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Growth performance and nutrient utilization of *Clarias gariepinus* fed processed rice chaff substituted diet

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Abstract
Aquaculture faces increasing pressure to develop sustainable and cost-effective feed ingredients to meet the growing demand for fish protein. This study investigated the growth performance and nutrient utilization of *Clarias gariepinus* juveniles fed diets containing processed rice chaff meal as a substitute for conventional feed ingredients. The proximate composition analysis of the experimental diets revealed variations in nutrient content across different inclusion levels of rice chaff meal. Fish fed diets containing 50% rice chaff meal exhibited optimal growth performance parameters. Mean weight gain, relative growth rate, and specific growth rate were highest in this group, with mean weight gain reaching 95.41g/fish. Survival rates were also favorable, with the highest survival rate of 98.77% observed in fish fed the 50% rice chaff diet. However, variations were observed in feed intake, feed conversion ratio, protein intake, and protein efficiency ratio among the experimental diets, suggesting differences in palatability, digestibility, and nutrient utilization efficiency. The physicochemical parameters of the water in the experimental tanks remained within the tolerable range for *Clarias gariepinus*. Overall, the findings suggest that processed rice chaff meal holds promise as a cost-effective alternative ingredient in fish diets, offering opportunities to optimize feed formulations in aquaculture practices. Further research is recommended to explore the long-term effects and economic viability of rice chaff inclusion in commercial aquaculture settings.

Keywords: *Clarias gariepinus*, growth performance, nutrient utilization, processed rice chaff

Introduction
The utilization of alternative feed ingredients has emerged as a crucial area of research. Rice chaff (RC), a by-product of rice milling, has garnered attention as a potential feed ingredient due to its abundance and nutrient-rich composition (Iyayi and Fagbenro, 2018) [4]. With its rich content of fiber, protein, and essential nutrients, rice chaff presents an opportunity to diversify and optimize aquafeed formulations (Li *et al*., 2017; Ogunji *et al*., 2019) [5]. Rice chaff is characterized by its significant levels of crude protein, ranging from 6% to 12%, depending on factors such as rice variety and processing methods. Additionally, it is abundant in dietary fiber, primarily composed of cellulose and hemicellulose. Alongside fiber, rice chaff contains carbohydrates, lipids, vitamins, and minerals, contributing to its nutritional value.

Despite its fibrous nature, rice chaff provides valuable nutrients essential for the growth and development of farmed fish species when properly processed and incorporated into aquafeed formulations (Oshodi *et al*., 2020) [19]. Utilizing rice chaff as a feed ingredient promotes sustainability by repurposing a by-product of rice processing that would otherwise be discarded or underutilized, thereby reducing waste and environmental impact. The agro waste offers a cost-effective alternative to traditional feed ingredients like maize. As a by-product, it is often available at lower costs, making it economically attractive for feed manufacturers and aquaculture producers. The high fiber content of rice chaff supports gut health and digestion in farmed fish, promoting peristalsis, enhancing nutrient absorption, and potentially reducing the incidence of digestive disorders.

As a source of dietary fiber, protein, and essential nutrients, processed rice chaff holds promise for improving the growth performance and nutrient utilization of farmed fish species. *Clarias gariepinus*, commonly known as African catfish, is a widely cultured freshwater species with high economic significance in aquaculture (Ozovehe *et al*., 2020) [16].

Its adaptability to various environmental conditions and omnivorous feeding habits make it an ideal candidate for exploring alternative feed ingredients such as processed rice chaff. However, limited research exists on the utilization of processed rice chaff as a dietary component in *C. gariepinus* feed formulations.

This study aims to investigate the growth performance and nutrient utilization of *Clarias gariepinus* fed processed rice chaff substituted diets. By evaluating parameters such as growth rate, feed conversion ratio, nutrient digestibility, and metabolic efficiency, this research seeks to elucidate the potential of processed rice chaff as a viable feed ingredient for *C. gariepinus*. Through a comprehensive assessment of growth and nutritional parameters, this study aims to contribute valuable insights into the feasibility and efficacy of incorporating processed rice chaff into aquafeed formulations for *C. gariepinus*. Such findings hold significance for advancing sustainable aquaculture practices, optimizing feed formulations, and promoting the utilization of agricultural by-products in aquafeed production.

Materials and Methods

The study was conducted at Modibbo Adama University, Faculty of Agriculture, Department of Fisheries, Yola, located in Girei Local Government, Adamawa State, Nigeria. The study spanned a period of 4 months and followed a Completely Randomized Design (CRD) with five diet treatments (control 0%, 25%, 50%, 75%, 100%) in triplicate, resulting in fifteen experimental units.

Rice chaff (RC) was obtained from Girei market, Girei Local Government Area, Yola, Adamawa State, and transported to the Department of Fisheries, Modibbo Adama University, where it was stored in the laboratory prior to the commencement of the experiment. The RC underwent solid-state fermentation to reduce antinutritional factors, following the method outlined by Sogbesan *et al*. (2012) [17]. Samples of the fermented substrates were submitted to the laboratory for phytochemical and proximate analysis at the end of the fermentation period, following the methods of the Association of Official Analytical Chemists (AOAC, 2020) [3].

Seventy-five *Clarias gariepinus* juveniles, with a mean weight of 0.87 g (Mean ± SD), were obtained from the West Africa Agricultural Productivity Programme (WAAPP-NIGERIA) Intervention Projects, Fish Hatchery and Culture (Demonstration Centre) Modibbo Adama University, Yola (MAU Fish Farm Yola), Girei Local Government Area, Adamawa State. After transportation to the wet laboratory of the Department of Fisheries, MAU, Yola, the fish were acclimatized for two weeks with the control diet. Five experimental diets of 40% crude protein were formulated using various ingredients, with rice chaff substituted for maize at graded levels. The feed formulation table is shown in Table 1. Fish meal, soybean meal, maize, agro-wastes (including rice chaff), palm oil, cassava starch, sodium chloride, mineral/vitamin premix, and calcium di-phosphate were among the ingredients used. The diets were formulated using the Pearson square method and processed into pellets of suitable size (3mm) using a pelletizing machine.

The proximate composition of the experimental diets was determined before the feeding trials using standard methods of the Association of Official Analytical Chemists. The fish were fed twice a day (morning 9:00 am and evening 4:00 pm) at the rate of 5% body weight per day for a period of 40 weeks. Feeding allowances were adjusted according to increases in body weight, and di*et al*lotments were increased bi-weekly after length-weight determination. Mortality monitoring was conducted daily throughout the 14-week indoor experimental period, with water samples collected biweekly from each experimental tank for assessment of key parameters including temperature, pH, dissolved oxygen concentration, ammonia levels, and nitrite levels. Fish weight measurements were obtained biweekly using a precision scale, and data were analyzed using descriptive statistics and One-Way Analysis of Variance (ANOVA) to determine significance.

Results

Table 1 presents the proximate composition of feed diets formulated with different inclusion levels of processed rice chaff meal. Dry matter content exhibited the highest value (83.43%) in the 100% rice chaff inclusion level and the lowest value of 81.52% in the control sample. Crude protein content was highest in the control sample (39.82%), while the lowest value (38.91%) was recorded in fish feed formulated with 100% inclusion level of rice chaff meal. Fibre content peaked at 8.77% in the feed formulated with 75% rice chaff inclusion level, whereas the control sample exhibited the lowest fibre content (5.72%). Lipid content was highest (11.68%) in the feeds formulated with 100% inclusion level, and lowest (8.39%) in the control sample. Ash content was highest in feed formulated with 100% rice chaff inclusion level (7.02%), and lowest in the control sample (6.26%). Nitrogen Free Extract (NFE) exhibited the highest value (21.40%) in the control sample, while the least value (17.52%) was recorded in fish feed formulated with 100% rice chaff inclusion level.

Growth performance of *Clarias gariepinus* fed with different inclusion levels of rice chaff substituted diets (0%, 25%, 50%, 75%, and 100%) is summarized in Table 2. The highest mean weight gain (MWG) of 95.41g/fish was observed in diet T_2 (50% inclusion level), while the lowest MWG of 73.37g/fish was recorded in the control diet (T_0). Significant differences ($p<0.05$) were observed between the MWG across the experimental diets. Relative growth rate (RGR) ranged from 0.87-1.45 (%/fish), with the highest value obtained from diet T_3 (75% inclusion level), and the lowest from the control diet (T_0). Specific growth rate (SGR) ranged from 0.045-0.048% day, with the lowest value recorded in the control diet (T_0). Survival rate ranged from 96.02% to 98.77%, with significant differences ($p<0.05$) observed between the experimental diets. Condition factor (K) ranged from 5.33 to 17.04, with significant differences ($p<0.05$) between the condition factors across the diets.

Mean feed intake (MFI) ranged from 47.18g/fish to 60.68g/fish, with significant differences ($p<0.05$) observed between the diets. Feed conversion ratio (FCR) ranged from 0.63 to 0.65, with the highest value recorded in T_4 (100% inclusion level), and the lowest in T_1 (25% inclusion level) and T_3 (75% inclusion level). Protein intake (PI) ranged from 374.54g/100g to 532.35g/100g diet/fish, with significant differences ($p<0.05$) observed between the diets. Protein efficiency ratio (PER) ranged from 0.14 to 0.25, with the lowest value recorded in the control diet (T_0), and the highest in T_3 and T_4 samples.

Table 4 presents the mean values for the physicochemical parameters of the different experimental units fed with rice chaff substituted diets. pH ranged between 6.90-7.32, with the control (T_0) exhibiting the lowest value, and T_1 (25%

inclusion level) the highest. Temperature ranged from 24.20 °C to 24.54 °C, with the highest value recorded in T_1 and T_4, and the lowest in T_1. Dissolved oxygen (DO) ranged from 2.74mg/L to 3.05mg/L, with the highest value observed in the control (T_0), and the lowest in T_1, T_3, and T_4. Ammonia levels were consistent at 0.01mg/L across all treatments.

Table 1: Proximate composition of experimental diet formulated with different inclusion level of processed rice chaff meal

	Control	25%	50%	75%	100%
Dry matter	81.58	82.00	82.51	82.97	83.43
Crude protein	39.82	39.59	39.36	39.10	38.91
Fibre	5.72	6.40	7.09	8.77	8.45
Lipid	8.39	9.22	10.04	10.86	11.68
Ash	6.26	6.45	6.64	6.83	7.02
NFE	21.40	20.73	19.38	18.37	17.52

Table 2: Growth Indices and Survival Rate of *Clarias gariepinus* fed Rice-Chaff Graded Level Diet Indoor for 14 Weeks (98 days)

Parameters	T_0 (0% Inclusion Level)	T_1 (25% Inclusion Level)	T_2 (50% Inclusion Level)	T_3 (75% Inclusion Level)	T_4 (100% Inclusion Level)
Mean initial weight (MIW) (g/fish)	0.86±0.02	0.83±0.01	0.84±0.01	0.84±0.01	0.85±0.02
Mean final weight (g/fish)	74.23±4.02	94.32±0.05	96.25±0.12	95.11±0.04	94.14±0.02
Mean weight gain (g/fish)	73.37±14.05	93.49±0.04	95.41±0.04	94.27±0.05	93.29±0.05
Mean initial length(cm/fish)	6.35±0.00	6.35±0.00	6.32±0.00	6.34±0.00	6.36±0.00
Mean final length (cm/fish)	14.43±1.05	16.35±0.04	18.46±0.04	15.22±0.51	14.54±1.05
Mean length gain (cm/fish)	8.08±0.02	10.00±3.74	12.14±5.12	8.88±0.02	8.18±0.002
Relative growth rate (%/fish) days	0.87±2.81	1.15±0.01	1.16±0.01	1.45±0.02	1.12±0.01
Specific growth rate (%/day)	0.045±0.00	0.048±0.00	0.048±0.00	0.048±0.00	0.048±0.00
Condition factor (K)	13.91±2.54	9.35±1.54	5.33±0.54	13.47±2.58	17.04±6.11
Survival (%)	97.65±0.55	98.05±0.84	98.77±3.00	97.23±0.51	96.02±0.52

Mean ± Std on the same row with different superscripts are significantly different (p<0.05)

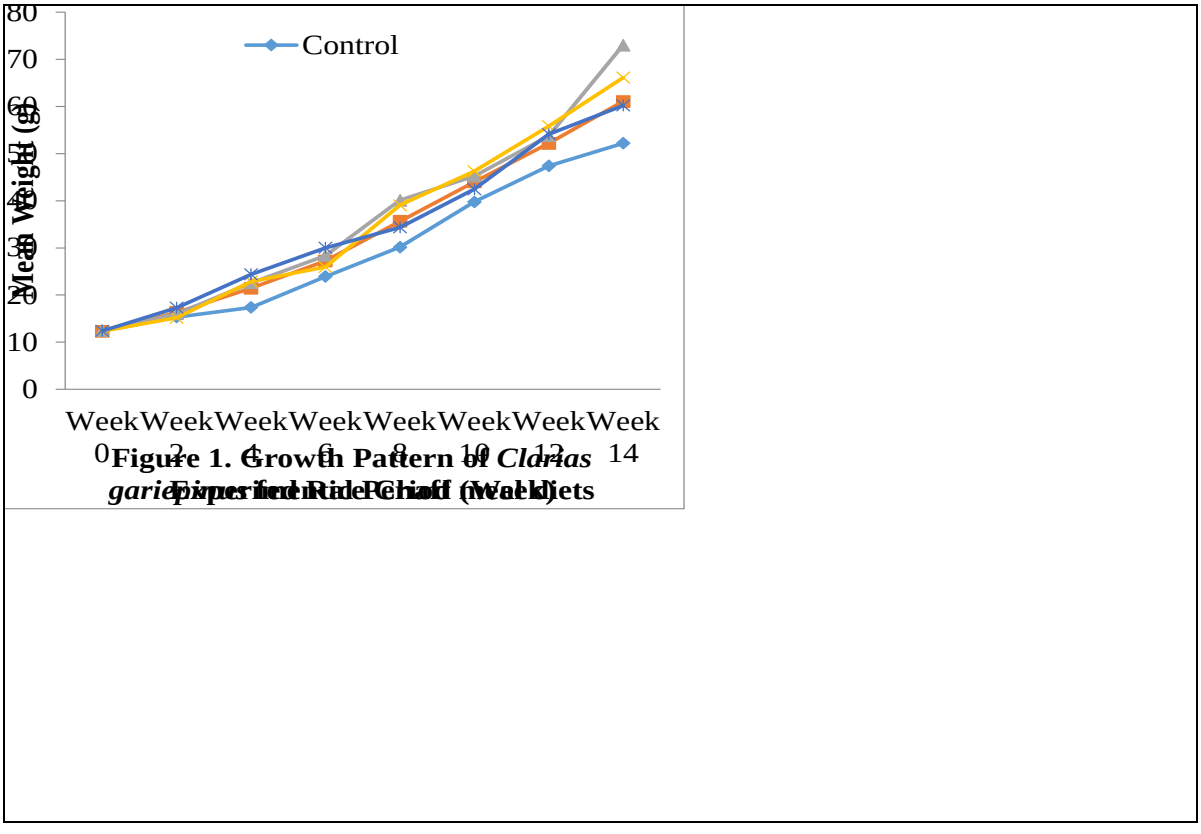

Figure 1. Growth Pattern of *Clarias gariepinus* fed Rice Chaff (Week) diets

Fig 1: Growth Pattern of Clarias gariepinus fed Rice Chaff meal diets

Table 3: Feed Intake and Nutrient Utilization Indices of *Clarias gariepinus* fed Rice-Chaff Graded Level Diet Indoor for 14 Weeks (98 days)

Parameters	T_0 (0% Inclusion Level)	T_1 (25% Inclusion Level)	T_2 (50% Inclusion Level)	T_3 (75% Inclusion Level)	T_4 (100% Inclusion Level)
Total feed intake (g)	707.65±24.54	881.20±35.54	910.21±54.60	895.21±35.54	904.05±52.56
Mean feed intake (g/fish)	47.18±0.45	58.74±0.65	60.68±0.84	59.68±0.69	60.27±0.82
Feed conversion ratio	0.64±0.02	0.63±0.01	0.64±0.02	0.63±0.01	0.65±0.03
Protein intake (g/100g diet/fish)	532.35±16.62	384.54±25.12	395.23±25.81	374.66±25.07	374.54±24.90
Protein efficiency rate	0.14±0.24	0.24±1.04	0.24±1.04	0.25±1.04	0.25±1.04

Table 4: Mean Water Quality Parameter of *Clarias gariepinus* fed with Rice Chaff Graded Level Diet Indoor for 14 Weeks (98 days)

Parameter	T_0 (0% Inclusion Level)	T_1 (25% Inclusion Level)	T_2 (50% Inclusion Level)	T_3 (75% Inclusion Level)	T_4 (100% Inclusion Level)
pH	6.90±0.05	7.32±.0.02	7.05±0.01	7.18±0.01	7.11±0.01
Temperature (°C)	24.41±0.14	24.20±0.12	24.54±0.15	24.25±0.07	24.54±0.15
Dissolved Oxygen (mg/L)	3.05±2.04	2.74±0.11	2.78±0.15	2.74±0.11	2.74±0.11
NH_3 (mg/L)	0.01±0.00	0.01±0.00	0.01±0.00	0.01±0.00	0.01±0.00

Discussion

The findings of this study underscore the potential of incorporating processed rice chaff meal into the diets of *Clarias gariepinus* juveniles, offering insights into growth performance and nutrient utilization dynamics. Proximate composition analysis revealed notable variations in nutrient content across different inclusion levels of rice chaff meal. As the inclusion level increased, there was a discernible rise in dry matter, fibre, lipid, and ash content, while crude protein and nitrogen-free extract (NFE) exhibited a declining trend. These observations align with previous research highlighting the influence of dietary composition on proximate composition in various fish species (Ngugi *et al*., 2018; Oladiran *et al*., 2020; Olanike *et al*., 2016; Omitoyin *et al*., 2019) [7, 18, 11, 15].

Regarding growth performance, the study documented significant differences in mean weight gain (MWG), relative growth rate (RGR), specific growth rate (SGR), and survival rate among fish fed with different inclusion levels of rice chaff meal. Fish fed with a diet containing 50% rice chaff meal exhibited the highest MWG, indicating optimal growth performance at this inclusion level. These findings corroborate previous studies demonstrating improved growth performance in fish fed diets containing plant-based ingredients (Adewumi *et al*., 2017; Olanrewaju *et al*., 2019; Xia *et al*., 2020) [2, 12, 18]. However, variations were observed in feed intake, feed conversion ratio (FCR), protein intake (PI), and protein efficiency ratio (PER) among the experimental diets, suggesting differences in palatability, digestibility, and nutrient utilization efficiency (Liti *et al*., 2021; Olanike *et al*., 2016; Olaniyi *et al*., 2020; Olufayo *et al*., 2017) [6, 11, 10, 13].

The physicochemical parameters of the water in the experimental tanks remained within the tolerable range for *Clarias gariepinus*, indicating suitable environmental conditions for growth and survival. This underscores the importance of maintaining optimal water quality parameters in aquaculture systems to support fish health and productivity (Adedeji *et al*., 2018; Olaniyi *et al*., 2020; Omitoyin *et al*., 2019) [1, 10, 14]. The findings of this study underscore the potential of processed rice chaff meal as a cost-effective alternative ingredient in fish diets, contributing to enhanced growth performance and nutrient utilization in *Clarias gariepinus* juveniles. However, further research is warranted to optimize inclusion levels, assess long-term effects on fish health, and evaluate economic viability in commercial aquaculture settings.

Conclusion

In conclusion, the utilization of processed rice chaff meal as a dietary ingredient in the feeding regimen of *Clarias gariepinus* juveniles demonstrated promising results in terms of growth performance and nutrient utilization. The proximate composition analysis revealed variations in nutrient content across different inclusion levels of rice chaff meal, with increasing levels leading to changes in dry matter, fibre, lipid, and ash content. The growth performance parameters, including mean weight gain, relative growth rate, specific growth rate, and survival rate, exhibited significant differences among fish fed with various inclusion levels of rice chaff meal. Fish fed with diets containing 50% rice chaff meal showed optimal growth performance, indicating the potential of rice chaff as a cost-effective alternative ingredient in fish diets. Further research is recommended to explore the long-term effects of rice chaff inclusion, assess economic viability in commercial aquaculture settings, and investigate potential interactions with other dietary components.

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