



# The impact of production systems on the meat quality of African catfish (*Clarias gariepinus*)

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**Abstract.** This study compared the physicochemical and technological qualities of African catfish (*Clarias gariepinus*) raised in recirculating aquaculture systems (RAS) and aquaponics systems (AS). The following parameters were analysed: colour, pH, water-holding capacity (WHC), cooking losses, and chemical composition. The absence of significant differences in the physical and technological characteristics, as well as for the chemical composition of the meat from African catfish reared in RAS and AS indicates that the production system does not affect the nutritional value of the meat. However, the significantly higher b\* value (blue–yellow axis) observed in fish reared in the aquaponics system compared to that in the recirculating system indicates a more intense fillet background color, leading to better consumer perception. This study provides valuable data for optimizing sustainable production systems for African catfish and improving the quality of catfish for processing and consumption.

**Keywords:** aquaponics system, physicochemical properties, RAS, technological qualities.

**Introduction.** The African catfish *Clarias gariepinus* (Burchell, 1822) is one of the most widely cultured freshwater fish species in global aquaculture. It is highly adaptable to diverse rearing conditions and grows rapidly. Its meat has favourable sensory quality (Klimuk et al 2024). It is a relatively new aquaculture species in Europe and Bulgaria (Uzunova et al 2023). In temperate regions, it is primarily raised in recirculating aquaculture systems (RAS). Due to its adaptability and low sensitivity to water quality, it is considered a good candidate for aquaponic production (Omboga 2024). African catfish meat is highly nutritious and has a favourable protein profile, making it important for producing high-quality fish products (Kyslytsia & Menchynska 2025).

The quality attributes of fish meat, including color, pH, water-holding capacity (WHC), cooking losses, and overall chemical composition, are key indicators that influence the perception of the product. These attributes may be affected by rearing conditions and production systems (Sobczak et al 2022).

As sustainable fish production systems are widely adopted, recirculating aquaculture systems (RAS) and aquaponics systems (AS) are emerging as viable approaches to optimize rearing conditions and final product quality (Lopchan Lama et al 2025). While RAS provides a high degree of control over physicochemical water parameters and enables intensive production, AS utilizes fish waste products for plant growth, thereby creating a mutually beneficial environment (Nishanth et al 2025).

Despite the growing interest in the effects of rearing conditions and feeding strategies on meat quality across various aquaculture technologies, studies addressing these factors remain limited. This study aimed to compare physicochemical and technological qualities of African catfish (*Clarias gariepinus*) raised in recirculating aquaculture systems (RAS) and aquaponics systems (AS).

## Material and Method

**Animals, supplements, and experimental design.** This research took place from 15 September to 14 December 2025. African catfish (*Clarias gariepinus*) of the same age were used in the experiment. The fish selected for this research were fingerlings weighing approximately 200 g. The fish were divided into two groups. One group was reared in a recirculating aquaculture system (RAS) consisting of six tanks, a mechanical filter, and a biofilter at the Training and Experimental Aquaculture Center of the Department of Animal Science (Non-ruminants and Special Branches) at the Faculty of Agriculture, Trakia University. The other group was raised in an integrated aquaponic system (AS), consisting of two fish tanks, a mechanical filter, and two tanks for growing mint (*Mentha piperita* L.) serving as a biofilter, at the Aquaponic Center, which is part of the Trakia University in Stara Zagora. The fish-rearing tanks in both experimental systems had a volume of 200 L each. A total of 30 fish were reared in each tank at a stocking density of 165 individuals m<sup>-3</sup>. In both systems, the fish were fed specialized 6 mm pellets from Aller Aqua (Denmark). All experimental procedures were conducted in compliance with Directive 2010/63/EU (2010) and Ordinance No. 20 (2012) regarding humane treatment of animals. Fish in both systems were reared for 90 days until they attained a mean body weight of 1000 – 1200 g. Ten catfish from each production system (RAS and AS) were euthanized, filleted, and deboned after removing their internal organs and heads. Samples were prepared to determine the physicochemical and technological meat quality parameters.

**Evaluation of the physical properties of meat.** The physical and technological quality parameters were determined in the laboratory facilities of the Agricultural Institute of Stara Zagora. The meat pH values were measured using a portable pH meter (Testo 205, Germany) equipped with a probe for solid substances and automatic temperature compensation. The meat color was determined using a Konica Minolta CR-400 portable colorimeter operating in the CIE L\*a\*b\* color space. The water-holding capacity (WHC) was determined using the classical method described by Hamm (1961). Cooking losses were determined according to the method described by Petracci and Baéza (2007).

**Determination of the chemical composition of meat.** Chemical composition was analysed in the "Meat and Meat Products" Laboratory of the Department of Animal Husbandry–Ruminants and Animal Product Technologies, Faculty of Agriculture, Trakia University, Stara Zagora, Bulgaria. The meat samples were minced, homogenized, and prepared according to the 983.18 method of AOAC (2006). Moisture content was determined by oven drying, according to the 950.46 method AOAC (1997). The crude protein content (%) was calculated based on the nitrogen content determined using an automated Kjeldahl system (Kjeltec 8400, FOSS, Sweden). Lipid content (%) was determined using an automated Soxtec 2050 system (FOSS, Sweden) according to the Soxhlet method. The ash content (%) was determined after incinerating the samples at 550°C for 8 h in a muffle furnace (MLW, Germany). The crucibles were weighed after cooling to room temperature.

**Statistical analysis.** Data analysis was performed using Statistica software (v. 14.0.0.15; 1984-2020 TIBCO Software Inc.). The experimental data are expressed as the mean and the standard deviation (mean ± SD) and standard error of the mean (SEM). The degree of confidence was determined using an independent t-test with  $p \leq 0.05^*$ ,  $p \leq 0.01^{**}$ , and  $p \leq 0.001^{***}$ , indicating different levels of statistical significance.

**Results and Discussion.** As shown in Table 1, most of the measured physical and technological parameters of African catfish meat were higher in fish reared in an aquaponics system (AS) than in a recirculating aquaculture system (RAS). However, no statistically significant differences were observed ( $p > 0.05$ ). Consistent with our findings, Wang et al (2024) reported no significant differences in the pH of the meat of largemouth bass (*Micropterus salmoides*) raised in ponds, in-pond raceways, or industrial

aquaponic systems. The only parameter that showed a statistically significant difference ( $p \leq 0.05$ ) was the  $b^*$  value (blue–yellow axis) of meat color. This value was higher in fish reared in AS than in RAS. However, Kralik et al (2022) found no significant differences in the  $b^*$  value of yellow perch (*Perca flavescens*) reared in aquaponics systems with tomatoes, in traditional ponds, or caught in the wild. Modzelewska-Kapituła et al (2022) reported higher pH values and  $a^*$  color parameters in wild pikeperch (*Sander lucioperca*) than in those reared in RAS. The authors also observed no significant differences in cooking losses between wild and RAS-reared pikeperch. Saengsuk et al (2024) reported higher pH values in giant river prawn (*Macrobrachium rosenbergii*) meat reared in traditional ponds than in vertical recirculating aquaculture systems. According to these authors, the  $L^*$ ,  $a^*$ , and  $b^*$  color parameters of the prawns' meat were significantly higher in prawns reared in RAS than in those reared in traditional ponds.

Table 1

Physical and technological parameters of African catfish (*Clarias gariepinus*) meat

Parameters	African catfish ( <i>Clarias gariepinus</i> )					
		n	mean±SD	SEM	mean±SD	SEM
pH		10	6.57 ± 0.25	0.10	6.68 ± 0.18	0.07
Colour	Inner fillet part	$L^*$	39.30 ± 1.90	0.60	41.17 ± 3.23	1.02
		$a^*$	14.13 ± 1.71	0.54	12.29 ± 2.44	0.77
		$b^*$	7.80 ± 1.19	0.38	8.06 ± 0.95	0.30
	Outer fillet part	$L^*$	41.65 ± 2.21	0.70	43.50 ± 4.85	1.53
		$a^*$	12.25 ± 2.01	0.64	12.94 ± 1.74	0.55
		$b^*$	3.86 ± 1.23 <sup>a</sup>	0.39	6.07 ± 2.57 <sup>b</sup>	0.81
WHC %		10	9.79 ± 3.47	1.42	11.64 ± 5.39	2.20
Cooking loss %		10	30.79 ± 3.14	1.28	31.38 ± 3.62	1.48

Note: Means in the same row, indicated by different superscripts, indicate a statistically significant difference between groups: a-b \* ( $p \leq 0.05$ ).

The analysis of the chemical composition of African catfish meat (Table 2) revealed no statistically significant differences ( $p < 0.05$ ) between fish reared in recirculating aquaculture systems (RAS) and those reared in traditional ponds. These results align with those of Kralik et al (2022), who also found no differences in fat and protein percentages in yellow perch (*Perca flavescens*) raised in AS with tomato seedlings, in traditional ponds, or caught in the wild. Additionally, Wang et al (2024) reported no significant differences in the moisture and ash contents of *Micropterus salmoides* meat raised in ponds, in-pond raceways, or industrial aquaponic systems. Saengsuk et al (2024) found no differences in the chemical composition of *Macrobrachium rosenbergii* meat from traditional ponds or vertical recirculating aquaculture systems. However, in contrast to our findings, Barbacariu et al (2023) reported significantly higher fat content and significantly lower moisture and ash content in European catfish (*Silurus glanis*) meat reared in recirculating aquaculture systems (RAS) compared to that reared in earthen ponds. Su et al (2025) reported lower fat content and higher protein content in mandarin fish (*Siniperca chuatsi*) meat reared in RAS than in traditional pond aquaculture systems. No significant differences were observed in the moisture and ash contents. Dai et al (2025) found higher protein content in genetically improved farmed tilapia meat from in-pond raceways and traditional ponds compared to RAS. Feng et al (2025) reported higher protein content in *Micropterus salmoides* meat reared in RAS than in fish from traditional ponds; no significant differences were observed in other chemical composition parameters. Ma et al 2024 reported higher moisture and fat content, as well as lower protein content, in common carp (*Cyprinus carpio*) meat reared in traditional pond systems compared to RAS. Modzelewska-Kapituła et al (2022) found that wild pikeperch (*Sander lucioperca*) meat had higher moisture and ash content but lower fat and protein content than fish reared in RAS.

Chemical composition of African catfish (*Clarias gariepinus*) meat

Parameters %	n	African catfish ( <i>Clarias gariepinus</i> )			
		RAS		AS	
		mean±SD	SEM	mean±SD	SEM
Moisture	10	75.63 ± 0.34	0.17	75.11 ± 0.56	0.28
Fat	10	6.27 ± 0.45	0.22	6.36 ± 0.18	0.09
Ash	10	1.08 ± 0.02	0.01	1.07 ± 0.02	0.01
Protein	10	17.02 ± 0.72	0.36	17.46 ± 0.50	0.25
Dry matter	10	24.37 ± 0.34	0.17	24.89 ± 0.56	0.28

**Conclusions.** The absence of significant differences in the physical and technological parameters, as well as the chemical composition, of African catfish (*Clarias gariepinus*) meat reared in recirculating aquaculture systems (RAS) and aquaponics systems (AS) indicates that the rearing method does not affect the nutritional value of the meat. The significantly higher b\* value observed in fish reared in the aquaponics system compared to those reared in the recirculating system indicates a more intense fillet background colour. This leads to better consumer perceptions. This study provides valuable data for optimizing sustainable production systems for African catfish and improving the quality of fish meat for processing and consumption.

**Authors Contributions.** Conceptualization: GZ. Methodology: GZ. Formal Analysis: GZ, NI, KZ. Investigation: GZ, NI, KZ. Data Curation: KZ. Writing – Original Draft: KZ. Writing – Review & Editing: NI. Supervision: GZ.

**Conflict of Interest.** The authors declare that there is no conflict of interest.

**Data Availability.** The data supporting the findings of this study are available from the corresponding author upon reasonable request.

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