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# Nutritional value of clariid catfish in the conditions of aquaculture in Ukraine

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**Abstract.** The nutritional value of raw materials is determined by a set of indicators that define the biological value of protein, lipids, mineral composition, and safety. Therefore, their investigation in the meat of one of Ukraine's aquaculture species – the clariid catfish – is relevant. The purpose of the study was to investigate the biological value of protein, lipids, mineral composition, and safety of catfish meat when grown in Ukraine and evaluate these indicators in accordance with the recommendations of FAO/WHO. The amino acid composition of the protein was determined by ion exchange liquid-column chromatography on an automatic analyser T 339 (Czech Republic); the fatty acid composition of lipids was determined on a gas chromatograph HRGC 5300 ("Carlo Erba", Italy). The mineral composition of meat was investigated by atomic emission spectrometry with inductively coupled plasma; the content of heavy metals was determined by atomic absorption spectrometry. The study of the amino acid composition of the protein established the presence of all essential amino acids in an amount significantly exceeded in the ideal protein in accordance with FAO/WHO recommendations, which indicates a high biological value. The fatty acid composition of lipids is typical for freshwater fish and catfish lipids from other aquacultures. The biological value of catfish lipids is determined by the ratio of fatty acids of the ω-6/ω-3 families as 1.8:1.0 at the recommended value of 10:5, which indicates the possibility of using lipids of this fish as a source of especially deficient ω-3 fatty acids in the human diet. The low level of polyunsaturated fatty acids and the absence of essential fatty acids eicosapentaenoic (EPA) and docosahexaenoic (DHA) acids gives the basis for developing the design of biologically valuable catfish meat products by enriching it with lipids from marine aquatic organisms. The practical significance of the findings is to obtain original data on the nutritional value of meat

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from one of the aquaculture species in Ukraine, determine the degree of satisfaction of the daily human need for its consumption, and develop recommendations for rational use

**Keywords:** catfish meat; essential amino acids; fatty acids; safety indicators; heavy metals; radionuclides

## Introduction

Ensuring a healthy human diet is a priority of the policy of any country in the world, including Ukraine (FAO, n.d.). The main objective of this policy is to create recommendations based on studies of the nutritional value and safety of raw materials and products. Fish is one of the main sources of biologically valuable protein, essential lipids, mineral elements, and vitamins. As a result, there is a tendency to increase its consumption in the world and by 2032 it is expected that the consumption of edible fish will reach 21.2 kg per capita, compared with 20.4 kg in the base period (average 2020-2022) (OECD/FAO, 2023). The contribution of aquaculture to global aquatic animal production reached a record 49.2% in 2020 and is planned to increase by another 15% by 2030, which could provide a larger share of humanity with food (FAO, n.d.). Freshwater aquaculture is also developing very rapidly in Ukraine. Along with the breeding of various carp species, the *Clarias gariepinus* catfish of the *Clariidae* family is a promising species for freshwater aquaculture in Ukraine. According to U.E. Sharylo *et al.* (2020), U. Knaus *et al.* (2021), M.V. Zadorozhnii (2023), this species is considered one of the most promising for aquaculture due to its unpretentiousness to growing conditions and relatively simple and easily controlled technology of mass reproduction. In Ukraine, the technology of growing this type of fish was also used during 2018-2023 (Zadorozhnii, 2023).

Research on the nutritional value of *C. gariepinus* meat in vivo and in aquaculture were conducted in Nigeria by C.O. Okonkwo *et al.* (2020), in aquaculture of Ukraine – by I.M. Bal *et al.* (2023a; 2023b). The analysis of the above sources indicates the dependence of the chemical composition of *C. gariepinus* meat depends on the growing conditions and weight of fish and is consistent with generally established patterns. Fish weighing from 989 g is characterised by a high protein and fat content in the aquaculture of Ukraine and is 67.74 ± 3.45 and 26.20 ± 1.32%, respectively, in terms of dry matter. In natural conditions and in aquaculture of Nigeria, with a fish weight of 200 g or more, the protein and fat content is almost half that (30.27 ± 1.79; 42.90 ± 3.37 and 12.0 ± 1.4; 12.9 ± 2.8 in %, respectively (Okonkwo *et al.,* 2020). Meat of *C. gariepinus* in the aquaculture of Ukraine has the highest caloric value (506.7 ± 7.1 kcal) compared to all the conditions of existence of this fish species in Nigeria. Fish with a low weight (200 g) is characterised by high fibre content (39.8 ± 1.8; 50.6 ± 4.2 vs. 0.22 – 1.01 ± 0.6%, respectively.

It is known that one of the most significant indicators of the nutritional value of fish meat is the amino acid composition of protein. Unfortunately, these data are not available in the literature, which makes it necessary to investigate these indicators. Evaluation of the lipid profile of the clariid catfish in aquaculture conditions is presented in the paper by Å. Krogdahl *et al*. (2022). The correspondence of the lipid profile of fatty acids of clariid catfish to the composition and ratio of fatty acids in freshwater fish lipids is shown, that is, the sum of biologically valuable fatty acids EPA and DHA is 5.3, the total amount of PUFAs ω-3 is 6.47 and ω-6 is 22.45% (Bal-Prylypko *et al*., 2018).

Clariid catfish is in demand in Ukraine due to its high taste properties and the possibility of producing a large variety of culinary dishes. Considering the recommendations of FAO/WHO and the European Organisation in the field of health nutrition, it is important to know the biological value of proteins, lipids, mineral composition, and safety indicators of catfish meat in aquaculture of Ukraine and assess their compliance with these recommendations. Therefore, the study of the amino acid, lipid profile, and mineral composition of meat of this type of fish in the aquaculture conditions in Ukraine is relevant.

The purpose of the study was to investigate the biological value of protein, lipids, mineral composition, and safety of catfish meat when growing in Ukraine and evaluate these indicators in accordance with the recommendations of FAO/WHO to meet the daily human need for essential nutritional factors.

## Materials and Methods

The research was conducted at the laboratories of the Department of Meat, Fish and Seafood Technology of the Faculty of Food Technology and Quality Management of the National University of Life and Environmental Sciences of Ukraine in June-December 2023.

The object of research was the nutritional value of the meat of clariid catfish *C. gariepinus* grown in the aquaculture farm LLC "Aqua System Organic" (Kyiv Region, Vasylkiv city). Meat samples were taken from fish weighing 956, 986 and 1,021 g, crushed in a blender, and the amino acid composition of protein, fatty acid profile of lipids, mineral composition and content of heavy metals and radionuclide $^{90}$Sr was analysed. The content and composition of fatty acids were determined by liquid chromatography at the O.V. Palladin Institute of Biochemistry of the National Academy of Sciences of Ukraine using an HRGC 5300 device ("Carlo Erba", Italy). The lipid extract was prepared according to the method described in (Folch *et al.*, 1957), dissolved in benzene, placed in a flask closed with a glass plug, and stored at a temperature of negative 18°C. An aliquot of 0.5 cm$^3$ of the lipid extract was placed in a glass ampoule, 1.5-2.0 cm$^3$, 1.0N of HCl solution in methyl alcohol was added, the ampoule was hermetically sealed and boiled for 50 min in a water bath. At the end of heat treatment, the ampoule was opened, the same amount of water was added, the organic component was extracted with distilled hexane and dried with anhydrous sodium sulphate. The dried extracts were evaporated on a rotary evaporator, the resulting fatty acid methyl esters were dissolved in benzene, applied to glass plates coated with KSK silica gel, and the solvent was evaporated. A layer of purified esters was removed from the glass plate and washed with hexane on a Schott No. 4 filter. The resulting pure ester mixture was dissolved in hexane and analysed using chromatographic columns filled with W/HP chromosome sorbent impregnated with Silar 5 cp liquid phase and analysed on an HRGC 5300 chromatograph at 140-250°C and temperature increase by 2°C per minute. The identification of individual fatty acids was carried out in accordance with Sigma-Aldrich standards. The content of each fatty acid was expressed as a percentage of the total amount. The mass fraction of essential amino acids was determined by liquid chromatography using an automatic analyser T-339 (T 339, Czech Republic) at the O.V. Palladin Institute of Biochemistry (Ukraine). The protein hydrolysis of *C. gariepinus* meat was carried out at 110°C for 24-36 hours. For this purpose, samples of crushed meat weighing 1-5 mg were mixed with 6N hydrochloric acid. Identification of individual amino acids was carried out based on Sigma-Aldrich standards. The content of the tryptophan amino acid was determined at the V. Dokuchaev Kharkiv National Agrarian University according to DSTU 4507:2005 (2008) method. Crushed fish meat was decomposed by alkaline hydrolysis to determine tryptophan with the conversion of the amino acid to free form, its isolation by column ion exchange chromatography with Post-column derivatisation with ninhydrin. The mineral composition was studied at the Ukrainian Research Institute of Alcohol and Food Biotechnology according to DSTU 7525:2014 (2015). The mineral composition was investigated at the Ukrainian Research Institute of Alcohol and Food Biotechnology in accordance with DSTU ISO 11885:2005, by inductively coupled plasma atomic emission spectrometry; the content of heavy metals was determined by atomic absorption spectrometry; the mineralisation of samples was carried out according to DSTU 7670:2014.

## Results

*Investigation of the amino acid composition of C. gariepinus meat protein in comparison with other freshwater fish*

An assessment of the compliance of the amino acid composition of *C. gariepinus* meat protein with FAO/WHO recommendations and its comparative characteristics with those of other freshwater fish are provided in Table 1.

***Table 1.*** *Compliance of the amino acid composition with meat protein of C. gariepinus and other freshwater fish, g/100 g of protein*

| Name of EAC | Name of fish | | | | Ideal protein according to FAO/WHO (Dietary Ref. 2017) |
|---|---|---|---|---|---|
| | ***C. gariepinus**** | ***C. carpio* (Bal-Prylypko *et al.*, 2018)** | ***C. idella* (Bal-Prylypko *et al.*, 2018)** | ***H. molitrix* (Bal-Prylypko *et al.*, 2018)** | |
| Protein content, in % of the total chemical composition | 16.80 | 15.60 | 17.10 | 18.70 | |
| AAE9, incl. | 48.4 | 50.38 | 45.09 | 32.60 | 27.70 |
| VAL | 4.8 | 6.47 | 4.19 | 2.24 | 3.90 |
| ILE | 4.3 | 4.71 | 4.90 | 3.68 | 3.00 |
| LEU | 9.9 | 10.58 | 8.80 | 7.38 | 5.90 |
| MET+CYS | 4.4 | 2.94 | 2.97 | 1.13 | 2.20 |
| THR | 4.3 | 5.29 | 4.60 | 2.63 | 2.30 |
| PHE + TOUR | 7.7 | 7.64 | 7.96 | 5.63 | 3.80 |
| TRP | 0.8 | 1.06 | 0.9 | Traces | 0.60 |
| LYS | 10.1 | 11.17 | 10.29 | 7.23 | 4.50 |
| HIS | 2.1 | 0.52 | 0.48 | 2.68 | 1.50 |

**Notes:** *– results of the author's own research
**Source:** developed by the author

Analysis of the data in Table 1 shows that the total amount of essential amino acids in the proteins of catfish meat in the conditions of aquaculture in Ukraine exceeds their recommended value in ideal protein by 74.72% (48.40 vs. 27.70 g/100 g of protein). In carp – by 81.87% (50.38 vs. 27.70 g/100 g of protein), in grass carp – by 62.77% (45.09 vs. 27.70 g/100 g of protein), in silver carp – by 17.68% (32.60 vs. 27.70 g/100 g of protein). The results obtained allow estimating the biological value of protein based on the amino acid score assessment of the protein value of *C. gariepinus* in terms of amino acid speed compared to this indicator in freshwater fish such as carp *C. carpio*, grass carp *C. idella*, and silver carp *H. Molitrix* shown in Figure 1.

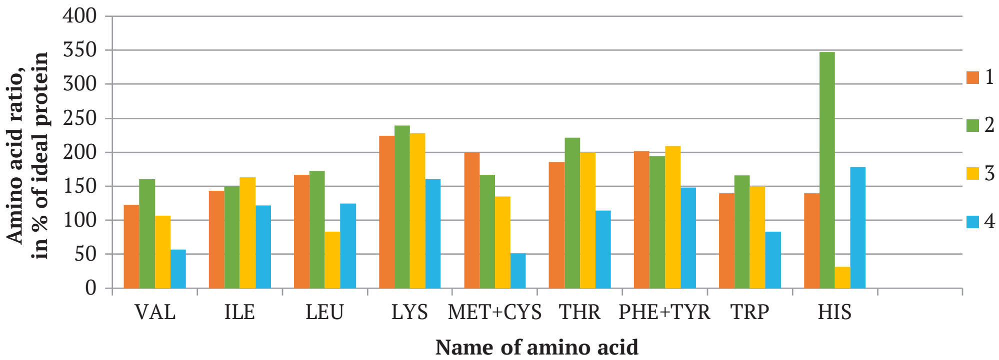


**Figure 1.** Protein amino acid composition of the main commercial freshwater fish of Ukraine
**Notes:** 1 – C. gariepinus; 2 – C. carpio; 3 – C. idella; 4 – H. Molitrix
**Source:** developed by the author

As can be seen from the figure, the scores of all AAE9 in meat protein *C. gariepinus* exceeds 100%, which characterises its high biological value. The highest rate for lysine was determined – 224%. This amino acid belongs to the aliphatic, the group of acids that ensure the growth of the body, takes part in the transport of fatty acids, and helps to reduce the level of triglycerides. Meat proteins of *C. sagrio, C. idella, H. Molitrix* also contain a high amount of this acid, the rate of which is 239, 228, and 160 %, respectively. The decrease in the rate of essential amino acids in catfish meat is found in the following sequence: LYS (224%), PHE+-TYR (202%), MET+CYS (200%), LEU (167%), ILE (143%), TRP I HIS (140%), VAL (123%). In other freshwater fish, the tendency to decrease the speed of AAE(9) is different: in carp, HIS – 347, LIS – 239, THR – 221, PHE+TYR – 194, LEU – 173, MET+CYS – 167, TRP – 166, VAL – 160, ILE – 150; in grass carp, LYS – 228, PHE+TYR – 209, IKE – 163, TET+CYS – 135, VAL – 107, LEU – 83, HIS – 32; in silver carp JIS – 178, LYS – 160, PHE+TYR – 148, LEU – 125, ILE – 122, THR – 114, TRP – 83, VAL – 57, MET+CYS – 51, %, respectively.

The protein of carp and catfish meat is also complete in contrast to the protein of grass carp and silver carp, in which limiting amino acids are determined, the rate of which is as follows: HIS – 32% and LEU – 83%; TRP – 83%, MET+CYS – 51% and VAL – 57%. Assessment of the biological value of lipids in *C. gariepinus in comparison with other freshwater fish.* Results of studies of the fatty acid composition of lipids in *C. gariepinus* meat in comparison with these indicators of this fish species obtained in central Europe and carp are presented in Table 2.

***Table 2.*** *Comparative characteristics of fatty acid composition of meat lipids in C. gariepinus from various aquaculture conditions and carp, in % of the total amount of fatty acids*

| Fatty acids | Acid code | Name of fish | | | FAO/WHO recommendations (Dietary Reference Values..., 2017) |
|---|---|---|---|---|---|
| | | *C. gariepinus** | *C. gariepinus* (Krogdahl *et al.*, 2022) | *C. carpio* (Bal-Prylypko *et al.*, 2018) | |
| Saturated, incl. | | 32.61 | 30.50 | 27.52 | 30 |
| F12DO | 12:0 | - | 0.03 | 0.23 | |
| F14DO | 14:0 | 2.69 | 2.87 | 1.75 | |
| F15DO | 15:0 | 0.93 | 0.25 | 0.31 | |
| F16DO | 16:0 | 21.93 | 21.76 | 18.39 | |

Table 2. Continued

| Fatty acids | Acid code | Name of fish | | | FAO/WHO recommendations (Dietary Reference Values..., 2017) |
|---|---|---|---|---|---|
| | | *C. gariepinus** | *C. gariepinus* (Krogdahl *et al.*, 2022) | *C. carpio* (Bal-Prylypko *et al.*, 2018) | |
| F17DO | 17:0 | - | 0.38 | 0.83 | |
| F18DO | 18:0 | 7.06 | 5.02 | 6.01 | |
| F20DO | 20:0 | | 0.19 | | |
| Monounsaturated, incl. | | 40.52 | 36.33 | 49.07 | 60 |
| F14D1 | 14:1 | - | 0.08 | - | |
| F15D1 | 15:1 | - | 0.02 | | |
| F16D1 | 16:1 | 6.89 | 0.67 | 7.32 | |
| F16D1CN9 | 16:1 cis9 | - | 4.69 | - | |
| F17D1 | 17:1 | - | 0.14 | 0.06 | |
| F18D1 | 18:1 | | | 4.86 | |
| F18D1CN9 | 18:1 cis9 | 31.09 | 28.08 | 35.99 | |
| F20D1 | 20:1 | | 2.35 | 0.54 | |
| F22D1 | 22:1 | 2.54 | 0.21 | 0.30 | |
| F24D1 | 24:1 | - | 0.09 | - | |
| PFA, incl. | | 21.87 | 29.99 | 11.44 | 10 |
| F14D2 | 14:2 | - | 0.05 | - | |
| F16D2 | 16:2 | - | 0.08 | - | |
| F18D2N6 | 18:2 | 10.99 | 19.79 | 4.86 | |
| F18D2TCON | 18:2 | - | 0.14 | - | |
| F18D3N6 | 18:3 | - | 1.85 | - | |
| F18D3N3 | 18:3 | 2.18 | 0.6 | 4.91 | |
| F18D4 | 18:4 | - | 0.72 | - | |
| F20:2D2 | 20:2 | 3.95 | 0.20 | 0.32 | |
| F20:3D3 | 20:3 | - | 0.48 | - | |
| F20:4D4 | 20:4 | 0.53 | 0.21 | - | |
| F20:4D4N6 | 20:4 | - | - | 0.36 | |
| F20:5D5N3 | 20:5 | 1.37 | 3.09 | 0.56 | |
| F22:5D5 | 22:5 | 0.46 | 0.57 | - | |
| F22:6D6N3 | 22:6 | 2.39 | 2.21 | 0.43 | |
| Unidentified | | 5.08 | 3.18 | 11.97 | |

**Source:** developed by the author

The results of the comparative characteristics show that the sum of saturated fatty acids of lipids of catfish grown in aquaculture conditions in Ukraine is slightly higher than the recommendations of FAO/WHO and amounts to 32.61 against 30% of the total amount of fatty acids. The mass fraction of monounsaturated fatty acids (MFA) is 32.61% less and the sum of polyunsaturated fatty acids (PFA) is 118.7% more than the FAO/WHO recommendations (Fats and fatty acids in human nutrition, 2010). Among saturated fatty acids, a high level of palmitic acid was observed both in lipids of catfish from the aquaculture conditions in Ukraine and from other aquaculture conditions of this species – 21.93; 21.76% (Krogdahl *et al.*, 2022) and freshwater carp – 18.39%, respectively. For monounsaturated fatty acids (MFA) in the lipids of catfish meat and other freshwater fish, the dominance of oleic acid (F18DICN9) 18:1 ω-9: 31.09 % – in catfish lipids in Ukraine aquaculture; 28.08% – in catfish in other aquaculture conditions; and 35.99% – in carp lipids were determined. The amount of polyunsaturated fatty acids (PFA) in catfish lipids in aquaculture conditions in Ukraine is more than twice the amount recommended by FAO/WHO and equals 21.87 against 10%. A high mass fraction of these acids was also found in catfish lipids under other aquaculture conditions – 29.99%. In freshwater carp fish, the content of these acids is closer to the recommended amount. Among the polyunsaturated fatty acids of catfish lipids, the largest mass fraction was determined for linoleic acid (F18D2N6) 18:2 ω-6. In the conditions of catfish aquaculture in Ukraine, this acid amounts to 10.99, in other conditions – 19.79 (Krogdahl *et al.*, 2022) and in carp – 4.86% (Bal-Prylypko *et al.*, 2018), respectively.

Assessment of the biological value of fish meat lipids based on the ratio of individual classes and certain fatty acids in accordance with the ideal lipid (Tsypriyan *et al.*, 2007) and the FAO/WHO recommendations (Fats and fatty acids…, 2010) are shown in Table 3.

***Table 3.*** *Assessment of the biological value of lipids in catfish meat and other freshwater fish*

| Name of lipid type | Fatty acid ratio | | | | |
|---|---|---|---|---|---|
| | SFA : MFA : PFA | PFA : SFA | F18D2N6 : F18D1CN9 | F18D2N6 : F18D3N3 | Σ ω-6 : Σ ω-3 (Fats and fatty acids ...2010) |
| | (Tsypriyan *et al.*, 2007) | | | | |
| Ideal lipid | 1 : 1 : 1 | 0.2 – 0.4 | >0.25 | >7 | 10 – 5 |
| *C. gariepinus** | 1.49 : 1.80 : 1 | 0.67 | 0.35 | 5.04 | 1.8 : 1 |
| *C. gariepinus* (Krogdahl *et al.*, 2022) | 1.98 : 1.80 : 1 | 0.98 | 0.70 | 7.71 | 3.39 : 1 |
| *C. carpio* (Bal-Prylypko *et al.*, 2018) | 2.40 : 4.28 : 1 | 0.41 | 0.13 | 0.98 | 0.9 : 1.0 |

**Source:** developed by the author

Analysis of the data in Table 3 shows that in catfish meat lipids in all aquaculture conditions, the ratio of saturated (SFA) to monounsaturated (MFA) and polyunsaturated (PFA) fatty acids does not correspond to the ideal lipid indicators due to the excess of the mass fraction of SFA and MFA and the amount of PFA by 1.49 and 1.80 (under the conditions of aquaculture in Ukraine) and by 1.98 and 1.80 times (under other aquaculture conditions) (Krogdahl *et al.*, 2022), respectively. The PFA : SFA ratio in catfish lipids under all aquaculture conditions is higher than in the ideal lipid and is 0.67 and 0.98 versus 0.2-0.4 in the ideal lipid. In carp lipids, this indicator is consistent with the ideal lipid – 0.41. The ratio of fatty acids F18D2N6 : F18D1CN9 in catfish lipids under various aquaculture conditions is higher than in the ideal lipid: in catfish from aquaculture of Ukraine, this indicator is 0.35 against >0.25 in the ideal lipid, in carp – less than twice (0.13). As for the indicator F18D2N6 : F18D3N3, in the ideal lipid it is >7 and is consistent only with catfish lipids in the aquaculture of another country (7.71); in the aquaculture of Ukraine – 5.04 against >7. The ratio of the sum of fatty acids ω-6: ω-3 has recently been given considerable attention due to their functional and metabolic significance in the regulation of lipid metabolism (Fats and fatty acids ..., 2010; Sharma & Agnihotri, 2020). According to the results of studies, the ratio of these acids does not coincide with the ideal lipid, but it indicates a high mass fraction of ω-3 fatty acids, which are particularly deficient in the human diet. In an ideal lipid, this ratio is 10 : 5, in catfish in the conditions of aquaculture in Ukraine – 1.8 : 1, and in the conditions of aquaculture in another country – 3.39 : 1. Carp lipids in this indicator can also be attributed to biologically valuable due to the high content of fatty acids of the ω-3 family, namely, almost on a par with acids of the ω-6 family (0.9 : 1.0).

*Investigation of the mineral composition of C. gariepinus meat in the conditions of aquaculture in Ukraine.*

Table 4 shows the content of mineral elements in *C. gariepinus* meat and its compliance with the daily requirement of an adult person.

***Table 4.*** *Characteristics of the mineral composition of meat of C. gariepinus, mg/100 g of meat*

| Name of mineral element | *C. gariepinus* | Daily requirement (Tsypriyan *et al.*, 2007) |
|---|---|---|
| K | 343 ± 15 | 2,500 |
| Na | 42.1 0.7 | 1,300 |
| Mg | 23.24 0.7 | 400 |
| Fe | 0.23 0.02 | 15.00 |
| Z | 0.4 0.02 | 12.00 |
| Se | 0.014 0.002 | 0.055 |
| P | 208 15 | 700-4,000 |

**Source:** compiled by the authors

According to the findings, the content of a single mineral element in the composition of *C. gariepinus* meat cannot cover the daily requirement of an adult (Tsypriyan *et al.*, 2007), however, is of interest as an additional source of essential macro- and micro-elements. In terms of the content of heavy metals such as Pb and Cd and the radionuclide $^{90}$Sr, catfish meat meets safety requirements (Codex general..., 2009) (Table 5).

***Table 5.*** *Content of heavy metals and radionuclides in the meat of C. gariepinus (n = 3, p < 0.05)*

| Indicator | Meat *of C. gariepinus* | Acceptable levels (Codex general..., 2009) |
|---|---|---|
| Heavy metals, mg/100 g | | |
| Pb | Not detected | 1.0 |
| Cd | Not detected | 0.2 |
| Radionuclides, Bq/kg | | |
| $^{90}$Sr | 0.039±0.001 | 100 |

**Source:** developed by the author

The heavy metals Pb and Cd are not detected in the meat of *S. gariepinus*, and the content of the radionuclide $^{90}$Sr is at a low level. Thus, according to the indicators under study, channel catfish meat is safe in the conditions of aquaculture in Ukraine.

## Discussion

During 2021-2023, the important contribution of fisheries and aquaculture to food security and nutrition of the population in the 21$^{st}$ century was increasingly recognised, as it has provided an increased supply of aquatic animals to global markets. Food products from aquatic organisms are one of the most popular food groups in the world. This is conditioned by the features of such products, which are a source of essential and non-essential elements of nutrition, namely, easily digestible proteins with all proteinogenic amino acids, monounsaturated fatty acids ω-9, polyunsaturated fatty acids ω-6 and ω-3, vitamins, macro- and micro-elements. Therefore, the world has determined an annual increase in the level of consumption of fish products, which in the future will be more than 20-22 kg per year. Fish raw materials and products are more closely related to the recommendations of domestic and international organisations to ensure the daily human need for high-quality and health-improving nutrition. However, no product made from any raw material can fully meet these needs (Mamndeyati & Tidi, 2023). Therefore, in the future, innovative technologies for the development of poly-component food products will be developed based on studies of all indicators of the quality and safety of raw materials, mathematical modelling of the recipe composition of products that would correspond to or be close to the recommended values to meet the needs of the human body. That is why the obtained data on the nutritional value of catfish meat from aquaculture in Ukraine are important for developing recommendations for improving its processing technologies and creating health-improving nutrition products.

In recent years, aquaculture of the *Clarias gariepinus* catfish of the *Clariidae* family has been developing in Ukraine, which was emphasised by U.E. Sharylo *et al*. (2020) and M.V. Zadorozhnii (2023), and this type of fish is in great demand among the population for the production of various culinary products. However, until the next time, data on nutritional value are limited only to materials regarding the chemical composition and some technological characteristics of meat. Thus, I. Bal *et al.* (2023a) established that organoleptic characteristics of fresh clariid catfish meet the requirements of the standard; in terms of mass composition, the largest share belonged to the carcass – 58.07 ± 2.40%, the fillet was 43.68 ± 2.00%, the last mass fraction of 20.01 ± 2.73% is accounted for by the head, bones, viscera, and fins.

According to I.M. Bal *et al.* (2023b), nutritional value of *C. gariepinus* is determined by a high fat content (26.2 ± 1.32%), which is not consistent with the data of this indicator in catfish from natural conditions and is higher than in aquaculture conditions in Nigeria. According to S.O. Okonkwo *et al.* (2020), catfish meat, both in aquaculture and in vivo, is low in fat (12.0 ± 1.4-12.9 ± 2.8%), this may be conditioned by the weight of the fish samples under study (200 g against 989.0 and 1,450 g in the conditions of aquaculture in Ukraine). The protein content of catfish meat from the conditions of aquaculture in Ukraine exceeds this indicator in fish from other countries and living conditions, which determined the highest energy value of its meat (506.7 ± 7.1 vs. 492.2 ± 7.2 kcal). These data once again highlight the influence of growing conditions and feed on the chemical composition of fish meat. In accordance with the recommended norms of physiological needs for the ratio of protein, fat, and carbohydrates in the daily diet as 1:1:4 (Order of the Ministry of Health of Ukraine No. 1073, 2017) the results of current research and literature sources on the chemical composition of catfish meat do not coincide. The protein content of channel catfish meat is 2.5 and 2.85 times higher than fat (Folch *et al.*, 2023; Bal *et al.*, 2023a).

Meat protein of catfish in the conditions of aquaculture in Ukraine is characterised by its biological value, which is determined by the high content of essential amino acids (AAE9). The total amount of these acids is 48.40 against the ideal protein content of 27.70 g/100 g of protein, that is, 74.29% higher. The qualitative and quantitative composition of AAE9 catfish meat protein is consistent with the literature data of this indicator in other freshwater fish. Thus, in the studies by L. Bal-Prylypko *et al.* (2018) the protein of carp and crass carp meat was determined to be 50.38 and 45.09 g per 100 g of these acids. Thus, channel catfish meat protein can be recommended as a source of biologically valuable animal protein in the human diet. Regularities in the composition of AAE9 in catfish and other freshwater fish meat have also been established, which are manifested in the high content of LYS (the ratio of this acid is 224% in catfish and 160 to 239% in other freshwater fish (Suleiman *et al*., 2023).

Lipids are produced, transported, and recognised by the coordinated action of numerous protein-binding enzymes and receptors. Therefore, a comprehensive analysis of lipids is crucial for understanding their impact on the nutritional value and technological properties of fish meat. The fatty acid composition of lipids is a very important indicator of the biological value of raw materials. As previously determined, the total amount of saturated fatty acids (SFA) in catfish lipids is slightly higher than the FAO/WHO recommendation, amounts to 32.61% versus 30% of lipids, and is a typical feature for other freshwater fish. Thus, in the lipids of catfish from other aquaculture conditions, the sum of these acids is set at 30.50%, in carp – 27.52 %. Among this class of fatty acids, a high content of palmitic acid F16D0 was determined – 21.93%. A similar dependence was obtained in the study of catfish meat lipids in other aquaculture conditions – 21.76% (Krogdahl *et al*., 2022) and in lipids of freshwater fish: 18.39% in carp and 24.40% in grass carp (Bal-Prylypko *et al*., 2018). Palmitic acid can simultaneously bring benefits and harm for human health, namely, positively affect the condition of the skin, take part in the synthesis of important fatty acids for humans, and support cellular functions, as noted by J.K. Grant *et al*. (2024). However, in large quantities, this acid can contribute to the deterioration of brain function, the appearance of excess weight, and cause the development of cardiovascular diseases, as noted by F.M. Sacks *et al*. (2017).

The total amount of monounsaturated fatty acids (MFA) in channel catfish lipids under aquaculture conditions in Ukraine is 33.34% less than the recommended amount (Fats and fatty acids…, 2010), which is consistent with this indicator in the main commercial freshwater fish and catfish under other aquaculture conditions. The researchers determined a total amount of MFA in the lipids of catfish aquaculture in another country is at the level of 36.33%, which is 39.45% less than recommended by FAO/WHO. The level of the sum of these acids in carp lipids is closer to their balanced content and is 49.07% (18.34% less). A characteristic feature of fatty acids of this class is the dominance of oleic acid F18DICN9 both in the lipids of catfish aquaculture of Ukraine, other aquaculture conditions, and lipids of freshwater fish. In studies of the fatty acid composition of catfish lipids in aquaculture conditions in another country, 28.08% of this acid was found (Krogdahl *et al*., 2022), in Carp-35.99% (Bal-Prylypko *et al*., 2018). Oleic acid ω-9 is not classified as essential (Grant *et al*., 2024), because it can be produced by the human body from unsaturated fatty acids and is not necessary in the diet. However, the positive effect of this acid on the duration and quality of human life, activation of lipid metabolism, and promotion of the penetration of active components into the stratum corneum of the skin has been shown. Therefore, a balanced intake of this acid is recommended.

The total amount of polyunsaturated fatty acids (PFA) exceeds the FAO/WHO recommendation by more than two times in the lipids of catfish aquaculture of Ukraine and is 21.87% against 10 (Table 2). In other aquaculture conditions, the content of these acids in catfish lipids is three times higher – 29.99% (Krogdahl *et al*., 2022). In carp lipids, the amount of PFA meets the recommendations and is 11.44% (Bal-Prylypko *et al*., 2018). In the first place in terms of quantity is linoleic acid F18D2N6 (10.99%). In the fatty acid composition of catfish lipids from other aquaculture conditions, a high content of this acid was also determined – 19.79% (Krogdahl *et al*., 2022). The lipid profile of freshwater fish is characterised by its low level: 4.86% was determined in carp, 10.66% in grass carp, and 4.54% in silver carp (Bal-Prylypko *et al*., 2018). With a sufficiently high mass fraction of polyunsaturated fatty acids (PFA) – (20.87 vs. 10% recommended), only the 1.8:1 ratio of ω-6/ω-3 fatty acids indicates the biological value of catfish meat lipids. The ratio of certain classes and individual fatty acids in an ideal lipid proposed by V.I. Zsyprian *et al.* (2007) is declarative and until further notice, experimental confirmation of these data is very limited. The effect of the ω-6/ω-3 fatty acid ratio on nutritional value has been studied to the greatest extent. This indicator has recently received considerable attention due to the participation of these acids in the regulation of lipid metabolism (Sharma & Agnihotri, 2020; Chen *et al.*, 2023). PFA deficiency of the ω-3 and ω-6 families disrupts metabolic processes in the human body, which can cause serious diseases. Low levels of essential fatty acids eicosapentaenoic (F20 : 5d5n3) – 1.37% and docosahexaenoic (F22 : 6d6n3) – 2.39% are typical for freshwater fish. Thus, in the lipids of carp, grass carp, and silver carp, these acids are present in a minimum amount: F20 : 5D5N3 – 0.56; 0.57; 1.47%, respectively; F20 : 5D5N3 – 0.43; 0.82; 0.35% (Bal-Prylypko *et al.*, 2018). Recently, these acids have received considerable attention in the human diet and are recommended for the prevention and treatment of cardiovascular and many other diseases, as indicated by P. Sharma & N. Agnihotri (2020). It was established that the use of sufficient amounts of these acids prevents the occurrence of atherosclerosis, coronary diseases, and stimulates the immune system. These acids have been shown to have anticholesterogenic and anti-lipogenic effects. The source of much-needed PFA of the ω-3 and ω-6 families is a variety of marine and oceanic species (Manson *et al.*, 2019; Menchynska *et al.*, 2021). Therefore, based on these data, it can be recommended to improve catfish meat processing technologies by enriching pasty products with fats from marine fish species to meet the daily human need for essential fatty acids F20 : 5D5N3 and F22 : 6D6N3. The technology of these products allows modelling their nutritional value with specified properties for almost all factors.

The importance of providing a person's daily needs with mineral elements is conditioned by their participation in many metabolic processes, so the results of the studies on these indicators and their agreement with the recommended values are important for evaluating the nutritional value of catfish meat. Low levels of K, Na, Mg, Fe, Z, Se, and P were found (Table 5), which cannot meet a person's daily need for these nutritional factors. Similar characteristics of the mineral composition of meat were noted by L. Bal-Prylypko *et al.* (2018) in freshwater fish. However, raw materials from freshwater fish can be used as an additional source of mineral elements. Catfish meat meets the safety requirements by the content of heavy metals such as Pb and Cd, and radionuclide $^{90}Sr$, and is consistent with the data of these indicators for other freshwater fish of aquaculture in Ukraine.

Thus, according to such indicators of nutritional value as the qualitative and quantitative composition of essential amino acids, clariid catfish meat in the conditions of aquaculture in Ukraine meets the recommendations for protein usefulness. The lipid component for the content of essential fatty acids requires the design of multicomponent food products by enriching catfish meat with lipids from marine aquatic organisms to provide the human diet with essential fatty acids F20 : 5D5N3 and F22 : 6D6N3.

## Conclusions

Aquatic food products make an important contribution to food security and nutrition, are in high demand among the Ukrainian population, and are among the most popular food groups. Over the past few decades, Ukraine has been farming *Clarias gariepinus*, a catfish that is in great demand. However, the lack of systematic studies of the nutritional value of its meat limits the improvement of processing technologies.

The biological value of catfish meat proteins is determined by the content of all essential amino acids, the sum of which is 74.72% higher than in the ideal protein according to the recommendations of FAO/WHO. The ratio of all essential amino acids is above 100% and indicates the absence of limiting ones. The composition of fatty acids and lipids of catfish meat is typical for freshwater fish and this species grown in other aquaculture conditions. A high content of palmitic acid – 21.93%, oleic acid – 31.09% and linoleic acid – 10.99% was determined. The biological value of lipids is determined by the ratio of fatty acids of the ω-6/ω-3 family as 1.8:1 at the recommended 10:5, which indicates the possibility of using lipids of this fish to regulate lipid metabolism and as a source of fatty acids of the ω-3 family that are particularly deficient in the human diet. The content of macronutrients K, Na, Mg, Fe, Z, Se, and P is significantly less than the daily requirement of an adult, but their presence in catfish meat can be an additional source of them when consumed. Catfish meat is safe in terms of the content of heavy metals Pb, Cd and the radionuclide $^{90S}$r.

Thus, the data on the nutritional value of *Clarias gariepinus* meat, grown in aquaculture in Ukraine, were obtained, namely, the biological value of protein and lipid components, the content of some essential mineral elements, heavy metals and $^{90}$Sr radionuclide. The totality of these data indicates a high biological value of proteins due to the qualitative and quantitative content of essential amino acids, the speed and sum of which exceeds the FAO/WHO recommendations for an ideal protein. Lipids are characterised by a low content of polyunsaturated fatty acids and almost no particularly valuable fatty acids EPA and DHA. However, the lipid value of this type of fish is determined by the ratio of fatty acids of the ω-6/ω-3 families as 1.8 : 1 with the recommended 10:5. Given the deficiency of ω-3 fatty acids in the adult diet, catfish lipids are of interest as a source of these acids. However, the nutritional value of any fish and other raw materials does not meet the recommendations for health-improving nutrition. Undoubtedly, the *C. gariepinus* is in great demand among the population of Ukraine. Therefore, promising areas for further research will be associated with the development of multicomponent paste products, the formulation of which is planned to be enriched catfish meat with polyunsaturated fatty acids such as eicosapentaenoic and dogosahexaenoic from marine aquatic organisms.

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## Conflict of Interest

None.

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## Харчова цінність кларієвого сомику в умовах аквакультури України

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**Анотація.** Харчова цінність сировини визначається сукупністю показників, які характеризують біологічну цінність білку, ліпідів, мінерального складу та безпеки. Тому їх дослідження у м'ясі одного із об'єктів аквакультури України – кларієвого сомику є актуальним. Мета роботи полягала у дослідженні біологічної цінності білку, ліпідів, мінерального складу, безпеки м'яса сомику при вирощуванні в Україні і оцінки цих показників у відповідності до рекомендацій ФАО/ВООЗ. Амінокислотний склад білку визначали методом іонообмінної рідино-колоночної хроматографії на автоматичном аналізаторе Т 339 (Чехія); жирно-кислотний склад ліпідів - на газовом хроматографі HRGC 5300 («Carlo Erba», Італія). Мінеральний склад м'яса досліджували методом атомно-емісійної спектрометрії з індуктивно-зв'язаною плазмою; вміст важких металів – методом атомно-абсорбційної спектрометрії. Дослідження амінокислотного складу білку визначило присутність усіх незамінних амінокислот у кількості суттєво перевищеної у ідеальному білку у відповідності до рекомендацій ФАО/ВООЗ, що свідчить про високу біологічну цінність. Жирнокислотний склад ліпідів є типовим для прісноводних риб та ліпідів сомику із інших умов аквакультури. Біологічна цінність ліпідів м'яса сомику визначається співвідношенням жирних кислот родин ω-6/ω-3 як 1,8:1,0 при рекомендованому 10:5, що свідчить про можливість використання ліпідів цієї риби у якості джерела особливо дефіцитних у раціоні людини жирних кислот ω-3. Низький рівень полі ненасичених жирних кислот та відсутність незамінних жирних кислот ейкозапентаєнової (ЕПК) та докозагексаєнової (ДГК) кислот дає підставу формувати дизайн біологічно цінних продуктів з м'яса сомику шляхом його збагачення ліпідами морських гідробіонів. Практична значимість результатів досліджень полягає в отриманні оригінальних даних щодо харчової цінності м'яса одного із об'єктів аквакультури України, визначені ступеню задоволення добової потреби людини при його споживанні та розробки рекомендацій щодо раціонального використання

**Ключові слова:** м'ясо сомику; амінокислоти незамінні; жирні кислоти; показники безпеки; важкі метали; радіонукліди