PAPER

GENDER DIFFERENCES IN THE CHEMICAL COMPOSITION AND SELECTED PROPERTIES OF AFRICAN CATFISH *(CLARIAS GARIEPINUS* Burchell, 1822*)* MEAT

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ABSTRACT

The objective of this study was to analyze gender differences in the chemical composition and selected physicochemical properties of African catfish meat. The experimental material comprised fish younger than 1 year, with estimated body weight of 1 kg, cultured in an intensive fish farm. Fillet acidity (pH_{24}) was determined 24 h *post mortem*, and the color of external and internal fillet surfaces was described based on L*, a*, b*, C* and h^o values. Samples of ground meat were analyzed to determine their proximate chemical composition, energy value and TBARS levels. The meat of male and female fish was characterized by high levels of total protein and fat, a low calorific value and optimal acidity. In males, internal and external fillet surfaces were darker and characterized by higher redness (a*) and lower yellowness (b*) values. In male fillets, significant ($p \leq 0.01$) correlations were noted between water content and fat content and between protein content and crude ash concentrations. The coefficients of correlation between protein content and L* values and between ash content vs. L* and b* values were also statistically significant ($p \leq 0.01$). In meat samples collected from male fish, the values of color components a* and b* were also highly correlated. High negative correlations were observed between protein concentrations and crude fat levels, and between pH_{24} vs. TBARS values in female fillets. Color lightness was also significantly ($p \leq 0.01$) positively correlated with oxidative stability.

Keywords: African catfish, meat and fillets, chemical composition, energy value, TBARS, pH, color

1. INTRODUCTION

The geographic range of the African catfish (*Clarias gariepinus)* extends from Africa to south-east Asia. In the course of evolution, the species has adapted to unsupportive environmental conditions. In its natural habitat, the catfish is an omnivorous predator that feeds on zooplankton, arthropods, mollusks, fish, reptiles and amphibians (VITULE *et al*., 2006; AMISAH *et al*., 2009). In fish farms, the African catfish easily adapts to pond conditions and has relatively low requirements regarding water quality. The main goal of intensive cultures is to produce catfish with the highest body weight within a short period of time, which can only be achieved under optimal conditions. In commercial farms, fish weighing 800-1000 g are produced in 6-8 months. According to ADAMEK (2011), fish heavier than 1200 g are in highest demand on the Polish market. The meat of the African catfish is a valuable and cheap source of easily digestible protein of high quality. Catfish meat is pink, almost boneless and tasty, which contributes to its popularity. The chemical composition of fish meat (in particular its protein and fat content), its energy value and sensory properties such as color, texture, taste and flavor are determined by feeding intensity, type and quality of feed, as well as natural feed intake (JANKOWSKA *et al*., 2007; PUCHAŁA and PILARCZYK, 2007).
There is a general scarcity of data relating to differences in the performance traits of *C. gariepinus* females and males raised in pond cultures. Therefore, the aim of the study was to analyze gender differences in the chemical composition and selected physicochemical properties of African catfish *(C. gariepinus)* meat.

2. MATERIALS AND METHODS

2.1. Experimental fish, diets and origin

The experimental material comprised 60 African catfish (*C. gariepinus*) younger than 1 year, with estimated body weight of 1 kg, and an equal number of males and females. Fish were harvested in autumn-winter of 2013 from a freshwater fish farm in northern Poland. Catfish were cultured in a 9000 L concrete pond (intensive system) with a closed circuit system and water temperature of 25±1°C. Fish were manually fed (every 3 h) pelleted feed prepared at the farm. Feed composition was as follows (per 100 kg): 17.8 kg of fish meal, 44.6 kg of extracted soybean meal, 14.9 kg of wheat grain, 7.4 kg of corn grain, 11.9 kg of rapeseed cake, 2.4 L of fish oil, and 1 kg of a vitamin-mineral premix. The nutrient content of feed was determined at the Laboratory of the Department of Animal Nutrition and Feed Science of the University of Warmia and Mazury in Olsztyn (Poland) according to AOAC guidelines (2005). The pelleted feed mixture contained: 33.57% of total protein, 5.82% of crude fat, 6.45% of crude ash and of 3.80% crude fiber. Its energy value was determined at 17.229 MJ/kg.

2.2. Preparation of skinned fillet samples

Fish were harvested 48 hours before slaughter, they were transferred to a separate pond at the farm, cleansed, stunned and slaughtered according to standard procedures (DIRECTIVE 2009/1099/EC). Catfish were manually gutted (body cavity was slit open, viscera and blood clots were removed), decapitated (cut behind epicranium outgrowths), fins were removed (caudal, dorsal, abdominal and pectoral fins were cut off approximately 0.5 cm from the base), and fish were filleted (the entire muscle was removed and skinned). The research material comprised 60 raw fillets without skin (left

side carcass), cooled for 24 h to a temperature of 4±1°C in a Frost Co. chilling chamber with relative air humidity of 85%. All qualitative analyses were performed at the Laboratory for Meat Quality Assessment of the Department of Commodity Sciences and Animal Raw Material Processing of the University of Warmia and Mazury in Olsztyn (Poland).

2.3. Chemical composition, energy and TBARS values in meat

The fillets of male (n=30) and female (n=30) fish were ground in a laboratory grinder (three times) equipped with a 2 mm mesh, and they were thoroughly mixed to prepare samples for chemical analysis. The proximate chemical analysis involved determinations of: water content (PN-ISO, 2000a), total protein content – by the Kjeldahl method (PN-A, 2002) in Foss Tecator Kieltec 2200 System I (Höganäs, Sweden), crude fat content according- by Soxhlet extraction (PN-ISO, 2000b) in the Foss Tecator Soxtec™ Avanti 2050 extractor (Höganäs, Sweden), and crude ash content (PN-ISO, 2000c). Oxidative changes in intramuscular lipids were analyzed by measuring the content of thiobarbituric acid-reacting substances (TBARS) in accordance with the method proposed by RAK and MORZYK (2002). Absorbance was measured with the Analityk Jena AG Specord 40 spectrophotometer (Jena, Germany) and expressed in mg of malondialdehyde per 1 kg of meat. The energy value of meat was calculated using conversion factors of 4.00 kcal (16.78 kJ/g) for protein and 9.00 kcal (37.62 kJ/g) for fat (JESZKA, 2010).

2.4. Acidity and color parameters of fillets

Muscle acidity was measured 24 h *post mortem,* immediately after carcass cooling (left side carcass) (n=60), with the 340i pH-meter and WTW TFK 150/E temperature sensor (Weilheim, Germany) equipped with a Hamilton Double Pore combination glass electrode (Bonaduz, Switzerland). The pH-meter was calibrated against buffers with known pH before measurements (PN-ISO, 2002).
The color of fillets (n=60) was described based on the values of L* (lightness), a* (redness) and b* (yellowness) in the CIELAB system (CIE, 1978) by measuring reflectance on the internal surface (abdominal side) and external surface of skinned fillets (Fig. 1) at the same points relative to the surface.

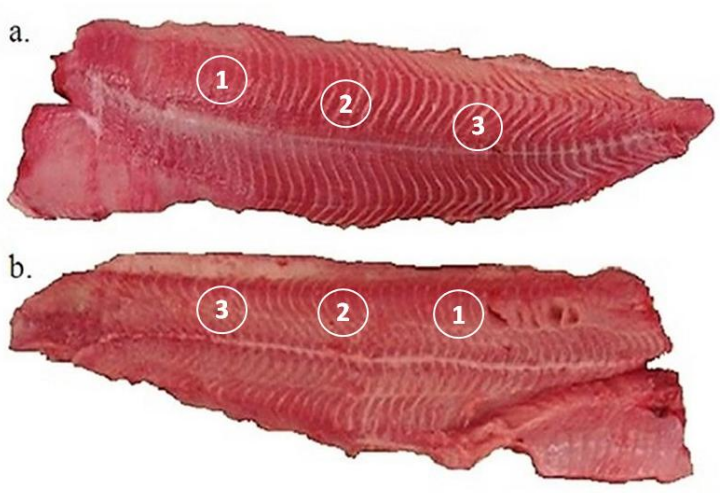

Figure 1: Color measurements on the external (a) and internal (b) surfaces of *C. gariepinus* fillets. Measurement points - 1, 2, 3 (own study).

Measurements were performed in three replications in the HunterLab MiniScan XE Plus spectrocolorimeter (Hunter Associates Laboratory Inc., Reston, VA, USA). Chroma (C*) and hue (h°) were calculated with the use of the respective formulas (HUNT *et al*., 1991):

$$C^* = \sqrt{a^2 + b^2} \text{ and } h^\circ = \tan^{-1}(b/a).$$

Color analyses were performed with D65 light source, 10° standard observer and aperture diameter of 2.54 cm. Measurements were carried out in fillets chilled at 4±1°C for 30 minutes. The spectrocolorimeter was calibrated against white and black standards before every measurement.

2.5. Statistical analysis

The results were processed statistically by one-way analysis of variance in the Statistica v. 10.0 program (2011). They were presented in tables as mean values, standard deviation and standard error of the mean (SEM). The significance of differences ($p \leq 0.05$ and $p \leq 0.01$) between the means of chemical composition, TBARS values and physicochemical properties in male (n=30) and female (n=30) catfish was analyzed by the Student's t-test. The coefficients of correlation between the analyzed groups of properties were determined separately for male and female fish. Data were checked for normal distribution (Shapiro-Wilk test) and equality of variances (Levene's test) before statistical analysis.

3. RESULTS AND DISCUSSIONS

The average protein content of fish is determined at 16-20%, but it can be as high as 25% in tuna fish. The African catfish is an interesting species in view of its processing suitability and chemical composition. According to KLASA and TRZEBIATOWSKI (1992), the muscle tissue of catfish is characterized by a low fat content (3.5%) and a high total protein content (17.9%). In a study by KAPELIŃSKI (2003), the fat content of farmed African catfish was estimated at 3-4%, which indicates that the species has a low calorific value and is particularly suited for cold smoking. ŁUCZYŃSKA *et al*. (2011) observed the lowest fat content (2.81%) in the dorsal muscle of carp, followed by trout (4.39%), whereas the highest fat levels were noted in salmon (11.57%). In this study, female fillets contained 17.42% of total protein and 5.76% of crude fat on a fresh weight basis. The above values were slightly higher than in males, but the observed differences were not statistically significant. Crude ash content, which is the total amount of mineral compounds remaining after incineration, is also an important indicator of meat quality. According to SKIBNIEWSKA *et al*., (2012), the composition and content of those nutrients in the meat of livestock animals, including fish, is determined mainly by their availability in feed as well as by the species, physiological status and age of animals. The conducted statistical analysis also confirmed that gender had a significant influence on the ash content of African catfish meat. Females were characterized by a higher (by 0.07%) crude ash content than males. In addition to higher concentrations of total protein, fat and crude ash, female fillets were also characterized by a lower water content in comparison with male fillets (75.15% in females vs. 76.03% in males). Gender differences in the chemical composition of African catfish fillets have never been explored in the literature. The only relevant information contributed by other authors (POLAK-JUSZCZAK, 2007; SKAŁECKI *et al*., 2013) was that the water content of muscle tissue in various fish species is inversely proportional to the combined content of total protein, fat and crude ash.

Table 1: Chemical composition, energy and TBARS values of meat and pH of *C. gariepinus* fillets.

Specification	Meat samples		SEM
	Male (n=30)	Female (n=30)	
Water content (%)	76.03±1.17	75.15±0.65	0.253
Total protein (%)	17.32±0.69	17.42±0.26	0.248
Crude fat (%)	5.15±1.35	5.76±0.65	0.298
Crude ash (%)	1.06^{b}±0.09	1.13^{a}±0.02	0.017
Energy value (kJ/100 g)	484.32±60.12	508.87±22.63	10.283
TBARS (mg MDA/kg meat)	0.24±0.10	0.36±0.12	0.026
pH_{24} (left-side carcass)	6.32±0.08	6.27±0.09	0.021

The results are expressed as means±SD.
The means denoted by different letters in rows differ significantly at ^{ab} ($p \leq 0.05$); SEM – standard error of the mean.

POLAK-JUSZCZAK (2007) determined the total protein content of African catfish fillets at 17.90%, free fat content at 5.30%, crude ash content at 0.98% and water content at 75.53%, and similar results were noted in our study. In comparison with the data presented in Table 1, the fresh meat of *C. gariepinus* evaluated by YANAR (2007) was characterized by significantly lower levels of fat (3.64%) and crude ash (0.68%), but somewhat higher content of protein (17.85%) and water (77.89%). In the work of GODA *et al*. (2007), the muscle tissue of African catfish administered standard feed contained 75.73% of water and 15.96% of protein. The cited authors also reported a significantly higher crude ash content (3.71%) and lower fat concentrations (4.60%). In studies of freshwater fish, the protein content of carp meat was determined at 17.21% by SKAŁECKI *et al*. (2013) and at 11.85-17.74% by PUCHAŁA and PILARCZYK (2007). Fat concentrations in carp muscles were determined at 4.44% by SKAŁECKI *et al*. (2013) and at 6.80-11.77% by PUCHAŁA and PILARCZYK (2007). Significant variations in the fat content of meat from carp and other fish species can be attributed mainly to the type of administered feed which also influences the final body weight and total length of fish (GODA *et al*., 2007; PUCHAŁA, PILARCZYK, 2007); SKAŁECKI *et al*., 2013).

The energy value of meat is determined by its carbohydrate, protein and fat content. The calorific value of an average serving of fish (100 g) ranges from less than 400 kJ to approximately 1225 kJ. Despite having higher gross energy value, fatty fish are still less calorific than other products of animal origin (JESZKA, 2010). In our study (Table 1), no statistical differences were determined between male and female fish, but a trend towards higher energy values (by 24.55 kJ) was noted in the meat of female catfish. As a species with 7% fat content, the African catfish can be classified into a group of medium-fat fish in line with the Polish Standards (PN-A, 1999). The calorific value of meat from *C. gariepinus* males and females was relatively low at 496.59 kJ/100 g on average. According to ROSA *et al*. (2007), the energy value of 100 g of fresh muscle tissue of catfish reached 457.90 kJ and was lower than the values presented in Table 1 (484.32 kJ/100 g for males and 508.87 kJ/100 g for females). Secondary products of lipid oxidation, whose presence is determined based on malondialdehyde (MDA) concentrations, are a direct symptom of autoxidation processes that adversely influence meat quality (KAMKAR *et al*., 2014). In our study, chilled muscles of both male and female African catfish were characterized by low TBARS values (0.24 and 0.36 mg MDA/kg of meat, respectively), which was indicative of high oxidative stability of lipids. In the experiment conducted by YANAR

(2007), the average TBA levels of fresh *C. gariepinus* muscles reached 0.45 mg MDA/kg. The initial MDA content of fresh silver carp fillets was determined at 0.54 mg MDA/kg by KAMKAR *et al*. (2014).

pH value is a critical determinant of microbial growth and food spoilage. The pH of fish ranges from 6.7 to 7.0, and it fluctuates subject to season, feed, exposure to stress and activity levels (MERKIN *et al*., 2010; YANAR, 2007). The data presented in Table 1 indicate that African catfish males and females were characterized by similar pH 24 h *post mortem* (6.32 in males, 6.27 in females). According to MARX *et al.* (1997), the boundary value of pH_{24} for fresh fish meat is 6.5. In a study by SKAŁECKI *et al*. (2008), cod meat was characterized by significantly higher pH_{24} (6.89) and pH_{48} (6.74) values than herring meat (6.67 and 6.49, respectively).

The analysis of color on the internal surface of African catfish fillets (Table 2) revealed that gender was significantly correlated with lightness (L*), the contribution of the red component (a*) and the yellow component (b*), and hue (h^o).

Table 2: Color parameters on the surface of *C. gariepinus* fillets.

Specification	Meat samples		SEM
	Male (n=30)	Female (n=30)	
Internal surface			
L*	46.65^{B}±1.68	49.31^{A}±0.85	0.422
a*	11.80^{A}±1.34	$8.69^{B±}$0.97	0.440
b*	$15.15^{B±}$0.92	16.55^{A}±0.41	0.220
C*	19.20±1.48	18.69±0.63	0.270
h°	52.08^{B}±1.95	62.29^{A}±2.10	1.268
External surface			
L*	41.81±1.69	43.07±1.43	0.376
a*	15.62±1.71	14.63±1.75	0.400
b*	11.20^{b}±1.39	12.71^{a}±1.52	0.365
C*	19.22±1.98	19.37±1.64	0.423
h°	35.64^{B}±1.71	40.98^{A}±2.17	0.810

The results are expressed as means±SD.

The means denoted by different letters in rows differ significantly at ^{a,b} ($p \leq 0.05$) and ^{A,B} ($p \leq 0.01$); SEM - standard error of the mean.

Female muscles were characterized by higher values of L* (49.31) and b* (16.55) in comparison with male fillets, and the observed differences were statistically significant ($p \leq 0.01$). JANKOWSKA *et al.* (2007) evaluated the quality of the meat of the European catfish *(Silurus glanis)* administered natural and formulated feed and did not find any differences in lightness or yellowness values. The L* values of the European catfish (47.98) were similar to those noted in the African catfish in our study (48.11). The contribution of yellow pigment in *C. gariepinus* fillets was determined at 15.85 on average in both sexes, and it was 5.81 higher than in *S. glanis* muscles. The color of fish meat is a species-specific trait which is determined by the number of red muscle fibers and pigment concentrations, including myoglobin, hemoglobin and carotenoids. WEDEKIND (1995) reported

significant sexual dimorphism in the quality of *C. gariepinus* fillets. The meat of males was characterized by intense red coloration, a lower fat content and higher cohesiveness (toughness) in comparison with female fillets. In our study, the value of the a* coordinate measured on the internal surface of fillets was significantly higher ($p \leq 0.01$) in males (11.80) than in females (8.69), which is consistent with the results reported by WEDEKIND (1995).
The results presented in Table 2 indicate that total chromaticity (C*) measured on the ventral side of the fillets was similar in males and females at 18.95 on average. Despite an absence of statistically significant differences, chromaticity was lower (by 0.51) in female fillets. Color hue differed significantly (at $p \leq 0.01$) between genders, and the value of h^o measured on the internal surface of fillets was higher in females (62.29).
The color profile of the external surfaces of *C. gariepinus* fillets is presented in Table 2. The values of L* and a* were not influenced by gender. Despite the above, male fillets were darker (L*=41.81) and more saturated with the red component (a*=15.62) than female fillets (43.07 and 14.63, respectively). The contribution of yellow, measured on the skinned side, was significantly higher ($p \leq 0.05$) in females at 12.71. Chromaticity (C*) on the external surface of fillets was similar in both genders at 19.22 in males and 19.37 in females. Statistical calculations revealed that color hue on the external side of the fillets was significantly higher in females (40.98) than in males (where it was up to 5.34 lower).
The data presented in Table 3 point to a highly significant ($p \leq 0.01$) negative correlation between water content and fat content (r = -0.88) in the meat of male African catfish. In male fillets, protein content was significantly ($p \leq 0.01$) correlated with crude ash levels (r = 0.84). In female meat samples, a high ($p \leq 0.01$) negative correlation was observed between protein concentrations and fat content (r = -0.85).

Table 3: Coefficients of correlation between the chemical components of *C. gariepinus* fillets.

Parameter	Total protein		Crude fat		Crude ash	
	Male	Female	Male	Female	Male	Female
Water content	0.09	0.55	-0.88**	-0.57	-0.13	0.26
Total protein	-	-	-0.50	-0.85**	0.84**	0.50
Crude fat			-	-	-0.23	-0.10

Explanatory notes: *correlation coefficients are statistically significant at *($p \leq 0.05$) and **($p \leq 0.01$).

The proximate chemical composition of fish meat was not significantly correlated with pH_{24} values in males or females (Table 4).

Table 4: Coefficients of correlation between chemical composition vs. pH_{24} and color parameters on the internal surface of *C. gariepinus* fillets.

Parameter	pH_{24}		L*		a*		b*	
	Male	Female	Male	Female	Male	Female	Male	Female
Water content	0.20	0.32	0.27	-0.16	0.29	-0.08	0.28	0.72*
Total protein	-0.12	0.44	-0.81**	-0.34	0.17	0.44	-0.45	0.31
Crude fat	-0.06	-0.60	0.06	0.38	-0.27	-0.48	-0.09	-0.13
Crude ash	-0.39	0.20	-0.76**	0.07	-0.17	-0.30	-0.77**	0.29

Explanatory notes: *correlation coefficients are statistically significant at *($p \leq 0.05$) and **($p \leq 0.01$).

A statistical analysis revealed a significant ($p \leq 0.01$) negative correlation between the protein and crude ash content of male fillets vs. color lightness measured on the internal surface of the fillets (r = -0.81 and r = -0.76, respectively). A significant ($p \leq 0.01$) negative correlation between crude ash content and the contribution of yellowness was also noted in male fillets (r = -0.77). Water content was significantly ($p \leq 0.05$) correlated with the yellow component on the external surface of female fillets (Table 5). In the meat of male catfish, a positive correlation ($p \leq 0.05$) was noted between fat content and the value of L* (r = 0.75). Protein and crude ash content were not correlated with any color parameters on the external surface of fillets (Table 5).

Table 5: Coefficients of correlation between chemical composition vs. color parameters on the external surface of *C. gariepinus* fillets.

Parameter	L*		a*		b*	
	Male	Female	Male	Female	Male	Female
Water content	-0.62	-0.35	0.44	-0.09	0.45	0.71*
Total protein	-0.48	-0.50	-0.00	0.60	-0.11	0.27
Crude fat	0.75*	0.34	-0.36	-0.43	-0.32	-0.22
Crude ash	-0.30	-0.41	-0.11	0.34	-0.16	0.35

Explanatory notes: *correlation coefficients are statistically significant at *($p \leq 0.05$) and **($p \leq 0.01$).

A significant ($p \leq 0.05$) negative correlation (r = -0.68) was observed between the lightness (L*) and redness (a*) on the internal surface of female fillets (Table 6). In male meat samples, parameter L* was positively correlated ($p \leq 0.05$) with the contribution of yellowness (r = 0.68). No significant correlations between the values of *a and *b were noted on the internal surface of male and female fillets. In the meat of female catfish, a positive correlation ($p \leq 0.01$) was observed between the values of L* and TBARS (r = 0.78), whereas a negative correlation (r = -0.78) was noted between pH_{24} and TBARS values (Table 6). In male fillets, significant correlations ($p \leq 0.05$) were noted between the values of b* and acidity (r = 0.65) and between pH_{24} and oxidative stability (r = -0.67). In an analysis of parameters measured on the external surface of catfish fillets (Table 7), an increase in color lightness was accompanied by a decrease in the contribution of redness and yellowness (r = -0.67 and r = -0.70, respectively; $p \leq 0.05$), and an increase in TBARS values (r = 0.70, $p \leq 0.05$). In male fillets, a significant positive correlation was also noted between color parameters a* and b* (r = 0.86).

Table 6: Coefficients of correlation between color parameters on the internal surface of fillets vs. pH_{24} and TBARS values.

Parameter	a*		b*		pH_{24}		TBARS	
	Male	Female	Male	Female	Male	Female	Male	Female
L*	-0.20	-0.68*	0.68*	-0.02	0.28	-0.49	-0.19	0.78**
a*	-	-	0.21	-0.01	0.50	0.05	-0.59	-0.29
b*			-	-	0.65*	-0.21	-0.60	0.01
pH_{24}					-	-	-0.67*	-0.78**

Explanatory notes: *correlation coefficients are statistically significant at *($p \leq 0.05$) and **($p \leq 0.01$).

Table 7: Coefficients of correlation between color parameters on the external surface of fillets vs. pH_{24} and TBARS values.

Parameter	a*		b*		pH_{24}		TBARS	
	Male	Female	Male	Female	Male	Female	Male	Female
L*	-0.58	-0.67*	-0.57	-0.70*	-0.10	-0.58	0.59	0.70*
a*	-	-	0.86**	0.01	0.17	0.34	-0.53	-0.52
b*			-	-	0.04	0.53	-0.29	-0.53

Explanatory notes: *correlation coefficients are statistically significant at *($p \leq 0.05$) and **($p \leq 0.01$).

4. CONCLUSIONS

A statistical analysis revealed that the chemical composition, energy and TBARS values in the meat of African catfish were not significantly influenced by gender. The analyzed fillets of male and female fish were characterized by a relatively high content of total protein, optimal concentrations of crude fat and a low calorific value. The muscle tissue of *C. gariepinus* was characterized by optimal acidity 24 h *post mortem*, and significant differences in this parameter were not observed between the genders. An analysis of color parameters revealed that the internal surface of male fillets was darker, more saturated with the red pigment (*a), less saturated with the yellow component (b*) and characterized by lower hue values (h°) in comparison with female meat samples. In female fillets, protein content was significantly correlated with fat concentrations, whereas in meat samples collected from male fish, significant correlations were noted between water content and fat content, and between total protein content and crude ash content. The value of parameter L* on the external surface of male fillets decreased with a rise in total protein and crude ash content. The contribution of yellowness (b*) was significantly correlated ($p \leq 0.05$) with water content in female fillets and with crude ash levels in male fillets ($p \leq 0.01$). In measurements performed on the external surface of male and female fillets, significant correlations were noted between fat content and color lightness, and between water content and yellowness (b*), respectively. The correlation coefficients indicate that an increase in TBARS values led to a significant increase in color lightness on the internal surface of fillets and a decrease in the pH_{24} values of female muscles. A significant ($p \leq 0.01$) positive correlation was observed between redness and yellowness on the external surface of male fillets. In conclusion, the results of this study indicate that sexual dimorphism in the African catfish significantly differentiates the color parameters of fillets, but it has no influence on the chemical composition, pH, energy values and lipid stability of meat from males and females.

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