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GROWTH PERFORMANCE, FEED UTILIZATION AND ECONOMIC ANALYSIS OF *Clarias gariepinus* JUVENILES FED DIFFERENT INCLUSION LEVELS OF AFRICAN STAR APPLE PULP (*Chrysophyllum albidum* Linn)

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Abstract
This study investigated the effect of African star apple pulp (ASA) on growth performance, feed utilization and economic analysis of *Clarias gariepinus* juveniles for 8 weeks. Six experimental diets 40% CP were formulated for the fish to contain African star apple pulp at different inclusion levels (0.0, 5, 10, 15, 20 and 25%) and denoted as ASA_1 – ASA_6 respectively. Two hundred and forty (240) *C. gariepinus* juveniles with the initial body weight of 14.20±0.2g were replicated twice with 20 fish per replicate fed at 3% body weight. Growth performance and feed utilization indices such as Weight Gain (WG), Specific Growth Rate (SGR), Percentage Weight Gain (PWG), Feed Conversion Ratio (FCR), Survival Rate (SR), Nitrogen Metabolism (NM), and Production Performance Index (PPI) were determined using standard methods. Results showed that *C. gariepinus* fed the control diet had better values of WG, PWG, SGR, and NM among the dietary groups, but ASA_3 had a significantly higher WG, PWG, SGR, and NM of 39.22g, 276.23%, 1.00g and 1039.50g respectively when compared with other treated groups. There were significant differences (P< 0.05) in these values when compared to the control. The highest Cost of Flesh Gain (CFG), Profit Index (PI), Net Production Value (NPV), Gross Profit (GP), Benefit-Cost Ratio (BCR) and Economic Conversion Ratio (ECR) were obtained in control than other dietary groups. The CFG, PI, NPV, GP. BCR and ECR were varied significantly (P <0.05) among the dietary groups. The results suggest that the partial replacement of African star apple pulp with rice bran in the diet of the experimental fish could be a potential, less expensive and promising replacement that would positively enhance weight gain, feed conversion ratio, and economic performance of *C. gariepinus* juveniles.
Keywords: *Clarias gariepinus, Chrysophyllum albidum*, Economic performance, Growth performance, Feed utilization

Introduction

Aquaculture is the cultivation of aquatic organisms which includes fish, mollusks, crustaceans, amphibians and algae in enclosed water bodies. Although its origin dates back to 475 BC, fish farming started in Nigeria in the 1950s (Omitoyin, 2007). Fish contributes over 40% of the total dietary protein consumption of Nigerians and is a staple source of protein of the average Nigerian diet (Ajani *et al.*, 2011). It is relatively cheaper than most other types of animal protein (Olusola *et al.*, 2020.). It is also a rich source of essential amino acids (EAAs) such as lysine, leucine, valine, tryptophan, histidine and methionine suitable for complementing a high carbohydrate diet (Falaye, 2013). Aquaculture has gained more popularity in recent years than it was decades ago in terms of yield nationally and globally. Yields have increased by 10% per annum throughout the past decades (Food and Agricultural Organisation FAO, 1994). This accounts for 30% of the world's food fish production. As fish continues to expand, it has been noted that certain constraints are impeding the realization of the desire to solve the malnutrition problem in Nigeria. The major constraints are a lack of sufficiently good quality fish seed and the unavailability of cost-effective nutritive fish feeds (Falaye and Oloruntuyi, 1998).

Feed is one of the major inputs in aquaculture production and fish feed technology is one of the least developed sectors of aquaculture particularly in Africa and other developing countries of the World (Gabriel *et al.*, 2007). The high cost of fish feed was observed as one of the problems hampering aquaculture development in Nigeria (Gabriel *et al.*, 2007). Expensive feeds will marginalize or even nullify the profitability of fish farming thereby incapacitating the expansion of farms to increase production and consequently low yield in terms of quality and quantity, resulting in the scarcity of the commodity (fish) and eventually the high cost of the few available ones to the disadvantage of the populace (Adikwu, 1992). Fish feed account for at least 60% of the total cost of production (Gabriel *et al.*, 2007). This has motivated the research for local, cheap and unsuitable for direct human consumption as alternative energy feed for *Clarias gariepinus* that aim to reduce the cost of production without compromising fish quality. The overall effect of food insecurity is not only inadequate food production but also imbalances in the nutritional status of the populace at large. The dearth of animal products in the diet of an average Nigerian increase yearly, mainly due to poverty, high cost of animal feeds, political and economic instability coupled with decreased interest in animal production with greater efforts directed towards petroleum exploitation. Feeds in aquaculture are formulated with a balance of nutrients to meet specific nutrient requirements for different species, life stages and other purposes.

Chrysophyllum albidum, from the Sapotaceae family, is commonly found in the Central, Eastern and Western parts of Africa (Amusa *et al.*, 2003; Adebayo *et al.*, 2010). The family Sapotaceae is of the order Ericales. The family comprises seventy (70) genera and eight hundred (800) species. Twenty-three (23) genera and over three hundred (300) species are found in West Africa including *Chrysophyllum, Kanton*, *Mimusops, Breviea*, *Delipdora* and *Manikara* (Abolaji and Adiaha, 2015). *Chrysophyllum albidum* is widely distributed in Nigeria, Uganda, Niger, Cameroon and Cote d‟voire (Adebayo *et al.*, 2006). The name *Chrysophyllum* is coined from the Greek word for "Golden leaf" which depicts the colour of the leaves of some of its species.

Chrysophyllum albidum is used as a remedy for yellow fever, malaria, anti–inflammatory, antioxidant activities, tonic, diuretic, febrifuge, anti-diarrhea, cancer and coronary heart diseases, antihyperglycemic and hypolipidemic effects (Burits and Bucar, 2002; Ige and Gbadamosi, 2007; Ajetunmobi and Towolawi, 2014; Ilondu and Bosah, 2015). However, there is a dearth of information on the use of *C. aldidum* on aquatic animals such as *C. gariepinus*. Hence, this work focuses on the growth performance, feed utilization and economic analysis of *C. gariepinus* juveniles fed African Star Apple (*Chrysophyllum albidum*) at different inclusion levels.

Materials and Methods

Identification of Plant, Source and Processing

The African star apple was bought from Ogbese market in Akure, Ondo State. The fruit or pulp of *C. albidum* was sundried for 4 weeks and ground into fine powder. The plant was identified at the herbarium unit of Olusegun Agagu University of Science and Technology, Okitipupa where a voucher specimen was deposited for future reference.

Experimental Fish

Four hundred (400) *C. gariepinus* juveniles average weight 14.2±0.02g were obtained from a renowned fish farm in Okitipupa, Ondo State, Nigeria. Fish were transported to the Fisheries and Aquaculture Laboratory, Olusegun Agagu University of Science and Technology, Okitipupa in a modified plastic jerry can containing sufficient water from the farm. The fish were acclimatized for 7 days and fed twice daily with imported feed (blue crown) containing 40% crude protein.

Formulation and Preparation of Experimental Diet

Six experimental diets were formulated at 40% crude protein diets using Pearson's square method to determine individual ingredient contribution at g/100g diet. The feedstuffs such as fish meal, soybean, maize, wheat offal, rice bran, vitamin-mineral premix, starch, vegetable oil, Di-calcium phosphate, groundnut cake, were obtained from Elegbeji Farms Limited, Odogbolu, Ogun State. African star apple was incorporated at different inclusion levels of 0%, 5%, 10%, 15%, 20% and 25%. These ingredients were mixed thoroughly using the manual method and each diet was treated separately. The powder African star apple pulp was added as feed additives in the study as a partial replacement for rice bran. Water was added and thoroughly mixed until the dough was obtained and pelleted through a 2mm die pelleting machine to form a noodle-like strand which was manually broken into suitable sizes for the *Clarias gariepinus*. The pelleted diets were sundried and stored in airtight nylon at room temperature to prevent mycotoxins formation until required (Table 1)

Experimental System

The experiment was carried out in twelve plastic tanks (50 x 34 x 27cm^3) for 8 weeks in the Fisheries and Aquaculture Laboratory of Olusegun Agagu University of Science and Technology, Okitipupa, Ondo State. The water level was maintained at the volume of 40 litres throughout the experimental period. Water in each tank was changed every three (3) days throughout the experiment to prevent fouling as a result of feed residues and faeces. The source of water was from the Olusegun Agagu University of Science and Technology, Okitipupa (OAUSTECH) borehole.

Experimental Procedure and Feeding Trials

The experiment was composed of six treatments (6) and each treatment has two replicates, 20 fishes per replicate with a mean initial weight of 14.20± 0.2g and uniform-sized fish were selected from 400 juveniles. Weighed and distributed in plastic tank. The fish was acclimatized for seven days in plastic tanks before the experiment. The fish were fed twice daily (morning and evening) at 3% body weight for 8 weeks. Measurement of the weight changes was done every week and the feeding rate is adjusted to the new body weight.

Table 1: Gross composition of the experimental diet (g/100g) fed to *C. gariepinus* Juveniles

Ingredients	Control (0%)	ASA_2 (5%)	ASA_3 (10%)	ASA_4 (15%)	ASA_5 (20%)	ASA_6 (25%)
Groundnut cake	26.28	26.28	26.28	26.28	26.28	26.28
Fishmeal	13.14	13.14	13.14	13.14	13.14	13.14
Soybean	26.28	26.28	26.28	26.28	26.28	26.28
Yellow maize	8.43	8.43	8.43	8.43	8.43	8.43
Wheat offal	8.43	8.43	8.43	8.43	8.43	8.43
Rice bran	8.43	8.01	7.59	7.17	6.74	6.32
Vegetable oil	2.00	2.00	2.00	2.00	2.00	2.00
Starch	2.00	2.00	2.00	2.00	2.00	2.00
DCP	1.00	1.00	1.00	1.00	1.00	1.00
Lysine	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
Vit-min premix	2.00	2.00	2.00	2.00	2.00	2.00
ASA	-	0.42	0.84	1.26	1.69	2.11
Total	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**

*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.**Proximate composition of experimental diet using standard methods of AOAC, (2005), ASA = Africa Star Apple

Growth Performance and Feed Utilization Indices

Growth performance indices such as weight gain, percentage weight gain, survival rate, specific growth rate, feed conversion ratio, nitrogen metabolism and protein efficiency ratio were calculated as described by Olusola and Olawoye, (2019).

Economic Performance

Economic performance of producing catfish using African star apple was carried out with emphasis on profit index, the incidence of cost determination, investment cost analysis, gross profit, and net production value as described by Ajang *et al.*, (2018); Bello *et al.*, (2012).

$$\text{Profit index} = \frac{\text{Value of fish produced (\#/Kg)}}{\text{Cost of feed used in production (Kg)}}$$

$$\text{Incidence of cost} = \frac{\text{Cost of feed used in production (Kg)}}{\text{Total weight of fish produced (kg)}}$$

$$\text{Economic Conversion Ratio (ECR)} = \frac{\text{Cost of the diet}}{\text{Feed conversion ratio}}$$

Investment Cost Analysis (ICA) = Cost of feeding + cost of fingerlings stocked

Net Production Value (NPV) = Mean weight gain of fish (g) x total survival x cost per kg

Gross Profit (GP) = NPV – ICA

Benefit Cost Ratio (BCR) = NPV/ICA

Determination of Phyto -constituents of African Star Apple (*C. albidum*)

The phyto – constituents of African star apple pulp such as saponins, tannins, flavonoids, triterpenes, phenols, glucosinolates, steroids, proteins and amino acid were obtained as described by Olusola *et al.*, (2017).

Statistical Analysis

All data were subjected to one-way analysis of variance (ANOVA) using SPSS (Statistical Package for Social 2006 version 20.0). Duncan multiple range tests were used to compare differences among individual mean (P<0.05).

Results

Phyto -constituents of African Star Apple (*C. albidum*)

Preliminary phytochemical investigation of the fleshy fruit pulp of African star apple revealed the presence of saponins, tannins, flavonoids, triterpenes and steroids, proteins and amino acid and phenols while glucosinolates were absent Table 2.

Table 2: Phytochemical constituents of *C. albidum* pulp

Phyto-constituents	*C. albidum*
Saponins	+++
Phenol	+++
Tannins	+++
Flavonoids	+++
Glucosinolates	_
Triterpenes and Steroids	++
Proteins and Amino acids	++

Low = + Moderate = ++ High = +++ Absent = -

Growth Performance and Nutrient Utilization of *C. gariepinus* fed Different Inclusion Levels of *C. albidum* Pulp for 8 weeks

The result shows that weight gain was highest (39.27) in fish fed the control diet and lowest (24.56) in fish fed 25%. Feed conversion ratio (FCR), were not significantly different (p>0.05) among the dietary groups with the least value (1.4) in the control and highest in fish fed ASA_5 (1.90). The highest specific growth rate was recorded in the control group (1.04) and lowest in ASA_6 (0.78) and there were significant differences (p<0.05) among the dietary groups. The highest nitrogen metabolism (NM) was recorded in the control (1040) and the lowest value in ASA_6 (814.03) (Table 3).

Table 3: Growth performance and nutrient utilization of *C. gariepinus* fed African star apple for 56 days

Parameters	Control (0%)	ASA_2 (5%)	ASA_3 (10%)	ASA_4 (15%)	ASA_5 (20%)	ASA_6 (25%)
Initial Weight (g)	14.20±0.00^a	14.20±0.00^a	14.20±0.00^a	14.20±0.00^a	14.20±0.00^a	14.20±0.00^a
Final Weight (g)	53.47±3.78^a	43.53±4.98^a	53.43±13.74^a	40.71±0.71^a	39.02±2.92^a	38.76±0.46^a
Weight Gain (g)	39.27±0.01^e	29.33±0.02^d	39.23±0.04^e	26.51±0.07^c	24.82±0.02^b	24.56±0.06^a
Percentage Weight Gain (%)	276.60±0.6^f	206.52±0.04^d	276.23±0.03^e	186.66±0.09^c	174.79±0.06^b	172.93±0.01^a
Specific Growth Rate(g)	1.04±0.06^{bc}	0.87±0.08^{ab}	1.00±0.21^c	0.82±0.02^{ab}	0.79±0.06^a	0.78±0.01^a
Feed Conversion Ratio	1.40±0.10^a	1.72±0.20^a	1.50±0.40^a	1.81±0.03^a	1.90±0.15^a	1.90±0.02^a
Survival Rate (%)	80.00±2.50^a	90.0±0.0^a	80.00±2.50^a	85.00±0.0^a	90.00±0.10^a	92.50±2.50^a
Nitrogen Metabolism (g)	1040.00±0.00^e	877.35±0.08^d	1039.50±0.00^e	844.00±0.04^c	818.11±0.02^b	814.03±0.00^a
Production Performance Index	59.49±1.82^a	69.95±8.00^a	59.02±12.95^a	61.78±1.07^a	62.19±2.23^a	64.04±2.49^a

Economic Performance of *Clarias gariepinus* fed the Experimental Diet for 8 weeks

The result revealed that the cost of flesh gain, profit index, net production value, gross profit, benefit-cost ratio and economic conversion ratio were varied significantly (P <0.05) among the dietary groups. ASA_3 performed better than other treated groups and there were significant differences (P<0.05) among the dietary groups (Table 4)

Table 4: Economic analysis of the differently inclusion levels of African star apple as replacement for rice bran in the diet of *C. gariepinus* juveniles

INGREDIENTS	CONTROL (0%)	ASA_2 (5%)	ASA_3 (10%)	ASA_4 (15%)	ASA_5 (20%)	ASA_6 (25%)
Groundnut cake (44% CP)	8.94	8.94	8.94	8.94	8.94	8.94
Fishmeal (72% CP)	52.56	52.56	52.56	52.56	52.56	52.56
Soybean (42% CP)	18.40	18.40	18.40	18.40	18.40	18.40
Yellow maize (10% CP)	3.70	3.70	3.70	3.70	3.70	3.70
Wheat offal (18% CP)	1.44	1.44	1.44	1.44	1.44	1.44
Rice bran (11% CP)	0.50	0.48	0.46	0.44	0.40	0.38
Vegetable oil	2.00	2.00	2.00	2.00	2.00	2.00
DCP	0.40	0.40	0.40	0.40	0.40	0.40
Starch	0.40	0.40	0.40	0.40	0.40	0.40
Lysine	2.60	2.60	2.60	2.60	2.60	2.60
Methionine	4.40	4.40	4.40	4.40	4.40	4.40
Vit-premix	8.00	8.00	8.00	8.00	8.00	8.00
Africa star apple	-	0.06	0.12	0.18	0.24	0.30
Total amount (cost /kg feed) ₦	103.34^{a}	103.38^{ab}	103.42^{bc}	103.46^{cd}	103.48^{cd}	103.52^{d}
Cost/ kg flesh gain (₦)	236.22^{e}	175.98^{c}	235.32^{d}	159.06^{b}	147.12^{a}	147.06^{a}
Profit index	2.29^{d}	1.70^{c}	2.28^{d}	1.54^{b}	1.42^{a}	1.42^{a}
Incidence of cost	1.93^{a}	2.37^{b}	1.94^{a}	2.54^{c}	2.65^{d}	2.67^{d}
Investment cost analysis	703.34^{a}	703.38^{ab}	703.42^{bc}	703.46^{cd}	703.48^{cd}	703.52^{d}
Net production value	65095.93^{f}	54578.44^{d}	64898.11^{e}	46626.32^{b}	46230.72^{a}	48208.23^{c}
Gross profit	64392.59^{f}	53875.06^{d}	64194.69^{e}	45922.86^{b}	45527.24^{a}	47504.71^{c}
Benefit-cost ratio	92.55^{f}	77.59^{d}	92.26^{e}	66.28^{b}	65.72^{a}	68.52^{c}
Economic conversion ratio	73.81^{e}	60.10^{c}	68.95^{d}	57.16^{b}	54.46^{a}	54.48^{a}

Mean value in each row with similar superscripts are not significantly different (p>0.05), cost of fish /kg at the prevailing market prices in Ondo State, Nigeria (October, 2021) is #800.00

Discussion

The result of the phytochemical analysis of *C. albidum* revealed the presence of saponins, tannins, triterpenes and steroids, phenol and flavonoids, while glucosinolates were absent. This result was similar to the report of MacDonald *et al.*, (2014), Akaneme, (2008) who reported the presence of saponins, tannins, flavonoids, terpenoids, proteins, and steroids in medicinal herbs. Flavonoids and tannins are likely to be responsible for the free radicals scavenging activities because their phenolic compounds which in turn are good primary antioxidants or free radical scavengers (Lalisa, 2017). The biological functions of flavonoids include protection against allergies, inflammatory, free radical scavenging, platelets aggregation, microbes, ulcers, hepatoxina, viruses and tumours (Okwu and Omodanuro, 2005; Okwu and Emenike, 2006).

The result of this study shows that the control group performed better than the treated groups. Weight gain and specific growth rate are usually considered as the most important measurement of productivity of diets. The experimental fish showed a great increase in weight, which indicates that the fishes were able to convert feed protein to extra muscles, and this revealed no inhibition in the consumption of the diets among the dietary groups but these values were significantly different ($P< 0.05$) among the dietary groups. The variations observed in growth performance among the dietary groups could arise as a result of protein utilization in the diets. The decrease in weight gain and feed conversion ratio among the *C. gariepinus* fed *C. albidum* based diets could be due to the effect of anti-nutritional factors in the *C. albidum*. The best food conversion ratio of 1.40 was recorded in the control diet, followed by ASA_3 (1.50) and lowest in ASA_5 and ASA_6 (1.90), they were no significant differences ($P> 0.05$) among the dietary groups. The growth rate of *C. gariepinus* fed control and ASA_3 (10% inclusion) diets were better than other treated groups. This study agrees with the report of Adeosun *et al.*, (2019) who recorded better weight gain and feed conversion ratio in the control diet of *C. gariepinus* fed *C. albidum* seed meal. Jenkins and Atwal, (1994) reported that saponins reduced growth, feed efficiency and interfere with the absorption of dietary lipids, cholesterol, vitamin A and E in livestock (fish) which is consistence with the report of this study.

The value of specific growth rate (SGR), feed conversion ratio (FCR), and nitrogen metabolism (NM) decreased with an increase in the inclusion level of *C. albidum* based diets. There were no significant differences ($P.>0.05$) among the dietary groups for FCR while a significant difference ($P<0.05$) was observed in SGR and NM among the dietary groups. This result was similar to the report of Adeosun *et al.* (2019) who observed a decrease in FCR and SGR in *Clarias gariepinus* fed varying inclusion levels of *C. albidum* seed meal. This finding disagrees with Alatise *et al.*, (2014) who reported better feed utilization in *C. gariepinus* juveniles fed Jatropha seed meal based diets.

The economic conversion ratio, which relates to the cost of diet and feed conversion ratio was higher in control compared to the other dietary groups. Also, the results of profit index show that the cost of feed affects both growth and profitability in catfish culture. This present study corroborates the report of Limbu, (2015) that the effect of different diets on the growth and cost-effectiveness of African catfish, that incidence cost reflects the cost of feed used to produce a kilogram of fish. The incidence of cost increased as the quantity of *C. albidum* increased in the treated groups. Also, the cost of the feeds increased as the quantity of rice bran was being replaced partially with *C. albidum* among the dietary groups. The result revealed that better economic performance was recorded in cost of feed per kg diet, cost of flesh gain, profit index, net production value, gross profit, benefit-cost ratio and economic conversion ratio of the control than other dietary groups. The cost of flesh gain, profit index, net production value, gross profit, benefit-cost ratio and economic conversion ratio were varied significantly (P <0.05) among the dietary groups. However, ASA_3 performed better than other treated groups and there were significant differences (P<0.05) among the dietary groups. When compared the values obtained in the control with ASA_3 (10% inclusion), these values were relatively similar and there were no significant differences (P >0.05) between the control and ASA_3. The results agree with Bello *et al.*, (2012) who reported the lowest cost of feed for producing 1 kg of fish feed for *C. gariepinus* fed walnut and onion bulb based – diets. Also, this study was similar to Ajang *et al.*, (2018) who reported the lowest cost of feed and economic performance in the control than the other dietary groups. However, this study disagrees with Bob-Manuel and Erondu, (2004) who reported that the cost of the feeds decreased as the quantity of fishmeal was being replaced by yeast in the diet of *Oreochromis niloticus.*

Conclusion

Chrysophyllum albidum is abundant in Nigeria and extremely less expensive compared to other feed ingredients. This study revealed that inclusion of 10% *C. albidum* pulp in the diet of *C. gariepinus* juveniles as a replacement for rice bran could positively enhance weight gain and profitability in organic aquaculture.

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