ASSESSMENT OF GROWTH PERFORMANCE, FEED EFFICIENCY AND SURVIVAL RATE OF AFRICAN CATFISH (*Clarias gariepinus*) JUVENILES FED GRADED LEVELS OF *Capsicum annuum* OLEORESIN

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Abstract

Feed additives are widely used in aquaculture to enhance nutrient utilization, improve fish growth, and promote carcass quality. This study investigated the effect of graded levels of *Capsicum annuum* Oleoresin (CAO) as a dietary additive on growth performance, feed efficiency and survival rate of *Clarias gariepinus*. Two hundred and eighty juveniles *C. gariepinus* (6.70 ± 0.02 g) were distributed into seven groups and fed isonitrogenous diets supplemented with different levels of CAO and denoted as CAO1 – CAO 7 for 56 days at 3% body weight of 40% crude protein. Growth performance indices, feed efficiency, survival, and carcass proximate composition were evaluated using standard methods. Data were analysed using one-way ANOVA at a 5% significance level. Fish fed CAO-supplemented diets recorded numerically higher weight gain, specific growth rate and feed conversion ratio than the control, although differences were not statistically significant (P > 0.05). Feed conversion ratio was improved in CAO-fed groups, with the best value in CAO 4 (1.27 ± 0.01). Protein productive value and protein efficiency ratio were better in the treated groups compared to the control with CAO 4 showing superior values. Carcass analysis revealed significantly higher crude protein in CAO 2 (70.83 ± 0.06%) and reduced fat deposition in CAO-fed groups compared to the control. Dietary supplementation with CAO enhanced weight gain, protein retention, improved feed efficiency, and lowered carcass fat in *C. gariepinus*, suggesting its potential as a functional feed additive.

Keywords: *Clarias gariepinus;* Feed efficiency; *Capsicum annuum;* Proximate composition, Feed additive

Introduction

Fish serves as a major source of protein for human, providing significant portion of nutrient to a large proportion of people particularly in the developing world (Nwotoye *et al.,* 2007; Olusola, 2020). The global production of fish and other aquatic animals for human use occurs either by commercial fishing or through aquaculture and farming techniques. Globally, aquaculture contributed to 49.9 percent of global aquatic animal production in 2021 (FAO, 2023). According to Food and Agriculture Organization (2010), the world production of fish in 2005 consists of 93.2 million tons captured by commercial fishing in wild plus 48.1 million tonnes produced by fish farms which has increased significantly over the years. Total fisheries and aquaculture production of aquatic animals reached a record of 182 million tonnes in 2021 (FAO, 2023). Nigeria, the largest producer in sub-Saharan Africa has experienced a declining trend since 2016 worsened in 2020 with a sharp decrease of 9.6 percent (FAO, 2022).

The African catfish, *Clarias gariepinus* is an excellent aquaculture species. They are hardy, tolerate captivity conditions, attain bigger table-size in ponds, more fecundity than other farmed fish species and are highly marketable. Catfish is known to be an opportunistic omnivore capable of feeding on varied sources of food in its natural habitat. The species has high plasticity in feeding habits that can translate into its good feed conversion and subsequent fast growth rate in a variety of aquaculture conditions. The good quality coupled with its ability to feed on virtually anything makes the fish a highly recommended species for aquaculture development in Nigeria. Nutrition is a fundamental parameter in intensive fish production, being dependent on factors such as the availability of diets and the potential for investment in production (Chung, 2020). In intensive aquaculture, fish are fed only commercial feeds, and thus functional diets can contribute to the sustainability of the industry by increasing growth and heightening immunity. A great number of studies have intensively focused on application of organic-based feed additives that have stress relieving, anti-inflammatory, immunostimulant, antifungal, and antimicrobial properties (Sönmez *et al*. 2022).

Globally, *Capsicum annuum* is the most widely used type of spice because of its intense and unique flavour. The active ingredients present in CAO are capsaicinoids, and the predominant major capsaicinoid component of CAO is known as capsaicin (Pérez-Gálvez *et al*., 2007; Sricharoen *et al*., 2017). It is a valuable source of vitamins (particularly high ascorbic acid and vitamin E level) and pigments (such as xanthophylls). Capsaicinoids are known for their antioxidant and antimicrobial activities. It was found that capsicum oil (1 mg/kg) had positive impacts on growth, haematological parameters, and serum biochemical indices in trout fries (Parrino *et al*., 2020). Moreover, the dietary impacts of saponified *C. annuum* extract and *C. annuum* oleoresin (Ingle de la Mora *et al.*, 2006) on the pigmentation and fillet colour of rainbow have been demonstrated. However, there is little or no information on utilization of *C. annuum* in *C. gariepinus* which command high economic price in Nigeria. This study investigated the effect of supplementing diets with CAO on the growth performance, feed efficiency and survival rate of *C. gariepinus* juveniles on different inclusion levels of *Capsicum annuum* oleoresin.

Materials and Methods

Plant source, identification and extraction

Dried long chili pepper (*Capsicum annuum*) was purchased from a market in Okitipupa, Ondo State and identified at the herbarium unit of Olusegun Agagu University of Science and Technology, Okitipupa. The pepper was manually peeled off of the anchor stalks, washed with distilled water and allowed to air dry at ambient temperature (25°C) for one hour and extracted as described by Olusola, (2020) and Bello *et al*, (2013). 200 g of *Capsicum annuum* was blended into pulp and soaked in 100 ml of 95% ethanol for 72 hrs. The pulp obtained was left in a clean, sterile glass container, shaken vigorously to allow for proper extraction, filtered using a sterile muslin cloth after which the extract was obtained using rotary evaporator and stored (4°C) until required.

Feed formulation and preparation

The experimental diets were formulated by using Pearson's square method. Seven sets of diets at 40% crude protein were formulated and prepared as described by Bello *et al.* (2012) for *Clarias gariepinus*. *Capsicum annuum* oleoresin (CAO) was supplied at different inclusion levels of 0, 0.1, 0.2, 0.4, 0.6, 0.8, 1.0% and denoted as control, CAO_2 CAO_3, CAO_4 CAO_5, CAO_6 and CAO_7, respectively. The feed ingredients such as fish meal, soya beans, ground nut cake, yellow maize, wheat offal, starch, methionine, lysine, vitamin- mineral premix, di calcium phosphate, vegetable oil and salt were obtained from ADOM feed mill, Ibadan, Oyo State. The ingredients were manually mixed and pelletized. The pelleted diets were sundried and stored in a container at room temperature until required (Table 1). Crude ash (%), crude protein (CP; %), moisture (%), and crude lipid (CL; %) of the test diets as well as the whole body of the fish (without visceral organs and fat) were determined using the AOAC procedures described by AOAC (2005) at Olusegun Agagu University of Science and Technology, Okitipupa Central Laboratory.

Table 1: Gross and proximate composition of experimental diets (g/100g)

	Control (0%)	CAO 2 (0.1%)	CAO 3 (0.2%)	CAO 4 (0.4%)	CAO 5 (0.6%)	CAO 6 (0.8%)	CAO 7 (1.0%)
Fish meal	13.52	13.52	13.52	13.52	13.52	13.52	13.52
Soya bean meal	27.04	27.04	27.04	27.04	27.04	27.04	27.04
Groundnut Cake	27.04	27.04	27.04	27.04	27.04	27.04	27.04
Yellow maize	6.99	6.99	6.99	6.99	6.99	6.99	6.99
Wheat offal	6.99	6.99	6.99	6.99	6.99	6.99	6.99
Rice bran	6.99	6.99	6.99	6.99	6.99	6.99	6.99
Vegetable oil	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Cassava starch	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Dicalcium phosphate	2.00	2.00	2.00	2.00	2.00	2.00	2.00
*Vitamin premix	3.00	2.90	2.80	2.60	2.40	2.20	2.00
Capsicum annuum oleoresin	-	0.10	0.20	0.40	0.60	0.80	1.00
Lysine	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Methionine	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Salt	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Total	100	100	100	100	100	100	100
Proximate composition							
Moisture	7.04	7.01	7.06	7.09	7.00	6.98	7.03
Crude protein	*40.13*	*40.38*	*40.41*	*40.31*	*40.18*	*40.31*	*40.25*
Crude fibre	10.17	10.34	10.31	10.81	10.68	10.59	10.81
Ether extract	9.87	6.39	7.01	6.97	6.89	6.87	6.98
Ash	12.38	14.81	14.39	14.86	14.32	14.58	14.88
NFE	20.41	21.07	20.22	19.96	20.93	20.67	20.05
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Metabolizable energy	1687.99	1567.78	1602.06	1563.07	1580.41	1578.21	1570.42

*vitamin - minerals premix. Each 2.kg of premix contain; 12.5 million international unit (MIU); D_3, 2.5 MIU;E, 40g; K_3 2g; B1,5.5g;BB6,5g; Niacin 55g; Calcium Pantothenate 11.5g; Chlorine chloride 500g; Folic acid, Biotin,0.08g;Manganese, 120g; Iron, 100g; Zinc, 80g, Copper,8.5g; Iodine, 1.5g;Cobalt,0.3g;Selenium, 0.12g; Anti-oxidant, 120g

Experimental set up and Feeding Trials

Two hundred and eighty (280) *C. gariepinus* juveniles (6.70 ± 0.02g) were randomly distributed into 14 tanks with two replications per treatment in a completely randomised design. Acclimatization was done for two weeks. Diets were allocated randomly to the tank and the dietary groups of fish was fed at 3% body weight per day at 8.00 – 9.00 hours and 1700 hour – 1800 hours for 56 days. All fishes were removed every two weeks and weighed using a meter weight balance in order to adjust their feed ratio. At the end of 56 days feeding trials the biological evaluation was measured as described by Bello *et al.*, (2012);

Weight gain = final body weight-initial body weight

Weight gain (%) =
$$\frac{\text{final body weight} - \text{initial body weight}}{\text{initial body weight}} \times 10$$

Specific growth rate (SGR) =
$$\frac{100\ (\text{logfinal weight gain} - \text{loginitial weight gain})}{\text{Time (days)}}$$

Feed conversion ratio (FCR) =
$$\frac{\text{Dry weight of feed fed (g)}}{\text{Fish weigt gain (g)}}$$

Protein Productive Index (%) =

$$\frac{\text{Weight gain (g)}}{\text{Protein intake (g)}} \times 100$$

Survival rate (%) =

$$\frac{\text{Initial number of fish stocked} - \text{Mortality}}{\text{Initial number of fish stocked}} \times 100$$

Condition factor (k) =

$$\frac{100W}{L3}$$

Where: W= weight of fish (g); L=standard length (cm)

Nitrogen metabolism $= \frac{(0.549)(a+b)h}{2}$

Where, a = Initial mean weight of fish; b= final mean weight of fish; h= experimental periods in days.

Fish Performance Index (FPI) =

$$\frac{\text{Mean weight gain (g)} \times \text{Survival rate (\%)}}{\text{Feed Conversion Ratio (FCR)}}$$

Protein Productive Value (%) =

$$\frac{\text{Retained Protein (g)}}{\text{Protein intake (g)}} \times 100$$

Protein Efficiency Ratio =

$$\frac{\text{Weight gain (g)}}{\text{Protein intake (g)}}$$

Statistical Analysis

Data generated from the study were subjected to one – way analysis of variance (ANOVA) in a completely randomized design using SPSS version 20 (2012). Duncan multiple range tests were used to separate significant mean at P= 0.05

Results

Proximate composition of fish before and after the experiment fed CAO supplemented diets for 56 days

The carcass composition of experimental fish fed the test diets is presented in Table 2. The crude protein content of fish carcass varied significantly (P<0.05) across the different inclusion levels of CAO. The highest crude protein value was recorded in fish fed diet CAO_1 (70.83 ± 0.06%), while fish on the control diet had the lowest value (55.85 ± 0.02%). The crude protein content of the initial fish was significantly lower than that of fish sampled at the end of the feeding trial. Significant differences (P<0.05) were also observed in the ash content of the fish carcass. Fish fed diet CAO_4 had the highest ash content (12.32 ± 0.08%), whereas those on the control diet (CAO_0) recorded the lowest (11.78 ± 0.07%). Fat content differed significantly among the treatments, with the highest value observed in fish fed the control diet (4.57 ± 0.04%) and the lowest in fish fed diet CAO_3 (1.99 ± 0.00%). Similarly, significant differences (P<0.05) were found in the nitrogen-free extract (NFE) content of the experimental fish.

Table 2: Proximate composition of fish before and after the experiment fed CAO supplemented diets for 56 days

	Moisture	Crude protein	Crude fibre	Ether extract	Ash	NFE	Total
Before	6.98± 0.03	55.85±0.02	5.00±0.00	8.80±0.09	11.78±0.07	12.59±1.00	100.00
Control (0%)	$4.81{\pm}0.05^{f}$	$67.82{\pm}0.03^{a}$	$5.67{\pm}0.02^{a}$	$4.57{\pm}0.04^{e}$	$11.97{\pm}0.08^{a}$	$10.16{\pm}0.09^{f}$	100.00
CAO 2 (0.1%)	$4.35{\pm}0.04^{d}$	$70.83{\pm}0.06^{c}$	$6.61{\pm}0.05^{d}$	$2.71{\pm}0.01^{d}$	$12.03{\pm}0.09^{ab}$	$3.47{\pm}0.02^{a}$	100.00
CAO 3 (0.2%)	$4.61{\pm}0.06^{e}$	$70.82{\pm}0.05^{c}$	$5.99{\pm}0.02^{c}$	$2.61{\pm}0.01^{c}$	$12.08{\pm}0.09^{bc}$	$3.39{\pm}0.03^{b}$	100.00
CAO 4 (0.4%)	$3.95{\pm}0.00^{bc}$	$70.61{\pm}0.06^{b}$	$6.01{\pm}0.03^{c}$	$1.99{\pm}0.00^{a}$	$12.11{\pm}0.07^{c}$	$5.33{\pm}0.08^{c}$	100.00
CAO 5 (0.6%)	$3.85{\pm}0.00^{a}$	$70.13{\pm}0.02^{b}$	$5.89{\pm}0.02^{b}$	$2.01{\pm}0.01^{a}$	$12.32{\pm}0.08^{d}$	$5.80{\pm}0.06^{e}$	100.00
CAO 6 (0.8%)	$3.89{\pm}0.01^{ab}$	$70.08{\pm}0.02^{b}$	$6.00{\pm}0.03^{c}$	$2.08{\pm}0.02^{b}$	$12.11{\pm}0.07^{c}$	$5.84{\pm}0.05^{e}$	100.00
CAO 7 (1.0%)	$3.99{\pm}0.02^{c}$	$70.43{\pm}0.04^{bc}$	$5.94{\pm}0.02^{bc}$	$2.02{\pm}0.00^{ab}$	$12.08{\pm}0.06^{bc}$	$5.54{\pm}0.04^{d}$	100.00

The mean of duplicate data, mean value in each row with similar superscripts are not significantly different (P > 0.05)

Growth performance and nutrient utilization of *Clarias gariepinus* fed experimental diets for 56 days

The growth performance and nutrient utilization of *Clarias gariepinus* fed experimental diets are summarized in Table 3. The final body weight (FBW) ranged from 35.04 ± 9.42 g in the control to 44.77 ± 0.34 g in fish fed diet CAO_4, with no significant differences (P>0.05) among treatments. Weight gain (WG) and percentage weight gain (WG%) followed a similar trend. The highest WG (38.07 ± 0.34 g) and WG% (568.13 ± 5.00%) were observed in fish fed diet CAO_4, while the lowest WG (28.34 ± 9.42 g) and WG% (422.91 ± 140.52%) were recorded in the control group. However, these differences were not statistically significant (P>0.05). Survival rate (SR) varied significantly (P<0.05) among treatments, ranging from 44.50 ± 5.50% (CAO_5) to 86.00 ± 14.00% (CAO_2). The specific growth rate (SGR) did not differ significantly (P>0.05) across diets, although the highest SGR (1.69 ± 0.01) was observed in fish fed diet CAO_4, compared to 1.40 ± 0.21 in the control. Feed conversion ratio (FCR) ranged between 1.27 ± 0.01 (CAO_4 and CAO_6) and 1.86 ± 0.62 (control), with no significant differences observed (P>0.05).

Production performance index (PPI) was significantly affected (P<0.05), with the highest value (175.51 ± 28.57) recorded in fish fed diet CAO_2, while the lowest value (88.82 ± 13.23) was observed in fish fed diet CAO_5. Nitrogen metabolism (NM) also differed significantly (P<0.05), with values ranging from 349.71 ± 13.45 (CAO5) to 450.59 ± 33.62 (CAO_2). Feed protein intake (FPI) showed numerical variations, with the highest value recorded in CAO_6 (206.74 ± 104.01) and the lowest in CAO_5 (100.62 ± 4.08). Protein intake (PI) varied significantly (P<0.05), with the highest value observed in CAO_7 (20.32 ± 0.01) and the lowest in CAO_6 (15.63 ± 0.02). Protein productive value (PPV) ranged between 0.30 ± 0.00 (control) and 0.37 ± 0.01 (CAO_2, CAO_3, and CAO_4), with significant differences among diets. Protein efficiency ratio (PER) was not significantly different (P>0.05) across treatments, though values ranged from 0.71 ± 0.24 in the control to 0.95 ± 0.01 in fish fed diet CAO_4

Table 3: Growth performance and nutrient utilization of *Clarias gariepinus* fed experimental diets for 56 days

	Control (0%)	**CAO 2 (0.1%)**	**CAO 3 (0.2%)**	**CAO 4 (0.4%)**	**CAO 5 (0.6%)**	**CAO 6 (0.8%)**	**CAO 7 (1.0%)**
IBWG	6.70±0.02^{a}	6.70±0.02^{a}	6.70±0.01^{a}	6.70±0.02^{a}	6.70±0.01^{a}	6.70±0.02^{a}	6.70±0.02^{a}
FBWG	35.04±9.42^{a}	39.61±3.22^{a}	42.81±0.19^{a}	44.77±0.34^{a}	39.49±1.38^{a}	39.39±8.31^{a}	40.00±2.25^{a}
WG	28.34±9.42^{a}	32.91±3.22^{a}	36.11±0.19^{a}	38.07±0.34^{a}	32.79±1.38^{a}	32.69±8.31^{a}	33.30±2.25^{a}
WG%	422.91±140.52^{a}	491.19±48.06^{a}	538.96±2.84^{a}	568.13±5.00^{a}	489.33±20.52^{a}	487.91±124.03^{a}	497.02±33.59^{a}
SR	66.50±5.50^{ab}	86.00±14.00^{b}	72.00±0.00^{ab}	50.00±11.0^{a}	44.50±5.50^{a}	69.50±2.50^{ab}	55.50±11.50^{ab}
SGR	1.40±0.21^{a}	1.57±0.07^{a}	1.65±0.01^{a}	1.69±0.01^{a}	1.57±0.03^{a}	1.55±0.19^{a}	1.58±0.05^{a}
FCR	1.86±0.62^{a}	1.46±0.14^{a}	1.39±0.01^{a}	1.27±0.01^{a}	1.44±0.06^{a}	1.27±0.30^{a}	1.53±0.11^{a}
PPI	135.72±11.23^{ab}	175.51±28.57^{b}	146.94±0.00^{ab}	102.04±22.45^{a}	88.82±13.23^{a}	141.83±5.11^{ab}	113.36±23.47^{ab}
NM	403.52±13.46^{ab}	450.59±33.62^{b}	416.97±0.00^{ab}	363.16±26.00^{a}	349.71±13.45^{a}	410.25±6.73^{ab}	376.62±6.91^{ab}
FPI	120.32±65.39^{ab}	191.32±5.76^{a}	187.73±1.67^{a}	150.43±35.47^{a}	100.62±4.08^{a}	206.74±104.01^{a}	125.78±41.96^{a}
PI	18.81±0.02^{b}	19.20±0.01^{d}	20.21±0.01^{f}	19.48±0.02^{e}	18.92±0.01^{c}	15.63±0.02^{a}	20.32±0.01^{g}
PPV	0.30±0.00^{a}	0.37±0.01^{a}	0.37±0.01^{b}	0.37±0.01^{b}	0.36±0.00^{b}	0.35±0.00^{b}	0.36±0.00^{b}
PER	0.71±0.24^{a}	0.82±0.08^{a}	0.90±0.01^{a}	0.95±0.01^{a}	0.82±0.04^{a}	0.81±0.21^{a}	0.83±0.06^{a}

IBW = Initial body weight gain, FBWG = Final body weight gain, WG = Weight gain, WG% = Percentage weight gain, SR = Survival rate, SGR = Specific growth rate, FCR = Feed conversion ratio, PPI = Production performance index, NM = Nitrogen metabolism, FPI = Fish performance index, PI = Protein intake, PPV = Protein productive value, PER = Protein efficiency ratio. The mean of duplicate data, mean value in each row with similar superscripts are not significantly different (P > 0.05)

Discussion

In this study, the final body weight (FBW), weight gain (WG), and specific growth rate (SGR) exhibited numerical increases with diets containing *Capsicum annum* Oleoresin (CAO), the differences were not statistically significant (P > 0.05), however, the increase suggests that the ingredient may enhance growth performance. This suggests that CAO inclusion did not impair growth potential of the experimental fish. This is in agreement with the report of Agbanimu and Adeparusi (2020) that a non-significant increase was observed in *C. gariepinus* fed deffatted African Palm weevils. Ebeneezar et al. (2020) also observed that higher SGR and WG% were recorded in clown fish fed diet supplied with paprika oleoresin (20 g/kg) in comparison with the control.

Feed conversion ratio (FCR) improved in diets containing CAO, with the lowest FCR observed in CAO$_3$ (1.27 ± 0.01). Though the differences were not statistically significant, this trend suggests enhanced feed utilization with CAO inclusion. The lower FCR indicates better feed utilization by the fish and is justified by better growth performance of fish fed CAO. This agrees with the report of Falaye *et al*., (2016) who reported a lower FCR in *C. gariepinus* fed sun flower seed meal diets compared to the control. Shofura et al. (2017) who stated that the lower the feed conversion ratio value, the more optimal the absorption of nutrients in the feed which is then used for growth so that weight gain is better. The lower a feed conversion value indicates the level of efficiency of good feed utilization. However, if the feed conversion value is higher, the efficiency of feed utilization is not good. It can be said that the value of feed conversion illustrates the level of efficiency of feed utilization achieved (Iskandar, 2015). These assertion of Shofura et al. (2017) supports the present study.

Production performance index (PPI) was significantly influenced, with CAO$_2$ yielding the highest PPI (175.51 ± 28.57) and CAO$_4$ the lowest (88.82 ± 13.23). This suggests that moderate inclusion of CAO enhances the efficiency of protein utilization. Nitrogen metabolism (NM) similarly showed significant differences (P < 0.05), which was moderate in CAO diets (e.g. CAO$_2$). These results point to better energy retention and protein conversion in those treatments. Protein intake (PI), protein productive value (PPV), and fish performance index (FPI) also varied among treatments, with CAO$_6$ showing the highest PI (20.32 ± 0.01) and control the lowest. This may reflect differential feed consumption, digestibility, or retention efficiencies across diets. Protein efficiency ratio (PER) did not differ significantly, though CAO$_3$ had one of the higher values. This suggests that overall protein conversion per unit protein fed was not drastically altered across diets. The pattern of improved FCR, PPI, FPI and specific growth rate (SGR) in CAO-fed groups can be interpreted as increased digestibility or bioavailability of nutrients when CAO is appropriately included.

The survival rate varied significantly among treatments, this trend was inconsistent with dietary inclusion levels of CAO. This suggests that factors other than diet may have contributed to the observed mortality. According to Karimah *et al.* (2018), fish survival is influenced by biotic and abiotic factors, namely competitors, stocking density, age and ability to adapt to the environment.

The carcass composition of *Clarias gariepinus* fed CAO-supplemented diets in this study, showed a significant improvement in crude protein content compared with both the control and the initial fish sample, indicating enhanced nutrient utilization and protein retention as a result of dietary CAO inclusion. According to Suleiman *et al*. (2019), the carcass proximate composition of fish serves as a reliable indicator of the physiological and nutritional status of fish in aquaculture systems. The increase observed in the crude protein agrees with report of Ali (2022) who reported that final fish carcass composition showed higher crude protein values for *Clarias gariepinus* fed betaine additive diet and attributed it to the optimum utilization level of the diet. Fish fed CAO-supplemented diets showed lower carcass fat content than the control group, which suggests that more of their energy was directed toward muscle growth instead of fat storage. The moisture content of fish fed CAO-based diets was also lower than that of the control, which may be attributed to increased dry matter concentration resulting from higher protein deposition. Similar results have been reported in *Clarias gariepinus* and other fish species (Abdel-Tawwab *et al*., 2010; El-Dakar *et al.*, 2017). Although the ash content of the fish varied among treatments, the values were within normal ranges for *C. gariepinus*, which means that CAO did not affect mineral balance in the fish.

Conclusion

Dietary CAO inclusion at moderate levels appears to enhance feed efficiency and protein utilization without substantially depressing growth or survival. The improved carcass composition characterized by higher protein, lower moisture, and reduced fat demonstrates the potential of CAO as a functional feed additive that enhances growth performance and feed efficiency, supports muscle development, and improves carcass quality in *C. gariepinus*.

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