0635
C23:0	ND	ND	0.57±0.00 [a]	ND	ND	0.45±0.59 [a]	0.8945
C24:0	ND	ND	0.21±0.00 [a]	ND	0.13 0.00[a]	0.51±0.73 [a]	0.8822
			MUFA				
C16:1 ω-7	4.92±2.57 [a]	2.90±1.34 [a]	10.33±2.19 [ab]	5.98±1.34 [a]	14.12±3.01 [b]	14.06±6.56 [b]	0.0011
C18:1 ω-9	41.02±6.26 [d]	38.87±4.16 [cd]	19.41±1.13 [ab]	39.58±6.25 [cd]	28.82±4.50 [bc]	13.59±1.85 [a]	<0.0001
C20:1 ω-9	0.69±0.00 [a]	ND	0.55±0.00 [a]	ND	0.38±0.00 [a]	1.70±1.79 [a]	0.8800
			PUFA				
C16:2 ω-7	ND	ND	ND	ND	ND	0,79±0,00	
C18 :2 ω-6	5.36±0.79 [ab]	7.65±1.37 [ab]	9.50±3.08 [b]	3.66±3.31 [a]	ND	6.5±1.02 [ab]	0.0657
C20 :2 ω-6	0.37±0.00 [a]	1.58±0.00 [a]	ND	0.16±0.00 [a]	ND	ND	0.1070
C16 :3 ω-7	ND	ND	0.35±0.00 [a]	ND	1.48±0.00 [a]	ND	0.0699
C18:3 ω-3	ND	6.79±0.00 [b]	1.97± 0.23 [a]	0.69±0.10 [a]	7.68±0.42 [b]	ND	0.0004
C20:3 ω-6	ND	0.69±0.00	ND	ND	ND	ND	
C22:3 ω-9	ND	ND	3.01±0.00	ND	ND	ND	
C20:4 ω-6	0.52±0.53 [a]	1.15±0.00 [ab]	6.34±0.00 [b]	0.45±0.00 [a]	0.88±0.19 [a]	1.94±1.33 [ab]	0.0357
C22:4 ω-9	ND	ND	ND	ND	ND	0.99±0.00	
C20:5 ω-3 (EPA)	0.25±0.11 [a]	1.42±0.00 [a]	0.78±0.00 [a]	1.24±0.45 [a]	1.92±2.37[a]	1.80±0.00 [a]	0.7965
C22:6 ω-3 (DHA)	0.29±0.00 [a]	ND	4.60±0.00 [a]	2.26±1.37 [a]	1.03±0.97[a]	0.87±0.77 [a]	0.1709
Σ SFA	46.57	38.94	43.16	45.98	43.68	57.75	
Σ MUFA	46.63	41.77	30.29	45.56	43.32	29.35	
Σ PUFA	6.79	19.28	26.55	8.46	12.99	12.89	
Σ ω-3	0.54	8.21	7.35	4.19	10.63	2.67	
Σ ω-6	6.25	11.07	15.84	4.27	0.88	8.44	
EPA+DHA	0.54	1.42	5.38	3.5	2.95	2.67	
Σ ω-3/ω-6	0.09	0.74	0.46	0.98	12.08	0.32	

The results are shown as mean±SD (n=5), and values in the same row that do not share a similar superscript letter (a, b, c, d) are significantly different (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.

Table 4: Comparison of our results with the French standards for food components (Anses, 2020).

Species	Moisture	Ash	Protein	Lipid	SFA	MUFA	PUFA
Raw carp (Ciqual)	77.3	1.01	17.7	4.76	27.89	51.42	20.70
Our carp (mean)	78.35	0.97	12,9	2.6	48.2	34.32	17.48
Raw tilapia (Ciqual)	78.5	0.82	18.1	2.13	34.15	39.02	26.83
Our tilapia (mean)	75.07	0.96	14.26	2.32	42.75	44.2	13.04

Moisture, ash, protein, and fat contents are expressed as a percentage of wet weight (g/100 g). Saturated Fatty Acid (SFA), Monounsaturated Fatty Acid (MUFA), and Polyunsaturated Fatty Acid (PUFA) are expressed as a percentage of total fatty acids.

Discussion

The pH level is one of the important indexes to assess the quality and freshness of aquatic products (Hu et al., 2021; Ruiz-Capillas and Moral, 2005; Salifou et al., 2018). Several factors such as the rate of glycogenolysis, slaughter conditions (high density, bleeding), temperature, and the species can influence the pH level of fish variations (Salifou et al., 2018). Salifou et al. (2018) determined the acceptable limit of pH in fish between 6.8 and 7; with pH of higher than 7, the fish is considered altered. If we stick to this limit, the quality of fish would be sufficient because all values are lower than 7. The pH level of tilapia (6.5) was lower, compared to the studies by Dergal et al. (2013) (6.66) and Fonseca et al. (2013) (6.6); this low pH value may signify increased stress at or before the moment of slaughter as reported by Emire and Gebremariam (2010). For the carp species, the obtained results (6.66 to 6.89 with an average of 6.77) were close to the findings of Hao et al. (2021) (6.85); such results improve the freshness of these species.

According to Matos et al. (2019), the fish's sensory

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quality, microbiological stability, and changes in nutritional composition following storage may be impacted by fillets in water, thus, determining their amount is very important. Also, the moisture content of fish fillet is perceived as a good indicator of its relative amount of proteins, lipids, and energy as described by Lipato and Kapute (2017). The amount of ash reveals the amount of minerals in fish, including selenium, iron, manganese, zinc, and copper, which are vital for human health (Bagthasingh et al., 2016; Dridi et al., 2018; Matos et al., 2019).

On this basis and according to the results obtained for moisture and ash, it could be concluded that the species of fish studied are rich in nutrients such as protein and fat, and also rich in mineral elements.

The protein level of tilapia species was considerably less than the amounts stated by Dergal et al. (2013) (17.3%), Ibrahim and El-Sherif (2008) (17.42%) for Nile tilapia. Furthermore, the carp species protein content was lower than what was reported by Matos et al. (2019) (15.8 to 18.4%) and Linhartová et al. (2018) (17.56 to 17.66%). Depending on the species, size, gender, and season, protein content differed significantly. In addition, the fish's capacity to consume or absorb important nutrients from their diet or their local environment and converting them into the biochemical qualities that the organism's body requires, may also be responsible for the differences shown in the acquired values as reported by Fawole et al. (2007).

Fish can be divided into three groups based on the amount of fat they contain: lean fish (less than 5% fat), medium fat fish (between 5 and 10% fat), and fatty fish (more than 10% fat) (Ghribi et al., 2023; Hong et al., 2014; Jabeen and Chaudhry, 2011; Matos et al., 2019). The six freshwater fish species examined are therefore categorized as lean fish. Lipid content of fish fillet depends on the species, diet, gender, season, geographical origin, and reproduction (Bagthasingh et al., 2016; Durmuş et al., 2017; El-Zaeem et al., 2012). Dergal et al. (2013) reported 0.3% of lipids for Algerian farmed tilapia; however, the values obtained for tilapia species in this study were higher. Raymond et al. (2020) discovered greater fat levels of 1.9 to 4.8%. Compared to the values reported by Matos et al. (2019) (0.4 to 8.2%) and Linhartová et al. (2018) (3.02 to 6.48%), the lipid content of the carp species in this investigation was lower.

These lower levels of lipids may be explained by the low levels of fat in the diet of these fishes.

The proximate composition of these freshwater fish species may be influenced by a variety of factors, including dietary composition, feeding habits and, rate, age, size, sex, habitat, and genetic characteristics (Ahmed et al., 2022).

Concerning fatty acids, similar results were observed regarding FSA and MUFA by Jaya-Ram et al. (2018), and Hong et al. (2014) on carp species, Linhartová et al. (2018) on Nile tilapia and other species, Citil et al. (2014) on common and crusian carp, and Dergal et al. (2013) on Algerian Nile tilapia. There were considerable differences in the proportion of these fatty acids across species. This similarity in the results is due to the fact that freshwater fish, unlike sea fish, are richer in FSA and MUFA than PUFA.

However, PUFA values of this research were the lowest, which can be explained by the low amount of PUFA in the fish diet.

PUFAs are essential to prevent autoimmune diseases, type 2 diabetes, inflammatory, and cardiovascular diseases. Numerous studies have demonstrated the benefits of omega-3 fatty acids for conditions such as schizophrenia and bipolar disorder as well as rheumatoid arthritis. DHA is necessary for healthy development of fetal brain and retina. Depending on all the above mentioned facts, PUFA should be included in the human diet, potentially in the form of fish, as fish is a good source of these fatty acids (Jabeen and Chaudhry, 2011; Linhartová et al., 2018; Matos et al., 2019).

Physiological state, size, age, reproductive cycle, aquatic environment, and water temperature can all impact fish lipid composition and fatty acid content. Fish can be classified as piscivorous, herbivorous, or omnivorous depending on their trophic position, which has been discovered to affect the content of their fatty acids (Özogul and Özogul, 2007, Vasconi et al., 2015).

In this study, the examination of each species revealed a large standard error, which might be due to the different diets ingested by each fish, resulting in a significant variation between replicates. Jaya-Ram et al. (2018) explained that, whatever the species, individual fish's fatty acid concentration is influenced by feeding patterns and the accessibility of organisms in the freshwater food web.

The high EPA+DHA content of fish confirms its high nutritional value (Citil et al., 2014).

Ugoala et al. (2008) reported that freshwater fish have a reputation for being richer in omega-6 fatty acids than marine fish, which are particularly well-known for being rich sources of omega-3 fatty acids.

Jabeen and Chaudhry (2011) reported that the ω-3/ω-6 ratio is a useful indicator for nutritional values of fish oils; consequently, the crusian carp have a good nutritional value.

Conclusion

The present study determined the proximate composition and fatty acid content of six species of freshwater fish cultivated in Algeria. Comparing the results of this study with the French standards for food components (Anses, 2020) (Table 4), the quality of the fish species was sufficient. The freshwater fish species under investigation seemed to have a good nutritional value for humans if

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included in the human diet.

The fatty acid composition differs for each fish species, common carp is a rich source of EPA and DHA, crusian carp has the greatest composition of ω-3, and Nile tilapia has significant levels of ω-6 PUFA.

On the other hand, PUFA values are low; this is influenced by the fish diet containing a low proportion of PUFA. Therefore, it is necessary to take care of the freshwater fish sector in Algeria, especially by providing foods rich in protein, fat, and fatty acids, in particular polyunsaturated fatty acids, to increase the nutritional value of these freshwater fish, and then, to give awareness to people to consume these products and benefit from their nutritional value.

Authors' contributions

All authors contributed to the study's conception and design. The first draft of the manuscript was written by E.S. and all authors: Y.B. and A.B. commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Conflicts of interest

The authors declared no conflict of interest.

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