

Research

Effect of Dietary Replacement of Yellow Maize with *Ipomoea batatas* Peel Meal on Growth Performance and Haematological Parameters of *Clarias gariepinus* Fingerlings

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Highlights

- Optimal growth achieved at 30–32% *Ipomoea batatas* peel meal inclusion in catfish diets.
- Sweet potato peel meal is a sustainable, low-cost substitute for maize in aquaculture feed.
- Feed conversion efficiency significantly improved at optimal inclusion levels.
- Growth declines beyond 30% inclusion due to likely anti-nutritional effects.
- Haematological parameters remain within safe physiological ranges, confirming dietary safety.

Abstract

This study assessed the growth performance and haematological responses of *Clarias gariepinus* fingerlings fed diets containing graded levels of *Ipomoea batatas* peel meal as a partial replacement for yellow maize. Five isonitrogenous diets (40% crude protein) were formulated to contain *I. batatas* peel meal at 0, 15, 30, 45, and 60% inclusion levels, designated as T1–T5. A total of 225 fingerlings with a mean initial weight of 4.55 ± 0.01 g were randomly distributed into 15 glass tanks (15 fish per tank) in three replicates. Fish were fed twice daily to apparent satiation for 56 days. Results showed that fish fed diet T3 (30% inclusion) exhibited significantly ($p < 0.05$) higher growth performance, feed intake, and better feed conversion ratio compared to other treatments. Growth performance declined beyond 30% inclusion. Haematological analysis revealed significant differences ($p < 0.05$) in white blood cell count (WBC), packed cell volume (PCV), and haemoglobin (Hb), with higher inclusion levels influencing these parameters, although values remained within acceptable physiological ranges. The study indicates that *I. batatas* peel meal can replace up to 30% of yellow maize in the diet of *C. gariepinus* fingerlings without adverse effects on growth and with manageable haematological variations.

Keywords: Growth performance; *Ipomoea batatas*; *Clarias gariepinus*; haematology

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1. Introduction

The increasing cost and limited availability of maize have necessitated the search for alternative energy sources in aquaculture feed formulation (Jimoh *et al.*, 2014). This has led to increased feed costs and intensified competition between human consumption and livestock utilisation. Agro-industrial by-products such as sweet potato (*Ipomoea batatas*) peels are increasingly being explored as alternative feed ingredients. The accumulation of these peels presents disposal challenges, while their utilisation offers potential economic and environmental benefits. Sweet potato peels are rich in carbohydrates and may serve as a viable substitute for maize in fish diets. However, variations exist between literature values and experimentally derived compositions, necessitating further investigation. Previous studies have reported improved growth performance and nutrient utilisation in fish species such as *Clarias gariepinus*, *Oreochromis niloticus*, and *Cyprinus carpio* when fed diets containing sweet potato peel meal (Abdurrazzaq *et al.*, 2022; Omoregie *et al.*, 2009; Soltan *et al.*, 2005). However, limited information exists regarding its effects on haematological parameters. This study therefore aimed to evaluate the effects of replacing yellow maize with *Ipomoea batatas* peel meal on growth performance, nutrient utilisation, and haematological parameters of *Clarias gariepinus* fingerlings.

2. Materials and Methods

Study Area

The study was conducted at the Department of Fisheries and Aquaculture Teaching and Research Farm, Federal University of Technology, Akure, Ondo State, Nigeria, for 56 days.

Plant Material

Fresh potato peels of *Ipomoea batatas* were collected from a mini-mart opposite the School of Agriculture and Agricultural Technology, Federal University of Technology, Akure, Ondo State, Nigeria, in June 2023. The peels were washed and sun-dried for seven days on pre-sterilised trays, covered with wire mesh to prevent contamination. They were then milled into fine powder and stored at 4°C until use.

Experimental Fish

Two hundred and eighty (280) apparently healthy *C. gariepinus* fingerlings were purchased from the Federal University of Technology fish farm, Akure, Ondo State, Nigeria. The fish were acclimatised for 7 days. During this period, they were hand-fed a commercial control diet containing 40% crude protein to apparent satiation twice daily, between 08:00–09:00 and 16:00–17:00 GMT.

Experimental Design

The experiment design was a completely randomized design. Out of the two hundred and eighty (280) *C. gariepinus* fingerlings that were obtained from the above-named stock, a total of two hundred and twenty-five (225) *C. gariepinus* fingerlings were randomly selected and distributed into 15 glass tanks of dimension

(65 litre) measuring (70 × 45 × 45 cm³) at the rate of fifteen (15) fish per tank representing five treatments in triplicates

Experimental Diets

Five isonitrogenous diets (40% CP) were formulated for the fish to contain *I. batatas* peel at different inclusion levels (0.0, 15, 30, 45 and 60%/kg) and labelled as T1- T5 respectively. The diet containing 0.0g/kg of *I. batatas* peel meal served as the control without any inclusion of additives. Other ingredients were fish meal, soya bean meal, groundnut cake, yellow maize, methionine, lysine vitamin- mineral mix, vegetable oil and starch. Table 1 shows gross composition of the experimental diets. The constituents of each diet were thoroughly mixed and pelleted using a Horbart A- 200T mixing and pelleting machine (Horbart Manufacturing Ltd. UK) using 2mm diameter die. The resultant strands obtained were sundried for 3 days and hand crumbled into smaller sizes that can be swallowed by the fingerlings, after which they were packed in separate airtight polyethylene bags, sealed and marked according to treatments and stored at 4°C until feeding.

Weighing of Experimental Fish

Fish weights were measured at the start of the experiment and subsequently every two weeks throughout the 56-day feeding trial. Fish were batch weighed using a digital electronic balance (Model PB3002) with a precision of ±0.01g. Care was taken to minimize stress and handling time during the weighing process.

Table 1: Gross Composition of the experiment diets (g/100g) for culturing *C. gariepinus* fingerlings

Ingredients	T1 (0.0%)	T2 (15%)	T3 30%)	T4 (45%)	T5 (60%)
Fish meal	25.6	25.6	25.6	25.6	25.6
Soybean meal	28.9	28.9	28.9	28.9	28.9
Ground nut cake	18.2	18.2	18.2	18.2	18.2
Yellow maize	15.7	13.34	10.99	8.63	6.28
<i>I. batatas</i>	0.0	2.36	4.71	7.07	9.42
Methionine	0.70	0.70	0.70	0.70	0.70
Lysine	0.70	0.70	0.70	0.70	0.70
Vegetable oil	5.0	5.0	5.0	5.0	5.0
Vitamin–mineral mix	2.20	2.20	2.20	2.20	2.20
Starch	3.00	3.00	3.00	3.00	3.00

Composition of vitamin-mineral mix (Aquamix) (quantity/kg), Vitamin A, 5,500,000 IU; Vitamin D3, 1,100,000 IU; Vitamin B2, 2,000 mg; Vitamin E, 750 mg; Vitamin K, 1,000 mg; Vitamin B6, 1,000 mg; Vitamin B12, 6 mcg; Calcium; Pantothenate, 2,500 mg; Nicotinamide, 10 g; Choline Chloride, 150 g; Mn, 27,000 mg; I, 1,000 mg; Fe, 7,500 mg; Zn, 5,000 mg; Cu, 2,000 mg; Co, 450mg. L- Lysine, 10 g; Selenium, 50 ppm.

Feeding of Experimental Fish

The fish were fed experimental diets twice daily at 08:00 and 16:00h GMT to satiation for 56 days. Unconsumed feed and faeces were removed every day from the glass tanks by siphoning at 08:00 and 2:00 hours daily before feeding with culture water partially drained and replenished with fresh water. Culture water in experimental units was completely drained and changed twice a week.

Water Quality Parameters

Water quality parameters (temperature, dissolved oxygen and pH) were determined twice a week. Temperature was measured using a mercury-in-glass thermometer (Jenway Model 3150). Hydrogen ion concentration (pH) was measured using a digital pH meter (Jenway Model 1960). While dissolved oxygen was measured using a Dissolved Oxygen test kit (HANNA Model: HI-9142).

Growth and Nutrient Utilization Parameters

Calculation of the growth performance data was done according to Kumar *et al.*, (2022). At the end of the experiment, fish were counted and weighed. The growth parameters and feed utilization indices were calculated as follows:

Weight Gain (g) = Final weight- initial weight

Specific Growth Rate (SGR)

This was calculated from data on changes of body weight over a given time interval;

$$\text{SGR (\% per day)} = \frac{(\ln \text{ final weight} - \ln \text{ initial weight})}{\text{Time (days)}} \times 100$$

Feed intake

This was obtained by adding daily mean feed intake (DFI) of fish under each treatment for the experiment period.

Feed Conversion Ratio (FCR) = Feed intake (g)/Weight gain (g)

Feed Efficiency Ratio (FER) = Weight gain (g)/Feed intake (g)

Survival (%) = Number of fish harvested/Number of fish stocked × 100

Proximate Composition

Proximate analysis was carried out on the *I. batatas* formulated feed and experimental fish according to the standard method of Association of Official Analytical chemist AOAC (2005) to determine the moisture, ash, crude protein, crude lipid, crude fiber and Nitrogen free extract (NFE)). Gross Energy was calculated as $(5.64 \text{ Kcal/g} \times \% \text{CP}) + (9.44 \text{ Kcal/g} \times \% \text{Lipid}) + (4.11 \text{ Kcal/g} \times \% \text{NFE})$ according to National Research Council NRC (2011)

Hematological Examination

Hematological Parameters was carried out on blood of *C. gariepinus* at the Federal University of Technology Health Centre. Five fish specimens were removed from each glass tanks for blood analysis. 1ml of blood from the fish was collected from the cardiac vein puncture using different 5ml disposable heparinized syringes, with ethylene diamine tetra acetic acid (10ml EDTA) as anticoagulant. The

blood analysis was carried out using standard laboratory techniques (Svobodova *et al.*, 1991).

Statistical Analysis

Data collected were subjected to one-way analysis of variance (ANOVA) as described by Steel and Torrie (1980) followed by Duncan's new multiple range test (Duncan, 1955) to separate differences among the mean. The statistical analysis was performed with the aid of the computer software SPSS (Statistical Package for Social Science Version 22) and Microsoft Office Excel Programme 2023.

3. Results

Proximate Composition of *I. batatas* peel powder

The result of proximate composition of *I. batatas* peel revealed that the carbohydrate values was the highest and Fiber had the lowest value which are 69.92 and 3.98 respectively as shown in Table 2. The percentage ash content of 6.59 means that the peel contains reasonable quantity of elements.

Proximate Composition of Experimental Diets

Table 3 shows the proximate composition of diets fed to the experimental fish. The moisture content varied from 7.51 to 8.65 with T5 had the highest value while T1 recorded the lowest value. The ash Content of the formulated diet varied from 14.55 to 15.06, T1 had the highest value while T3 had the lowest. Protein content varied from 39.12 to 39.54 with T3 recording the highest value while T1 recorded the lowest value. Crude fiber increased with increasing levels of *I. batatas* replacement in the diets. Furthermore, Crude fat varies from 5.97 to 6.53 with T4 recording the highest value while the lowest value was recorded in T1 respectively.

Water Quality Parameters

The water quality parameters measured during the feeding trial for 56 days varied as follows; dissolved oxygen ranged from 6.50 to 7.51mg/l, temperature ranged from 27.39 to 27.570C, and hydrogen ion concentration (pH) ranged from 7.31 to 7.52 Table 4. Higher dissolved oxygen improves fish metabolism and feed efficiency, while lower DO can reduce growth, emphasizing the need for optimal oxygen in culture systems.

Table 2: Proximate composition of dry *I. batatas* peel meal and yellow maize

Parameters (%)	<i>I. batatas</i>	Yellow maize
Moisture	9.13	9.56
Ash	6.59	1.98
Protein	5.68	9.20
Fibre	3.98	2.24
Fat	4.73	3.71
Nitrogen free extract	69.89	73.31

Table 3: Proximate composition of the experimental diets containing different inclusion levels of *I. batatas* peel meal

Parameters	T1	T2	T3	T4	T5
Moisture	7.51	8.26	8.43	8.29	8.65
Ash	15.06	14.82	14.55	14.62	14.73
Protein	39.12	39.36	39.54	39.43	39.52
Fibre	9.23	9.48	9.52	9.57	9.64
Fat	5.97	6.16	6.38	6.53	6.41
Nitrogen free extract	23.11	21.92	21.58	21.05	
Gross energy	3724.3	3706.9	3723.9	3731.0	3703.8

Key; NFE = Nitrogen free extract, GE = Gross Energy

Table 4: Physico-chemical parameters for culture of *C. gariepinus* fingerlings

Treatments	T1	T2	T3	T4	T5
DO (mg/l)	7.22±0.25bc	6.63±0.11 ab	6.50±0.16a	6.77±0.05ab	7.51±0.33c
Temperature (°C)	27.43±0.10a	27.39±0.15a	27.40±0.22a	27.42±0.32a	27.57±0.21a
pH	7.40±0.20a	7.45±0.03a	7.52±0.23a	7.31±0.22a	7.46±0.13a

Means in same row with different superscripts are significantly different (P<0.05)

Key: DO = Dissolved Oxygen, pH = Hydrogen ion concentration

Growth performance of the Experimental Fish

The growth performance and nutrient utilisation of *C. gariepinus* during the experiment are presented in Table 5. Highest growth performance was obtained from the group fed with T3 which indicate that (30%) inclusion level of *I. batatas* can be considered as the optimal level of inclusion in the diet of the fish. A reduction in growth as the *I. batatas* peel meal increased beyond 30% was observed. Significantly higher (p<0.05) feed intake was recorded in fish feed T3 while the lowest was recorded in fish feed T1. The best FCR was recorded in fish fed T3 as 1.51 and the poorest in the T1 with 1.78. Highest survival (%) was recorded in fish fed T5 while the lowest survival (%) was recorded in fish fed T3. However, 4th degree polynomial regression revealed (32%) as the optimum growth level. Although the T3 treatment (30% *I. batatas* inclusion) showed the highest observed growth performance, 4th degree polynomial regression analysis estimated the optimum growth level at 32% inclusion. This slight discrepancy may be due to the discrete treatment levels tested experimentally, whereas the regression analysis allows interpolation

between these levels, providing a more precise estimate of the theoretical optimum inclusion for growth.

Hematological Parameters

The effects of dietary inclusion of *I. batatas* peel meal on the haematological parameters of *Clarias gariepinus* fingerlings are presented in Table 6. White blood cell (WBC) counts were significantly higher in fish fed 45% (T4) and 60% (T5) *I. batatas* peel compared to the control and lower inclusion levels (T1–T3), indicating a possible stimulation of the immune response. Packed cell volume (PCV) and haemoglobin (Hb) values, on the other hand, decreased significantly with increasing levels of peel inclusion, suggesting mild alterations in red blood cell indices at higher dietary levels. Red blood cell (RBC) count, mean cell haemoglobin (MCH), mean cell haemoglobin concentration (MCHC), and mean corpuscular volume (MCV) were not significantly affected across treatments.

Table 5: Growth performance and nutrient utilization of *C. gariepinus* fingerlings fed experimental diets

Parameters	T1	T2	T3	T4	T5
MIW (g)	4.55±0.01a	4.56±0.01a	4.56±0.03a	4.55±0.12a	4.52±0.07a
MFW (g)	25.93±0.36a	29.27±0.89ab	39.65±1.25c	34.20±5.70bc	31.27±3.07b
MWG (g)	21.38±0.35a	24.71±0.90ab	35.09±1.28c	29.65±5.58bc	26.75±3.14b
SGR (%/day)	3.11±0.02a	3.32±0.06ab	3.86±0.07c	3.58±0.25bc	3.45±0.20b
TFI (g/fish)	37.96±0.38a	42.54±0.48ab	52.99±3.26c	48.32±7.19bc	45.71±7.45b
FCR	1.78±0.01c	1.72±0.08bc	1.51±0.04a	1.64±0.07ab	1.70±0.08b
FCE	0.56±0.00a	0.58±0.03ab	0.66±0.02b	0.61±0.02ab	0.59±0.03ab
Survival (%)	83.34±3.34b	83.34±3.34b	76.67±3.34a	83.34±3.33b	93.33±6.67c

Mean in the same row with different superscripts differ significantly (P<0.05).

Key: MIW= Mean initial weight; MFW= Mean final weight; MWG= Mean weight gain; SGR= Specific growth rate; TFI= Total feed intake; FCR= Feed conversion ratio, FCE= Feed conversion efficiency.

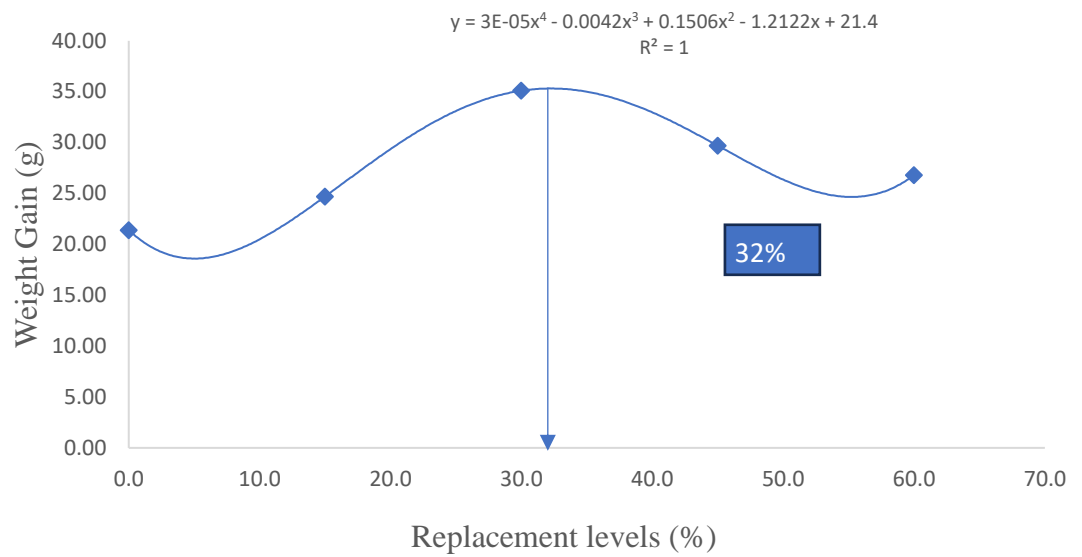


Figure 1: Fourth degree polynomial regression relationship between dietary inclusion of *I. batatas* peel meal and weight gain of *C. gariepinus* fed with experimental diets

Table 6: Haematological parameters of *C. gariepinus* fingerlings fed *Ipomoea batatas* peel meal diet

Parameters	T1	T2	T3	T4	T5
WBC (×103 /mm3)	6.35±0.95a	6.65±1.45a	6.55±1.95a	8.15±0.45b	8.20±0.60b
RBC (×103 /mm3)	2.98±0.23a	2.88±0.23a	2.90±0.40a	2.63±0.08a	2.40±0.20a
PCV (%)	27.0±2.00c	26.5±3.50b	24.5±0.50b	24.5±0.50ab	22.0±2.00a
Hb (g/100)	9.00±0.70b	8.65±0.65ab	8.85±1.25ab	8.20±0.10ab	7.40±0.70a
MCHC (%)	33.3±0.10a	33.25±0.50a	33.35±0.35a	33.50±0.30a	33.65±0.15a
MCH (pg)	30.25±0.50a	30.10±0.10a	30.50±0.10a	30.70±0.50a	30.85±0.35a
MCV (fl)	90.75±0.15a	90.45±0.15a	91.45±0.55a	91.60±0.02a	90.59±0.03a

Mean in the same row with different superscripts differ significantly (P<0.05).

Key: WBC- White Blood Cell, RBC- Red Blood Cell, Hb- Hemoglobin, PCV- Pack Cell Volume, MCHC- Mean Cell Hemoglobin Concentration, MCH- Mean Cell Hemoglobin, MCV- Mean Corpuscular Volume

4. Discussion

Proximate Composition of *Ipomoea batatas*

The proximate analysis of *I. batatas* peel in this study revealed a protein content lower than the 7.94% reported in previous studies, but higher than the 4.64% and

5.19% reported by Moein *et al.* (2012) and Ali *et al.* (2017), respectively. The observed differences in protein content could be attributed to variations in geographical location, differences in cultivars, processing methods, soil type, and the time of harvesting. These factors are known to influence the nutrient composition of plant by-products and may explain the discrepancies among studies.

Proximate Composition of Experimental Diets

The proximate composition of the experimental diets showed that they were iso-nitrogenous, with protein content ranging from 39.12% to 39.54%, which falls within the recommended 20–40% range for warm-water fish such as *C. gariepinus* (Uys and Hecht, 1997). The crude fibre content may influence gut transit time and nutrient absorption, potentially affecting feed utilization efficiency. Dietary fat provides essential fatty acids and serves as a concentrated energy source, supporting growth and metabolic activities. NFE, as the carbohydrate fraction, supplies readily available energy that can be used for maintenance and growth. These variations, although slight, may have contributed to the differences in growth performance observed among treatment groups, as reflected in parameters such as weight gain and feed conversion ratio.

Physico-chemical Parameters

The values of the physico-chemical parameters of the water used for the experiment were within the optimum range for the normal physiological functioning of not only *Clarias gariepinus* but also other freshwater fishes. These parameters compared favourably with those reported by Idowu *et al.* (2019) and Jimoh *et al.* (2013) for freshwater fishes, including *C. gariepinus*. However, significant differences in dissolved oxygen (DO) were observed across treatments. Although all DO values remained within acceptable limits for freshwater fish survival and growth, these variations could have had a potential influence on growth performance. Higher dissolved oxygen levels are generally associated with improved metabolic activity and feed utilization, which may enhance growth. Therefore, while the overall water quality was suitable, the observed differences in DO should be considered when interpreting the growth performance results, as they may have contributed, to some extent, to the variations recorded among treatments.

Growth Performance and Nutrient Utilisation

Growth performance and nutrient utilisation indices differed significantly ($P < 0.05$) among *C. gariepinus* fed the control diet and those fed varying inclusion levels of

I. batatas peel meal. Fish fed the diet containing 30% *I. batatas* peel meal exhibited the highest ($P < 0.05$) mean weight gain and specific growth rate compared to those fed the control and other experimental diets, indicating that 30% inclusion is optimal for growth. A common challenge associated with incorporating alternative feed ingredients into aquaculture diets is reduced palatability and feed acceptance by fish. However, in the present study, feed intake increased with inclusion level up to 30%, suggesting that *I. batatas* peel meal was well accepted at moderate levels. The weight gain observed in this study was lower than that reported by Abdurrazzaq *et al.* (2022) for *C. gariepinus* fed *I. batatas*-based diets over 56 days. Moein *et al.* (2012) reported that *Cyprinus carpio* tolerated up to 15% inclusion of *I. batatas* peel meal, which contrasts with the present findings where *C. gariepinus* performed optimally at a higher inclusion level (30%). This discrepancy may be attributed to species-specific differences in digestive physiology and tolerance to dietary fibre. The results obtained in this study are consistent with those of Omoregie *et al.* (2013), who reported reduced growth performance with increasing inclusion of plant-based alternative ingredients. Although their study focused on palm kernel meal in *Oreochromis niloticus*, the similarity lies in the general response of fish to increasing levels of non-conventional feed ingredients, which may negatively affect nutrient availability at higher inclusion levels. Growth performance improved up to the 30% inclusion level but declined at higher inclusion levels. This reduction may be due to increased levels of anti-nutritional factors (such as tannins, phytates, and fibre) present in *I. batatas* peels, which can impair nutrient digestibility and absorption when included beyond optimal levels. This finding is consistent with Nwanna *et al.* (2000), who reported optimal growth in *O. niloticus* at a 30% inclusion level of potato peel meal. The highest feed intake was recorded in fish fed the 30% inclusion diet, while the lowest was observed in fish fed the control diet. This agrees with Ali *et al.* (2017), who reported increased feed intake in *C. carpio* fed potato peel-based diets. The results of the present study indicate that partial replacement of yellow maize with *I. batatas* peel meal up to 30% in *C. gariepinus* diets did not adversely affect feed conversion ratio. This suggests that *I. batatas* peel meal can serve as a cost-effective alternative to yellow maize, with potential improvements in feed utilisation. Although similar trends were reported by Soltan (2002) in *O. niloticus* fed tomato by-product, differences in fish species.

Hematological parameters

Blood is a complex physiological fluid responsible for the transport of nutrients, respiratory gases, and metabolic waste products, and it serves as a key indicator of the health status of fish (Storz, 2016). Variations in dietary composition are known to influence the haematological profile of fish, reflecting changes in physiological and metabolic conditions. The results of the present study showed that no significant differences ($P > 0.05$) were observed in the haematological parameters of *Clarias gariepinus* fed graded levels of *I. batatas* peel meal-based diets. This indicates that inclusion of *I. batatas* peel meal up to the tested levels did not adversely affect the haematological status of the fish, suggesting that the diets were physiologically safe. The recorded ranges for haemoglobin (Hb), red blood cell count (RBC), packed cell volume (PCV), and mean corpuscular volume (MCV) were lower than those reported by Olaniyi (2010) for *C. gariepinus* fed sweet potato leaf meal-based diets. These differences may be attributed to variations in the form of the test ingredient (peel versus leaf), nutrient composition, processing methods, and experimental conditions. However, the mean corpuscular haemoglobin concentration (MCHC) values (33.25–33.65%) recorded in this study were higher than those reported by Olaniyi (2010). Elevated MCHC values generally indicate improved haemoglobin synthesis and oxygen-carrying capacity of erythrocytes, suggesting that the diets supported adequate physiological functioning of the fish. Packed cell volume (PCV), also referred to as haematocrit, is a widely accepted indicator of the oxygen-carrying capacity and general health status of fish (Erondy *et al.*, 2003). The PCV values observed in this study (22.0–27.0%) fall within the normal physiological range reported for healthy fish, indicating that the inclusion of *I. batatas* peel meal did not induce anaemia or physiological stress.

Although no statistically significant differences were observed, a gradual decline in PCV and haemoglobin levels with increasing inclusion of *I. batatas* peel meal was noted. This trend may suggest a mild reduction in erythropoietic activity or nutrient availability at higher inclusion levels, possibly due to the presence of anti-nutritional factors such as phytates and fibre, which can interfere with iron absorption and haemoglobin synthesis. In contrast, white blood cell (WBC) counts showed an increasing trend at higher inclusion levels (T4 and T5), which may indicate a physiological response to dietary stress or the presence of anti-nutritional compounds. Elevated WBC levels are often associated with enhanced immune response, suggesting that the fish may have activated defence mechanisms to maintain homeostasis under increasing dietary inclusion of *I. batatas* peel meal.

5. Conclusions

In conclusion, *Ipomoea batatas* peel meal can replace yellow maize in the diet of *Clarias gariepinus* at inclusion levels up to 30% without negatively affecting growth performance and feed utilisation. Although significant variations were observed in some haematological parameters (WBC, PCV, and Hb), these remained within normal physiological ranges, indicating no serious health impairment. Polynomial regression analysis identified an optimal inclusion level of approximately 32%, consistent with the observed results. However, higher inclusion levels may induce mild physiological stress. The findings also highlight the potential of *I. batatas* peel meal as a cost-effective and environmentally sustainable feed ingredient. Further studies under outdoor pond culture conditions are recommended to validate these results.

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Conflict of interest: All authors declare that they have no conflict of interest.

References

1. Abdurrazzaq, I. A., Bolanle, S. B., Shuaibu, A. A., & Adikwu, O. (2022). Effects of dietary replacement of maize with sweet potato peel in the diet of African catfish *Clarias gariepinus*. *Journal of Aquaculture Research*, 13(2), 1–11.
2. Ali, S. M., El-Nadi, I., Hesham, A., & Mohamed, M. (2017). Graded levels of potato peels effects as partial replacement for corn in diet of common carp (*Cyprinus carpio*). *International Journal of Chemical and Technical Research*, 10(2), 566–572.
3. AOAC. (2005). *Official methods of analysis* (15th ed.). Association of Official Analytical Chemists. Official Methods of Analysis, 15th Edition., Washington.
4. Ape, D. I., Nwogu, N. A., & Uwakwe, E. I. (2016). Comparative proximate analysis of maize and sorghum bought from Ogbete Main Market of Enugu State, Nigeria. *Greener Journal of Agricultural Sciences*, 6(9), 272–275.
5. Domingues, P., Sykan, N. O., Sammerfield, A., & Andrade, J. P. (2003). Effect of feeding live or frozen prey on growth, survival and the life cycle of the cuttlefish *Sepia officinalis* (Linnaeus, 1758). *Aquaculture International*, 11, 397–410.
6. Duncan, D. B. (1955). Multiple range and multiple F-test. *Biometrics*, 11, 1–42.

7. Erondy, E. S., Nnubia, S., & Nwanukwe, F. O. (2003). Haematological studies on four catfish species raised in freshwater pond. *Nigerian Journal of Applied Ichthyology*, 9(3-4), 250-256.
8. Ghazalah, A. A., Goma, I. A., Hyam, D., & Tonsy, D. (2002, Month Day). The use of date stone meal (DSM) and potato by-product meal (PBM) as non-conventional energy feed sources in Nile tilapia (*Oreochromis niloticus*) diets. Paper presented at *The 1st Scientific Conference of the Egyptian Aquaculture Society*, Cairo, Egypt.
9. Idowu, A. A., Somorin, Y. M., Ogundele, O. J., & Ikokoh, P. P. (2019). Physico-chemical parameters of major rivers in Ekiti State, Nigeria. *Journal of Applied Sciences and Environmental Management*, 23(4), 741-745.
10. Jimoh, W. A., Aderolu, A. Z., Ayelaja, A. A., & Shodamola, M. O. (2013). Replacement value of soybean meal with *Luffa cylindrica* in diet of *Clarias gariepinus* fingerlings. *International Journal of Applied Agricultural and Apicultural Research*, 1&2, 98-105.
11. Jimoh, W. A., Sodamola, M. O., & Ayelaja, A. A. (2014). The influence of replacing maize with *Chrysophyllum albidum* seed meal on growth response and nutrient utilisation in *Clarias gariepinus*. *Agrosearch*, 14(1), 54-61.
12. Kumar, V., Singh, S. and Sharma, R. (2022). Effects of dietary pumpkin (*Cucurbita pepo*) seed powder on growth and hematological indices of *Clarias batrachus*. *International Journal of Aquaculture*, 12(3): 45-53.
13. Moein, F., Mohammad, L., Saeed, K., & Farnaz, I. (2012). Influences of different levels of sweet potato peels on growth and feeding parameters and biochemical responses of *Cyprinus carpio* (Cyprinidae). *American-Eurasian Journal of Agriculture and Environmental Science*, 12(4), 449-455.
14. National Research Council (NRC). (2011). *Nutrient requirements of fish and shrimp*. The National Academies Press.
15. Nwanna, L. C., Falaye, A. E., Olarewaju, O. J., & Oludapo, B. V. (2009). Evaluation of Nile tilapia (*Oreochromis niloticus* L.) fed dietary potato peels as replacement for yellow maize. Paper presented at the *24th Annual Conference of the Fisheries Society of Nigeria (FISON)*, Akure, Nigeria, 156-159.
16. Olaniyi, C. O. (2010). Growth performance and blood profile of African catfish fed sweet potato (*Ipomoea batatas*) leaf meal. In *Proceedings of the 5th International Seminar on Tropical Animal Production, Community Empowerment and Tropical Animal Industry* (pp. 228-230), Yogyakarta, Indonesia, October 19-22, 2010.
17. Olukunle, O. (2006). Nutritive potential of sweet potato peel meal and root replacement value for maize in diets of African catfish (*Clarias gariepinus*) advanced fry. *Journal of Food Technology*, 4(4), 289-293.
18. Omoregie, E., & Ogbemudia, F. I. (2013). Effect of substituting fishmeal with palm kernel on growth and food utilisation of the Nile tilapia (*Oreochromis niloticus*). *Israeli Journal of Aquaculture*, 43(1), 113-119.
19. Omoregie, E., Igoche, L., Ojobe, T. O., Absalom, K. V., & Onusiriuka, B. C. (2009). Effect of varying levels of sweet potato (*Ipomoea batatas*) peels on growth, feed utilisation and some biochemical responses of the cichlid (*Oreochromis niloticus*). *Aquaculture*, 9(2), 700-712.
20. Saleh, H., & Tonsy, D. (2001). *The use of non-conventional energy and protein feed sources in Nile tilapia diets* (Doctoral dissertation, Cairo University).
21. Shouqi, X., & Jokumsen, A. (2007). Replacement of fish meal by potato protein concentrate in diets for rainbow trout (*Oncorhynchus mykiss*): Growth, feed utilisation and body composition. *Aquaculture Nutrition*, 13, 65-69.
22. Soltan, M. A. (2002). Using tomato and potato by-products as nonconventional ingredients in Nile tilapia (*Oreochromis niloticus*) diets. *Annals of Agriculture Science, Moshtohor*, 40(4), 2081-2096.
23. Soltan, M. A., Abdella, M. M., Abou-Seif, R. A., & Hassan, M. S. (2005). Using tomato and potato by-products as partial replacements for soybean meal and yellow corn in practical diets for the common carp (*Cyprinus carpio*). *Egyptian Journal of Nutrition and Feeds*, 8(2), 257-272.

24. Steel, R. G. D., & Torrie, J. H. (1980). *Principles and procedures of statistics: A biometrical approach*. McGraw-Hill.
25. Storz, J. F. (2016). *Haemoglobin: Insights into function, evolution, and adaptation*. *Annual Review of Physiology*, 78, 545–567.
26. Svobodova, Z., Pravda, D., & Palackova, J. (1991). *Unified methods of haematological examination of fish* (Methods No. 20, 31 pp.). Research Institute of Fish Culture and Hydrobiology, Vodnany.
27. Uys, W., & Hecht, T. (1997). Evaluation and preparation of a suitable dry feed and optimum feeding frequency for primary nursing of *Clarias gariepinus* larvae. *Aquaculture*, 47, 173–183.

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