Open Journal of Animal Sciences, 2024, 14, 123-136
https://www.scirp.org/journal/ojas
ISSN Online: 2161-7627
ISSN Print: 2161-7597

Effect of the Dietary Substitution of Fish Meal with *Achatina fulica* Meat Meal on the Growth Performance and Production Cost of African Catfish (*Clarias gariepinus*) Fingerlings

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How to cite this paper: Ewane, D., Andoh, A.A., Ambeno, F.N., Nkemnyi, B.A., Arrey, M.A., Oben, B.O. and Oben, P.M. (2024) Effect of the Dietary Substitution of Fish Meal with *Achatina fulica* Meat Meal on the Growth Performance and Production Cost of African Catfish (*Clarias gariepinus*) Fingerlings. *Open Journal of Animal Sciences*, **14**, 123-136.
https://doi.org/10.4236/ojas.2024.142009

Received: November 7, 2023
Accepted: April 26, 2024
Published: April 29, 2024

Abstract

Fishmeal is the most preferred source of protein in aquafeeds, but it is expensive and scarce. Hence, *Achatina fulica* meat meal (AFM), which is much less preferred for human consumption out of three species of African giant land snails, was tested as a fishmeal substitute for *Clarias gariepinus* growth. Five iso-nitrogenous and iso-calorific diets were formulated, in which AFM substituted fish meal at 0% (control or Diet A), 25% (Diet B), 50% (Diet C), 75% (Diet D) and 100% (Diet E). These dietary treatments were each replicated thrice in a completely randomized design experiment, using 36-L plastic tanks in which the fish were fed daily rations corresponding to 5% of their body weight, for 8 weeks. Water quality parameters in the tanks were monitored. Proximate analyses were conducted on the fish meal, snail meal and experimental diets before the feeding trials. Cost-benefit analysis of the different diets was performed. The crude protein content of AFM (69.18%) was significantly higher than that of fish meal (55.81%). There was no significant difference ($P > 0.05$) in the mean weight gain, specific growth rate, feed conversion ratio, protein efficiency ratio and survival rate in fish fed Diet A and Diet B. The best protein efficiency ratio (0.77) was recorded in fish fed Diet B. Furthermore, the survival rate of fish increased with increased levels of AFM substitution. Water quality parameters were within a suitable range for tropical fish culture, indicating that the AFM did not pollute the water. The fish fed 25% AFM diet significantly ($P < 0.05$) had the lowest cost per kg of fish produced, the highest cost differential and the highest relative cost advantage, compared to all the other four diets. Therefore, AFM is an alternative protein source to fish meal in *Clarias gariepinus* diets at a 25% substitution level. The aquaculture industry can thus exploit the availability of this feed resource.

Keywords

Fish Meal, *Achatina fulica* Meat Meal, Aquafeeds, *Clarias gariepinus*

1. Introduction

Profitable farm animal production is dependent on feed, which may account for up to 70% of the cost [1] [2]. Other components of animal production such as reproduction, breeding, animal health and welfare, play supporting albeit important roles [3]. Feeds have generally been valued based on their protein and energy content. Proteins constitute the main cost in the feed of farmed aquatic animals compared to their terrestrial counterparts. This is because aquatic animals have comparatively higher protein requirements. Consequently, fishmeal is the most preferred source of protein in aquafeeds because of its high content of quality protein. Unfortunately, fishmeal is expensive and scarce. Statistics indicate that the global price of fishmeal increased by 350% while soybean increased by 150% within the same period [4]. This has prompted the search for whole and partial substitution strategies for fishmeal.

There is a paucity of information on the use of *Achatina fulica*, as one of the African giant land snails, in the diets of African catfish (*Clarias gariepinus*). *Achatina fulica* meal has been assessed for its nutritive value and utilization in the diets of broiler chickens [5], laying chickens [6] and gestating rabbits [7]. However, *Achatina fulica*, as one of three species of African giant land snails, is least preferred for human consumption compared to the other two species (*Archachatina marginata* and *Achatina achatina*). This is because it has a very soft body and there are some taboos concerning its consumption by humans. Therefore the use of *Achatina fulica* in fish diets may reduce competition between humans and farmed animals for food. This study aims to investigate the growth performance of *Clarias gariepinus* fingerlings fed *Achatina fulica* meat meal at different substitution levels in replacement of fish meal in fish diets.

Clarias gariepinus constitutes the largest group of cultured fish species in the world after carp, salmonids and tilapia, and it grows well under various culture systems. It is an omnivorous scavenger that eats everything it finds, therefore, *C. gariepinus* is particularly amenable to the farming practices of smallholders, who comprise the majority of farmers in developing countries. There is demand for the African catfish as food and for the control of over-population in mixed-sex tilapia culture in earthen ponds-"police fish" [8] [9]. According to [10] *Clarias* *gariepinus* is favored for controlling tilapia recruitment because it fetches higher market prices than other "police" species. The above importance of the African catfishes as a farm animal has prompted their use in the feeding trials of many other conventional and non-conventional feedstuffs.

2. Materials and Methods

2.1. Collection and Processing of Snails

The study was carried out at the Institute of Agricultural Research for Development (IRAD) at Ekona in the South West Region of Cameroon. Adult *Achatina fulica* snails were purchased from a local snail collector, who collected the snails from farms around Ekona. Good quality snails having no cracks or wounds on the shell, with the slime clearly present, were selected and euthanized by immersion in hot water, after which the flesh was extracted from the shells using wire spokes. They were gutted, washed and oven-dried at 70˚C for 2 days [5]. The dried snails were then ground and used in the formulation of the experimental diets.

2.2. Experimental Diets

The proximate composition of experimental feed ingredients: *Achatina fulica* meat meal (AFM), fish meal (FM), maize, groundnut cake, soybean meal and wheat bran were obtained using the methods of AOAC [11]. These were then used to formulate five iso-nitrogenous and iso-calorific diets with graded levels of AFM replacing fish fishmeal. The control treatment was diet A, having zero AFM. The test treatments were Diet B (25% AFM), Diet C (50% AFM), Diet D (75% AFM) and Diet E (100% AFM), as shown in **Table 1**. After formulation, the dried powdered ingredients were measured using a sensitive electronic scale balance with an accuracy limit of 0.1 g (OHAUS CS SERIES) and thoroughly mixed for 30 minutes to ensure homogeneity. The resulting wet dough was further mixed to a given consistency and pelleted into 2 mm pellets with a dry pelletizer (Stak-Pellet mill). The pelleted feed was dried for one hour in sunlight, then packaged in covered plastic bowls and labelled before storing at room temperature.

2.3. Experimental Set-Up and Management

The experiment was done in a completely randomized design, comprising five treatments with three replicates each. Each replicate was a plastic tank with dimensions 0.47 × 0.32 × 0.24 m, having a volumetric capacity of 36 L. Before the start of the experiment, the tanks were cleaned and disinfected using Virunet® and then allowed to dry for 24 hours, after which they were filled with dechlorinated tap water (which had been obtained by allowing tap water to stand for 24 hours) to two-thirds of the volume of the tanks. Water in the culture media was regularly changed. Daily, solid wastes were siphoned out before feeding. The tanks were washed and disinfected and the water completely changed, weekly.

Table 1. Gross composition of formulated experimental diets.

Ingredients (g/100g dry diet)	A (0% AFM)	B (25% AFM)	C (50% AFM)	D (75% AFM)	E (100% AFM)
Fish meal	32.0	24.0	16.0	8.0	0.0
Snail meal	0.0	8.0	16.0	24.0	32.0
Yellow maize	20.0	20.0	20.0	20.0	20.0
Groundnut cake	20.0	20.0	20.0	20.0	20.0
Soya bean meal	18.0	18.0	18.0	18.0	18.0
Wheat bran	5.0	5.0	5.0	5.0	5.0
Palm oil	1.5	1.5	1.5	1.5	1.5
Common salt	0.5	0.5	0.5	0.5	0.5
Bone meal	1.0	1.0	1.0	1.0	1.0
Cassava meal	1.0	1.0	1.0	1.0	1.0
Premix**	1.0	1.0	1.0	1.0	1.0
Total	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

*AFM = *Achatina fulica* meat meal. **Premix: composed (mg vitamin and mineral/kg premix): vitamin A 4,800,000 IU, vitamin D_3 800,000 IU, vitamin E4800 mg, vitamin K 800 mg, thiamine 600 mg, riboflavin 2800 mg, vitamin B_3 4800 mg, pyridoxine 600 mg, vitamin B_{12} 4 mg, folic acid 200 mg, cobalt 160 mg, copper 1200 mg, iron 9000 mg, iodine 480 mg, magnesium 2730 mg, manganese 28,000 mg, zinc 20,000 mg.

2.4. Fish Stocking

Clarias gariepinus fingerlings (averaging 3.31 ± 0.18 g mean weight and 7.6 ± 0.16 cm mean total length) were bought from the IRAD Batoke fish hatchery in Limbe and transported to the research site at IRAD Ekona. Hand aerators were used to supply oxygen to the fingerlings during transportation. They were acclimatized for 2 weeks in 50 L aerated plastic holding tanks, during which time the fishes were fed the control diet. Deaths due to transportation, stress and the effect of the new conditions of dissolved oxygen (DO), pH (hydrogen potential) and temperature of the new environment were monitored during this period. After the two-week acclimation period and prior to stocking, the fingerlings were starved overnight to clear their gut. Two hundred and twenty-five fingerlings were then randomly sorted, weighed individually and stocked in the aerated experimental tanks at the rate of fifteen fingerlings per tank. The fingerlings were fed at 5% body weight twice daily between 8 am and 9 am in the morning, and between 2 pm and 3 pm in the afternoon except on days before sampling, for a period of 8 weeks. The quantity of feed in each tank was then adjusted weekly in accordance with weight gain of fish and the number of fish present in each tank. The tanks were monitored daily for fish mortality; dead fish were removed, counted and the number recorded.

2.5. Determination of Growth and Nutrient Utilization Parameters

The fishes were starved 24 hours before data collection so as to clear their gut. The lengths and weights of all the fishes present in each tank were measured using a transparent meter rule and a sensitive electronic scale with an accuracy limit of 0.1 g (OHAUS CS SERIES), respectively. Physico-chemical properties of water quality, such as dissolved oxygen, water temperature and pH were measured and recorded weekly, using a Lutron® dissolved oxygen meter (LT, DO-5509), a Combo-pH/EC meter (HANNA-HI 98130) and a pocket-sized pH meter (PH-107), respectively.

Proximate analyses were conducted on the fish meal, snail meal and experimental diets before the feeding trials, and on carcasses of whole fish after the feeding trials, using methods proposed by AOAC [11].

The amount of feed given to the fingerlings was used to compute the growth and nutrient utilization parameters [12] as follows:

$$\text{Mean weight gain} = \text{Wf} - \text{Wi}$$

(where Wi = initial body weight, Wf = final body weight, n = number of fish and t = duration of experiment in days).

Relative growth rate = Weight gain/Initial body weight × 100

Specific growth rate = (LogWf − LogWi)/t × 100

Feed conversion ratio = Feed supplied (g)/Weight gain (g)

Protein efficiency ratio = Mean weight gain (g)/Mean protein intake

(where mean protein intake = Feed supplied × % Protein of diet)

Survival rate = 100 × Number of fish at end of experiment/Number of fish stocked

2.6. Cost-Benefit Analysis of Diets

Cost of feed (cost per kg diet) was calculated based on the prevailing cost of ingredients at the time the experiment was conducted. The cost of *Achatina fulica* meat meal was calculated based on the cost of purchase and the cost of processing. From the cost per kg diet, the total feed consumed during the whole period of the experiment and the total weight gain of the fingerlings, the following were calculated:

$$\text{Cost per kg weight gain}(\text{frs/kg}) = \frac{\text{Cost per Kg diet}(\text{Frs per kg}) \times \text{Total feed consumed}(\text{kg})}{\text{Total weight gain}(\text{kg})}$$

Cost differential (frs/kg) = Cost/kg weight gain of control diet–cost/kg weight gain of test diet:

$$\text{Relative cost advantage}(\%) = \frac{\text{Cost differential}}{\text{Cost per kg weight gain of control}} \times 100$$

2.7. Statistical Analysis

All data collected were computed in Microsoft Office Excel version 2007 and analyzed using the software GraphPadInStat Version 3.5 (2000). The Kolmogorov-Smirnov test was used to test for normality. The independent samples t-test was used to compare the means of two data sets. ANOVA was used to compare more than two means of normally distributed data and the Tukey-HSD test for means separation. Where data departed from normal distribution, the Kruskal-Wallis test was used to compare groups for significant differences. Confidence level was set at 95% (Alpha = 0.05).

3. Results

3.1. Proximate Composition of Fish Meal and *Achatina fulica* Meat Meal

The proximate composition of fishmeal and *Achatina fulica meat meal* is indicated in Table 2. The crude protein content and metabolisable energy of AFM (69.18% and 2465 kcal/kg, respectively) were higher than those of fish meal (55.81% and 1893.5 kcal/kg, respectively); while the ether extract content of AFM (7.03%) was similar to that of fish meal (7.83%). Furthermore, the ash content of AFM (3.63%) was significantly lower than that of fish meal (22.85%), while the organic matter content of AFM (96.36) was significantly higher than that of fish meal (47.37%).

3.2. Physico-Chemical Water Quality Parameters

The mean values and ranges of the physico-chemical water quality parameters of the different experimental treatments during the experimental period are shown in Table 3. Highest mean water pH (7.43 ± 0.05) and dissolved oxygen (5.26 ± 0.106 mg/L) were recorded in Treatment A, while lowest pH (7.14 ± 0.05) and dissolved oxygen (4.20 ± 0.14 mg/L) were recorded in Treatment E. The highest and lowest mean temperatures were recorded in Treatment C (26.7˚C ± 0.19˚C) and Treatment E (26.66˚C ± 0.19˚C), respectively. All the above values fall within the recommended aquaculture ranges for *Clarias gariepinus*.

Table 2. Proximate composition of fish meal and *Achatina fulica* meat meal used for the experiment.

Components	Fish meal	*Achatina fulica* meat meal	T-test*
Crude protein (% DM)	55.81 ± 7.79	69.18 ± 9.79	P = 0.001
Ether extract (% DM)	7.83 ± 1.86	7.03 ± 2.34	P = 0.238
Ash (% DM)	22.85 ± 4.88	3.63 ± 0.96	P = 0.001
Crude fibre (% DM)	3.79 ± 0.95	0.58 ± 0.3	P = 0.001
Metabolisable Energy (kcal/kg DM)	1893.50 ± 402.06	2465.00 ± 249.86	P = 0.001
Dry matter (%)	91.1 ± 16.47	84.45 ± 11.38	P = 0.146
Organic matter (% DM)	47.37 ± 10.92	96.36 ± 12.21	P = 0.001

*Independent samples t-test. There is significant difference at P < 0.05.

Table 3. Ranges and mean values of the physico-chemical water quality parameters measured in the different treatments during the study.

Parameter	Statistic	Tanks fed diets with *Achatina fulica* meat meal at substitution rate of:					ANOVA	Recommended range (Author[s])
		Diet A (0%)	Diet B (25%)	Diet C (50%)	Diet D (75%)	Diet E (100%)		
Water temperature (˚C)	Range	25.4 - 27.7	25.8 - 27.6	26.0 - 27.6	26.0 - 27.4	26.0 - 27.3	P = 0.933	20 - 30 (Viveen *et al.*, 1985)
	Mean ± SE	26.5 ± 0.3^{a}	26.6 ± 0.2^{a}	26.7 ± 0.2^{a}	26.7 ± 0.2^{a}	26.7 ± 0.2^{a}		
pH	Range	7.23 - 7.60	7.13 - 7.60	7.03 - 7.50	6.90 - 7.40	6.93 - 7.37	P = 0.018	6.5 - 9.0 (Wurts and Durborow, 1992)
	Mean ± SE	7.43 ± 0.00^{a}	7.35 ± 0.05^{ab}	7.24 ± 0.05^{ab}	7.25 ± 0.07^{ab}	7.14 ± 0.05^{b}		
Dissolved oxygen (mg/L)	Range	4.17 - 5.73	4.33 - 5.50	4.00 - 4.93	4.10 - 4.83	3.50 - 4.87	P = 0.000	5 - 8 (Bhatnagar and Devi, 2013)

SE = Standard error of mean. ^{a,b,c}Tukey-HSD: Means on the same row with the same superscript are not significantly different (P > 0.05).

3.3. Growth Performance and Nutrient Utilization of *Clarias gariepinus* Fingerlings

The substitution of fish meal with *Achatina fulica* meat meal in the experimental diets affected the growth of the fish. The relative growth rate was significantly reduced (P < 0.001) by increasing levels of substitution of fishmeal with AFM. However, although the specific growth rate also decreased with the inclusion of AFM, Diets B and C corresponding to 25% and 50% levels of AFM substitution, respectively, were statistically similar to the control-diet A—with 0% AFM. Diet C was also similar (P > 0.05) to diets D and E in specific growth rates.

A summary of the growth performance and nutrient utilization of the fingerlings is shown in Table 4. The final mean body weight of *Clarias gariepinus* fingerlings decreased with increasing substitution levels of AFM in the diets. The final mean body weight for fish fed diet B (25% AFM) (10.43 g) was statistically similar (P > 0.05) to 10.69 g recorded for fish fed the control diet A (0% AFM). However, the final mean weight for diets A and B were significantly higher (P < 0.01) compared to the other diets (C = 7.68 g, D = 7.08 g and E = 6.85 g). The protein efficiency ratio was also statistically similar (P > 0.05) for Diets A = 0.77 and B = 0.83, but significantly lower for diets C = 65, D = 56 and E = 52.

The survival rate was high in all five diets. However, the highest value was recorded in fishes fed a 100% AFM diet (86.66%) and this differed significantly (P < 0.01) from the survival rates of fish fed the other four diets.

3.4. Carcass Composition of the Flesh of *Clarias gariepinus* Fingerlings Fed *Achatina fulica* Meat Meal Diets

The proximate analysis of the carcasses of fish after the experiment (Table 5) indicates that fish fed AFM diets had higher crude protein content but were

Table 4. Growth performance and nutrient utilization of *Clarias gariepinus* fingerlings fed different substitution levels of *Achatina fulica* meat meal in their diets for 56 days.

	A (0% AFM)	B (25% AFM)	C (50% AFM)	D (75% AFM)	E (100% AFM)	ANOVA
Initial mean total length (cm)	7.77[a]	7.87[a]	7.99[a]	8.02[a]	8.04[a]	P > 0.05
Initial mean weight (g)	3.32[a]	3.53[a]	3.38[a]	3.41[a]	3.61[a]	P > 0.05
Final total length (cm)	11.9[a]	10.73[ab]	10.69[abc]	10.24[bc]	9.9[c]	P = 0.0001
Final mean weight (g)	10.69[a]	10.43[a]	7.68[b]	7.08[b]	6.85[b]	P < 0.01
Mean weight gain (g)	7.37[a]	6.90[ab]	4.30[bc]	3.67[bc]	3.24[c]	P = 0.0001
Relative growth rate (%)	222.50[a]	195.58[b]	127.34[c]	107.62[d]	89.70[e]	P < 0.0001
Specific growth rate (%)	0.91[a]	0.84[ab]	0.64[abc]	0.56[bc]	0.49[c]	P = 0.0001
Feed conversion ratio	2.87[a]	3.11[ab]	3.60[abc]	4.41[bc]	5.89[c]	P = 0.0001
Protein efficiency ratio	0.77[a]	0.83[a]	0.65[b]	0.56[c]	0.52[c]	P < 0.0001
Survival rate (%)	60[c]	60[c]	60[c]	73.3[b]	86.66[a]	P < 0.0001

AFM = *Achatina fulica* meat meal. [a,b,c]Tukey-HSD: Means on the same row with the same superscript are not significantly different (P > 0.05).

Table 5. Carcass composition of *Clarias gariepinus* fed the various experimental diets for 56 days.

Proximate Components	Diets of *Achatina fulica* meat meal at substitution rate of:					ANOVA
	Diet A (0%)	Diet B (25%)	Diet C (50%)	Diet D (75%)	Diet E (100%)	
Crude protein (% DM)	55.63 ± 8.4[a]	56.11 ± 8.08[a]	60.26 ± 7.18[a]	58.45 ± 8.06[a]	56.9 ± 7.95[a]	P = 0.346
Ether extract (% DM)	14.42 ± 3.34[a]	11.69 ± 2.89[ab]	11.73 ± 2.21[ab]	12.13 ± 4.04[a]	13.27 ± 3.11[a]	P = 0.032
Ash (% DM)	20.40 ± 4.94[a]	23.65 ± 4.43[a]	20.98 ± 6.2[a]	19.18 ± 5.35[ab]	18.72 ± 4.34[ab]	P = 0.026
Crude fibre (% DM)	4.50 ± 1.54[a]	4.30 ± 1.38[a]	4.1 ± 1.4[ab]	3.23 ± 1.05[b]	3.22 ± 1.07[b]	P = 0.003
ME (kcal/kg DM)	3503.30 ± 662.5[a]	3239.70 ± 614.6[a]	3368.8 ± 679.0[a]	3541.2 ± 636.4[a]	3623.4 ± 664.8[a]	P = 0.370
Organic matter (% DM)	79.59 ± 11.37[a]	76.34 ± 8.88[a]	79.01 ± 8.93[a]	80.81 ± 8.93[a]	81.20 ± 7.35[a]	P = 0.423

DM = Dry matter. [a,b]Tukey: Values on the same row with the same superscript are not significantly different (P > 0.05).

lower in ether extract and crude fiber contents compared to the control. However, fish fed diets B (25% AFM) and C (50% AFM) had higher contents of ash but lower content of metabolisable energy, compared to the other treatments including the control.

3.5. Cost-Benefit Analysis

The cost per kilogram diet of the experimental diets decreased significantly with increased snail meal substitution, hence Diet A had the highest cost per kg of diet (544.1 FCFA/kg or USD 0.90/kg), while Diet E had the lowest cost per kilogram of diet (384.1 FCFA/kg or USD 0.63/kg). However, Diet B (25% AFM) had the lowest and best cost per kilogram weight gain (1508.43 FCFA/kg or USD 2.48), the highest and best cost differential (50.34 FCFA/kg or USD 0.083/kg), as well as the highest and best relative cost advantage (3.33%), as shown on Table 6.

Table 6. Economic evaluation of *Clarias gariepinus* growth performance following the consumption of *Achatina fulica* meat meal based-diets for 56 days.

Economic Parameter	Treatment					ANOVA
	Diet A (0% AFM)	Diet B (25% AFM)	Diet C (50% AFM)	Diet D (75% AFM)	Diet E (100% AFM)	
Cost/100g diet (FCFA/100g)	54.41	48.41	46.4	41.41	38.41	
Cost/kg diet (FCFA/kg)	544.1[e]	484.1[d]	464.1[c]	414.1[b]	384.1[a]	P < 0.0001
Cost/kg diet (USD/kg)	0.9	0.8	0.76	0.68	0.63	
Cost/kg weight gain (FCFA/kg)	1558.77[b]	1508.43[a]	1672.92[c]	1813.08[d]	2252.44[e]	P < 0.0001
Cost/kg weight gain (USD/kg)	2.57	2.48	2.75	2.98	3.71	
Cost differential (FCFA/kg)		50.34[a]	−114.15[b]	−254.31[c]	−693.67[d]	P < 0.0001
Cost differential USD/kg)		0.083	−0.2	−0.42	−1.14	
Relative cost advantage (%)		3.23[a]	−7.32[b]	−16.31[c]	−44.5[d]	P < 0.0001

AFM = *Achatina fulica* meat meal. [a,b,c,d]Tukey: Values on the same row with different superscripts are significantly different (P < 0.05).

4. Discussion

The results of the proximate analysis indicated that the *Achatina fulica* meat meal used in this study had a nutritive value comparable with that of fish meal. The AFM used in this study had 69.18% crude protein content and 7.03% ether extract while the fish meal had 55.81% crude protein content and 7.83% ether extract; this makes AFM suitable for substituting fish meal in the diets of fish and other animals. The crude protein for AFM was lower than that reported by [13] for *Achatina fulica* (83.13), but higher than those reported by [5] and [7] (62.4% and 39.2% respectively) (P < 0.05). It was also higher than the crude protein of 63.45% reported by [14] for *Achatina achatina*, but closer to the value reported by [12] for the *Limicolaria aurora* (66.76%).

The ash content (which represents the minerals in a food substance) of AFM (3.63%) was similar to that reported by [12] (4.10%). The higher ash content of fish meal (22.85%) is attributed to the fact that the fish meal was produced from whole fish including all the bones, while the AFM was produced from the snail meat only, excluding the shell. The higher organic matter content of AFM (96.36) compared to that of fish meal (47.37%) further confirms the suitability of AFM as a source of animal protein in fish feed.

In the present study, the best growth performance and nutrient utilization parameters were recorded in fingerlings fed the control diet (0% AFM) and Diet B (25% AFM). This implies that lower substitution levels of AFM in the diet of *Clarias gariepinus* fingerlings favor an enhanced growth rate. The mean weight gain of *Clarias gariepinus* fingerlings in this study decreased in response to higher levels of AFM in replacement of fish meal. The values and trend of the mean weight gain of *Clarias gariepinus* fingerlings in response to AFM substitution of fish meal in this study (7.37 g, 6.9 g, 4.3 g, 3.67 g and 3.24 g for 0%, 25%, 50%, 75% and 100% substitution levels, respectively) were higher and disagreed with those reported by [12] who reported mean weight gains of 2.76 g, 4.17 g, 3.11 g, 2.61 g, and 3.05 g for *Clarias gariepinus* fingerlings fed 0%, 25%, 50%, 75% and 100% garden snail meal respectively; and by [15] who reported mean weight gains of 1.78 g, 2.49 g, 1.94 g, 1.56 g, and 1.93 g for *Clarias gariepinus* fingerlings fed 0%, 25%, 50%, 75% and 100% garden snail meal diets, respectively.

The specific growth rate was highest in fingerlings fed the control diet (0.91%/day), which was not significantly different (P > 0.05) in fingerlings fed the 25% AFM diet (0.84%/day). These values were higher than those reported by [12] (0.54%/day and 0.71%/day for *Clarias gariepinus* fingerlings fed 0% and 25% garden snail meal diets, respectively); and by [15] (0.51%/day and 0.56%/day for *Clarias gariepinus* fingerlings fed 0% and 25% garden snail meal diets, respectively).

The feed conversion ratio was best in fingerlings fed the control diet (2.87), which was not significantly different (P > 0.05) from that in fingerlings fed the 25% AFM diet (3.11). These were lower and better than the feed conversion ratio obtained by [16] in *Clarias gariepinus* fingerlings fed toad (*Bufo regularis*) meal (4.45, 7.06, 10.29, 12.06 and 5.87 at 0%, 25%, 50%, 75% and 100% substitution levels, respectively). A lower feed conversion ratio indicates better utilization of the feed by the fish fed this diet [12]. However, the feed conversion ratio was relatively much higher in fish fed snail-based diets above 50% substitution levels (4.41 in fish fed Diet D, and 5.89 in fish fed Diet E) than that in fish fed the control diet (2.87), indicating that there will be more "trash" from the fingerlings fed the snail-based diets [12]. Nevertheless, all the diets supported the growth of the trial fish. This was an indication that all the diets met the nutrient requirements (crude protein = 32% - 40%) of fish to promote growth and tissue development [17], with better results observed in fish fed diets with crude protein levels above 35% for the African catfish in question [18].

The highest protein efficiency ratio (0.83) was obtained in fingerlings fed the 25% AFM diet, but was not significantly different (P > 0.05) from (0.77) observed for fingerlings fed the control diet. This agrees with results obtained by [19] who reported a protein efficiency ratio of 1.21 and 1.24 in *Clarias gariepinus* fingerlings fed diets containing 0% and 25% garden snail offal meal as a substitute for fishmeal, respectively. The ability of an organism to convert nutrients, especially protein, positively influences its growth performance [12] and the protein efficiency ratio is a measure of how well the protein sources in a diet can provide the essential amino acid requirements of the fish [20]. Therefore Diet B, which has the highest protein efficiency ratio (0.83), is most suitable for the growth of *Clarias gariepinus* in the present study.

It has been recorded that up to 6% substitution of *Achatina achatina* meal in grower diets for broiler chicks had no negative effects on weight gain, feed conversion ratio and the utilization of protein and energy when fed for a shorter period during 7 - 28 days of age [21]. This study shows that *C. gariepinus* may utilize *Achatina fulica* meat meal better than broilers because even at 25% substitution of fish meal and a longer feeding period (56 days), higher protein efficiency ratio as well as similar weight gain and feed conversion ratio were observed relative to those in fishes fed the control diet without snail meal.

The high survival rates recorded with increased AFM substitution (60% for each of Diets A, B and C and 73.3% and 86.66% for Diets D and E, respectively) indicate that feeding *Clarias gariepinus* fingerlings with a snail meal diet could enhance survival of fish. This is corroborated by [12] who observed the highest survival rate (97.5%) in *Clarias gariepinus* fingerlings fed a 100% garden snail meal diet. This may probably be due to better feed conversion and nutrient utilization of fish in the snail-based diets. It is known that living organisms incorporated into animal feeds enhance the survival and healthy state of fish at their early stages [22]. Mortality was thought to be caused by stress due to handling and management, especially during measurements of fish weight and length.

The generally higher crude protein levels in the carcass of *Clarias gariepinus* fingerlings fed diets containing *Achatina fulica* meat meal than in the control diet is an indication of the suitability of *Achatina fulica* meat meal as a substitute for fish meal in fish diets. The average carcass crude protein and ether extract contents of the test fish (57.46% and 12.65%, respectively) also show that the fish produced is rich in nutrients when compared to results of previous works: 62.34% and 7.22% reported by [16]; 64.44% and 13.38% reported by [23]. *Achatina fulica* meat meal is therefore a good candidate to partially replace fish meal in the diets of *C. gariepinus.*

The health and subsequent growth of fish are directly related to the quality of water in which the fish are raised [24]. Changes in the environment of fishes impose stress on them and the larger and faster the changes, the greater the stress. Therefore, the maintenance of water quality parameters is essential for obtaining maximum yield in a facility. The water quality parameters in each treatment were adequate for fish growth. The temperature, dissolved oxygen, and pH agreed with the values recorded in the reports of [25].

The progressive decrease in cost per kilogram of diet from 544.1 FCFA/kg (USD 0.90) for control diet (0% AFM) to 384.1 FCFA/kg (USD 0.68) for diet E (100% AFM) is simply due to the higher cost of fish meal (1000 FCFA/kg or USD 1.65) relative to that of *Achatina fulica* meat meal (500 FCFA/kg or USD 0.82). However, Diet B (25% AFM) had the lowest and best cost per kilogram weight gain (1508.43 FCFA/kg or USD 2.48). The positive and best cost differential (50.34 FCFA/kg or USD 0.083) obtained for Diet B as opposed to those obtained for diets C, D and E (−114.15 FCFA, −254.31 FCFA and −693.67 FCFA respectively), means that less money (50.34 FCFA or 0.083) will be spent in producing a kilogram of fish using diet B as compared to the control diet. Therefore, for every 100 kg of fish produced using Diet B, a farmer would save 5034 FCFA (USD 8.28) compared to another farmer who feeds his fish using the control diet (0% AFM). Conversely, increasing the level of AFM levels in diets—C (50%, AFM) D (75% AFM) and diet E (100% AFM)—increased production costs beyond that in the control diet. Diet B also showed a positive and the best relative cost advantage (3.33%) of production over the control diet, while Diets C, D, and E (with −7.23%, −16.31% and −44.5%) instead showed relative cost disadvantages with respect to the control diet respectively. Diet B is therefore most suitable for *Clarias gariepinus* culture due to its lower cost of production over the control diet as well as its higher cost differential and relative cost advantage over the control diet and Diets C, D and E.

5. Conclusion

The nutrient value of one of the three African giant land snails, *Achatina fulica* meal, and its acceptance by the African catfish (*Clarias gariepinus*) indicate that *Achatina fulica* meat meal is an alternative protein source to fish meal in African catfish diets, at 25% substitution level. The aquaculture industry can thus exploit the availability of this feed resource. Future research should focus on mass capturing of *Achatina fulica* in areas where it constitutes an agricultural pest and then transforming it into fish and livestock feeds.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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