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Nutrient Enhancing and Flesh Quality Improvement in Catfish (*Clarias gariepinus)* Fed Dietary Sweet Potato (*Ipomoa butatas)* Leaves Aqueous Extract

Ukwe, I. O. K. [a*] and Uwom, B. I. [a]

[a] *Department of Fisheries and Aquatic Environment, Rivers State University, Rivers State, Nigeria.*

Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Dietary sweet potato (*I. batatas*) leaves extract was assessed for nutrient enhancing ability and improvement of flesh quality in catfish (*C. gariepinus).* Thirty five (35) % crude protein feed was formulated using locally available ingredients. Four different diets were prepared from the formulated feed by adding varying quantities of sweet potato leaves extracts as follows: Oml/kg; 50ml/kg; 100ml/kg; and 150ml/kg and labeled as Do, D1, D2 and D3 respectively. One hundred and twenty (120) sub-adult *C. gariepinus* were used for the experiment, they were divided into four groups in triplicates of 10. Feeding with the experimental diets (Do-D3) commenced after two

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**Corresponding author: Email: oyekuotorisaac@gmail.com;*

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weeks of acclimatization and they were fed for eight (8) weeks, and water quality parameters such as temperature, dissolve oxygen and pH were determined daily, and measurement of length and weight was done fortnightly. After the feeding period fish were collected from each of the groups for proximate composition analysis and organoleptic assessment. The proximate composition of the diets were done to assess the effects of *I. batatas* on the quality of the diets. The results revealed the following: (i) the diets had no effects on the assessed water quality parameters; (ii) there were no significance difference in the proximate composition of the experimental diets; (iii) the *I. batatas* leave extracts enhanced the lipids, protein and fibre contents on the flesh of *C. gariepinus;* (iv) the *I. batatas* improves texture, taste, appearance and general acceptability of *C. gariepinus* flesh; (v) nutrient utilization parameters such as protein intake (PI), protein efficiency ratio (PER), protein retention (PR), fat retention (FR) and net protein retention (NPU) increases significantly as the quantity of *I. batatas* extracts increases in the diet (Do- D3). It was concluded that sweet potato (*I. batatas)* leaves extracts improves nutrients utilization and flesh quality in *C. gariepinus* by enhancing bioavailability, digestion and absorption of nutrients.

Keywords: Nutrient utilization; organoleptic assessment; proximate composition of experimental fish flesh; proximate composition of experimental diets.

1. INTRODUCTION

Fisheries and aquaculture plays significant role in the promotion of food sufficiency, and it contributes above 15% to the protein consumed by humans especially in the underdeveloped countries of the world (Ayoola 2010). One of the problems in aquaculture is the availability of good quality fish feed and a healthy environment free of diseases. Good quality feed will boost the production of fish, enhance growth rates and reduce disease presence (Alatise et al. 2006, Effiong et al. 2019). The quality of a fish feed is determined by the quality of nutrients in its ingredients, and how the fish utilizes these nutrients determines the growth rate and taste of the fish. The growth and taste of the fish is further determined by the bioavailability of nutrients in the fish feed (Parada and Aguilera 2007).

One of the essential ingredients in fish feed production is protein, because of its unique role in the development of fish. Protein plays an important role in the growth and health of fish (Effiong et al. 2019). Fishmeal is among the desirable protein ingredients because of it's high content of amino acids, but the decrease in it's supply as a result of demand and cost is putting the sustainability of the aquaculture industry at risk (Ayoola 2010). Since the cost of fishmeal is increasing each passing day, identifying alternative feedstuffs to fishmeal will enhance productivity in aquaculture (Idowu and Afolayan 2013).

So many authors have reported the importance of plants in the improvement of growth and health in fish (Lawal et al. 2021, Abu et al. 2023, Ukwe and Deekae 2022). Ukwe and Deekae **(**2024) reported that sweet potato leaves (*Ipomoa batatas)* contains varying percentages of ash, fat, protein, fibre, carbohydrate etc, and posses some important phytochemicals such as flavonoid, coumanins, sapoinine, tannins, anthraquinnies, alkaloids and phenols. Ukwe and Deekae (2024) further stated that these components of the *I.batatas* has the capacity to boost growth and health in fish culture. The phytochemicals contained in *I. batatas* have the ability to enhances digestibility and absorption of nutrients in fish (Koushik and Mraz 2021).

African catfish (*Clarias gariepinus)* is one of the most cultured fish outside its environment because of its ability to survive in high stocking density, resist disease and good flesh quality. This research investigated the dietary effects of sweet potato (*I. batatas*) leaves on the nutrient utilization and flesh quality of *Clarias gariepinus.*

2. MATERIALS AND METHODS

2.1 Experimental Area

The experiment was carried out in the fish farm of the Department of Fisheries and Aquatic Environment, Rivers State University, Nigeria.

2.2 Experimental Fish/Acclimatization

The fish (sub-adult *Clarias gariepinus)* was purchased from a reputable fish farm within Rivers State, and was taken to the experimental area between the hours of 6am – 7am in the morning. The fish was acclimatized for two

(Alatise et al. 2006) weeks and observed for disease presence. The fish were fed to satiation twice a day, and water parameters were monitored.

2.3 Preparation of Experimental Herb/Diets

Sweet potato (*Ipomoa batatas*) leaves were harvested within Rivers State. It was washed clean and processed using the methods of (Leon 2023). The *I. batatas* leaves were pounded to paste and soaked in hot water (50oc) at 500g/L for twelve (Ukwe and Jamabo 2020) hours. It was filtered and the filtrate was used immediately.

35% crude protein feed was formulated using locally available ingredients, and four different diets were produced from the feed by adding varying quantities of the prepared *I. bantatas* extracts as follows: 0ml/kg, 50ml/kg 100ml/kg and 150ml/kg and labeled as Do, D1, D2 and D3 respectively.

2.4 Experimental Design and Feeding Trials

A total of one hundred and twenty (120) sub-adult *Clarias gariepinus* were distributed into four (4) groups in triplicates of ten (10) fish per replicate into twelve (12) aquariums (10 fish/aquarium). The fish were acclimatized in the aquariums for two weeks and were fed to satiation twice a day with a commercial diet. After the acclimatization period, the fish were fed with the experimental diets (Do – D3) according to their group for a period of eight (8) weeks, and complete water exchange was done ones daily.

2.5 Proximate Analysis of the Experimental Diets and Experimental Fish

The proximate analysis of the experimental diets and fish were carried out in the Department of Food Science and Technology in the Rivers State University, using the methods in (Oh et al. 2022).

2.6 Determination of Nutrient Utilization

The following parameters were evaluated to determine the nutrient utilization, using the methods in (Yilmaz et al. 2012) and (Ukwe et al. 2019):

Feed Intake (FI)

$$FI = \frac{Weight\ of\ feed\ consumed\,(g)}{Number\ of\ fish}$$

Net Protein Utilization (NPU)

$$NPU = \frac{Fish\ Protein}{Protein\ Fed} x100$$

Food Conversion Ratio (FCR)

$$FCR = \frac{Feed\ intake\,(g)}{Weight\ gain\,(g)}$$

Protein Intake (PT)

PI = Percentage crude protein of feed X Feed Consumed (g)

Protein Efficiency Ratio (PER)

$$PER = \frac{Weight\ gain\,(g)}{Protein\ intake\,(g)}$$

Fat Retention (FR)

$$FR = \frac{FFC\,x\,FFW\,(g) - (IFC\,x\,IFW\,(g)}{FCD\,x\,FCR\,x[FFW\,(g) - IFW\,(g)]} X\ 100$$

Where: FR = Fat retention; FFC = Final fat concentration; FFN = Final fish weight; IFC = Initial fish weight; FCD = Fat content of diet; FCR = Feed conversion ratio.

Protein Retention (PR)

$$PR = \frac{FPC - FFW\,(g) - (IPC\,x\,IFW\,(g)}{PCD\,x\,FCR\,x[FFW\,(g) - IFW\,(g)]} X\ 100$$

Where: FR= Protein retention; FPC = Final protein concentration; FFC = Final fish weight; IPC = Initial protein concentration; IFW = Initial fish weight; FCR = Fed conversion ratio

2.7 Determination of Water Quality Parameter

The temperature (Temp) and dissolve oxygen (Do) were monitored daily. While the pH was monitored twice a week. They were monitored as follows:

- Temperature: The temperature was determined using mercury glass thermometer

- PH: The PH was determined using pH meter
- DO: The dissolve oxygen was determined using the Do meter

2.8 Organoleptic Assessment of the Experimental Fish Flesh

This was determined using the sense of touch, smell, taste and sight (Lubis et al. 2021). A ten man panel of judges were constituted for the assignment. Five fish from the different diets were eviscerated and soak in brime solution for five (5) minutes; they were later dried in an electric fish smoking oven. At the end of every taste exercise the panelists were given cabin biscuits and water to erase the taste before tasting another set.

2.9 Statistical Analysis

The data analysis was expressed as a mean + SE for each of the variables. The statistical difference (P<0.05) of the determined values were tested using one way ANOVA. Followed to a turkey multi-comparison test with spss 17.0 package software (Wahua 1999).

3. RESULTS

3.1 Physicochemical Parameters of the Experimental Waters

The results of the physicochemical parameters is shown in table 1. There were no significant difference across the treatments, the values for the tested parameters were similar.

3.2 Proximate Composition of Experimental Diets

The proximate composition of the experimental diets formulated with different levels of *Ipomoa batatas* are presented in Table 2. The results obtained indicated that the values for moisture content were within the same range (11.30– 11. 43) in diets D1-D2. However, a lower value of 10.82±1.29 % was recorded in diet D3. The same trend was equally observed in ash, where the same values (16.20-16.92) were recorded in diets D0- D2 and a higher value of 17.55±3.72 % was recorded in diet across the diets D3. The value of crude fiber and lipid were within the same range. The values for lipid crude fibre and carbohydrate were higher in Do (6.69±0.29 and 15.08±3.19 respectively).

3.3 Proximate Composition of the Flesh of the Experimental Fish (*C. gariepinus*)

The proximate composition of the flesh of *Clarias gariepinus* fed dietary *Ipomea batatas* for eight weeks are presented in Table .3. The results indicated that the values for moisture, crude protein and lipid were higher in the *I. batatas* fed fish (D1-D2) compared to the control (Do). While the values of carbohydrates in the experimental fish varied significantly (P<0.05) among the dietary treatments with no definite pattern. However, the values of ash and crude fibre were within the same range of 2.36-2.90 and 0.29-0.42 respectively.

3.4 Organoleptic Assessment of *Clarias gariepinus* Fed Dietary *Ipomea batatas* Leaf

The organoleptic assessment of *Clarias gariepinus* fed dietary *Ipomea batatas* leaf extracts for eight weeks are presented in Table 4. The results revealed a significant (P<0.05) difference in the taste of the experimental fish between the control (D0) and other experimental diets of D1, - D3. The aroma of *C. gariepinus* were within the same range of 7.33-7.67 in the fish fed Do – D2, while the fish fed D3 had higher value (8.33 $\pm$ 0.58). However, the fish fed diets D1- D3 had higher value (8.33 $\pm$ 0.58). The fish fed diets D1 – D3 had higher values (6.00 $\pm$ 1.00 – 8.33 $\pm$ 1.53) for texture compared to the value in the control (Do) (5.00 $\pm$ 1.00). In terms of appearance, the fish fed with dietary treatments of *Ipomea batatas* of D1,- D3 recorded significantly (P<0.05) higher values of 7.33±1.16 , 8.95±1.16 and 8.67±0.07 respectively while the fish fed Do had 6.67 ±1.53. The result for mouthful and acceptability shows that C.*gariepinus* fish fed with dietary treatments of *Ipomea batatas* of D1 - D3 recorded significantly (P<0.05) higher values than the those fed with control diet D0, but diet D2 recorded the highest among all the dietary treatments.

3.5 Nutrient Utilization of *Clarias gariepinus* Fed Dietary *Ipomea batatas* Leaf

The summary of nutrient utilization of *Clarias gariepinus* fed dietary *Ipomea batatas* for eight weeks are presented in Table 5. The results indicated that the values of protein intake (PI) in the experimental fish fed with different dietary treatments were within the same range, however higher values of 34.84±0.01, 34.56±1.16 and 35.33±0.09 were observed in D1, D2 and D3 respectively. In food conversion ratio (FCR), lower values of 1.21±0.07 andm 1.20±0.04 were observed in D2 and D3. While higher values of 1.97±0.05 and 1.50±0.09 were observed in D2 and D3.

For protein efficiency ratio of the experimental fish fed with different dietary treatments were within the same range of 2.07-2.45 between diets D1 to D3. However, a higher value of 1.85±0.36 were recorded at diet D0. In Apparent Net Protein Utilization (ANPU) in *C.gariepinus* fed with different levels of *Ipomea batatas* inclusion dietary treatments over eight weeks, the values of ANPU obtained were within the same range of 7.14-8.11 in diets D0, D2, and D3. However,

Table 1. Summary of the physicochemcial parameters of the experimental waters (Mean +SE)

	Treatments			
Parameters	**D_o**	**D_1**	**D_2**	**D_3**
Dissolve oxygen (mg/L)	4.65±0.17	4.11 ±0.31	4.01 ±0.21	**3.81 ± 0.34**
Temperature (^oC)	25.09±1.01	28.37±1.13	28.17±0.91	27.39±1.21
pH	6.91±1.31	6.31±0.09	6.09±0.09	6.13±1.23

Means within the same column with different superscript are significantly different (P<0.05)

Table 2. Proximate composition of experimental diets (Mean ±SD)

Treatments	Proximate Parameters (%)					
	Moisture	**Ash**	**Crude Protein**	**Lipid**	**Crude Fibre**	**Carbohydrate**
D_0	11.30±0.71^b	16.86±1.49 ^{a}	35.15±0.23 ^{a}	6.69±0.29 ^{b}	15.08±3.19^b	29.15±0.28 ^{b}
D_1	11.43±0.69 ^{b}	16.20±0.30 ^{a}	35.24±0.09 ^{a}	4.57±0.50 ^{a}	12.72±2.32^a	26.72±0.92 ^{a}
D_2	11.36±0.35 ^{b}	16.92±0.45 ^{a}	35.34±0.15 ^{a}	5.76±0.88 ^{a}	12.74±7.78^a	25.93±0.56 ^{a}
D_3	10.82±1.29 ^{a}	17.55±3.72 ^{b}	35.17±0.01 ^{a}	4.10±0.06 ^{a}	11.10±3.48^a	26.16±0.24 ^{a}

Means within the same column with different superscript are significantly different (P<0.05)

Table 3. Proximate Composition of CC. gariepinus Flesh Fed Dietary I. batatas Leaves Extract (Mean ±SD)

Treatments	Proximate Parameters					
	% Moisture	**% Lipids**	**% Protein**	**% Carbohydrate**	**% Ash**	**% Fibre**
Before Experiment	58.73±1.50^a	4.80±0.45^a	14.91±0.59 ^{a}	0.76±0.14 ^{a}	2.26±0.16 ^{a}	0.29±1.31^a
D_0	71.90±0.04^c	5.82±1.20 ^{a}	16.52±1.22 ^{b}	1.02±0.56 ^{b}	2.88±0.60 ^{a}	0.40±1.12 ^{a}
D_1	71.90±0.08^c	6.81±1.12 ^{b}	17.17±1.30 ^{c}	0.86±1.91 ^{a}	2.93±0.43 ^{a}	0.41±0.35 ^{a}
D_2	71.61±1.36^c	6.66±0.97 ^{b}	18.37±0.91 ^{d}	0.91±0.79 ^{a}	2.66±0.93 ^{a}	0.42±0.77 ^{a}
D_3	69.29±1.53 ^{b}	6.35±0.59 ^{b}	17.89±0.07 ^{c}	0.87±1.23 ^{a}	2.28±1.15 ^{a}	0.41±0.29 ^{a}

Means within the same column with different superscript are significantly different (P<0.05)

Table 4. Organoleptic assessment of *Clarias gariepinus* Fed Dietary *Ipomea batatas* Leaf extracts for Eight Weeks (Mean ±SD)

Treatments	Organoleptic Parameters					
	Taste (10)	**Aroma (10)**	**Texture (10)**	**Appearance (10)**	**Mouth Full (10)**	**Acceptability (10)**
D_0	6.67±2.08^a	7.67±1.53^a	5.00±1.00 ^{a}	6.67±1.53 ^{a}	7.07±2.08 ^{a}	34.33±7.09 ^{a}
D_1	8.00±0.00 ^{b}	7.33±0.37 ^{a}	7.33±1.33 ^{b}	7.33±1.16 ^{a}	7.67±0.58 ^{a}	38.00±0.00 ^{a}
D_2	8.67±1.53 ^{b}	7.33±2.08 ^{a}	8.33±1.53 ^{b}	8.95±1.16 ^{b}	9.00±1.00 ^{b}	41.00±4.36 ^{b}
D_3	7.67±1.53 ^{b}	8.33±0.58 ^{b}	6.00±1.00 ^{a}	8.67±0.07 ^{b}	8.00±0.00 ^{b}	39.33±2.31 ^{a}

Means within the same column with different superscript are significantly different (P<0.05)

Table 5. Summary for Nutrient Utilization of *Clarias gariepinus* Fed Dietary *Ipomea batatas for Eight Weeks (Mean ±SE)*

Nutrient Utilization Parameters								
FW	**WG**	**FI**	**PI**	**FCR**	**PER**	**NPU (%)**	**PR (%)**	**FR (%)**
D_0 231.01±3.50^a	54.00±2.75^a	89.46±2.03 ^{a}	31.32±0.72^a	1.97±0.05^b	1.85±0.36 ^{a}	46.99±0.92^a	31.62±7.97^a	16.47±7.41^a
D_1 263.65±3.90^b	74.65±4.90^b	99.53±0.93 ^{a}	34.84±0.33^a	1.50±0.09 ^{b}	2.07±0.11^b	48.72±0.72^a	43.48±1.82^b	53.00±35.02^b
D_2 259.87±0.87^b	84.37±4.13^c	98.72±0.02 ^{a}	34.56±0.01^a	1.21±0.07 ^{a}	2.41±0.12^b	50.98±2.43^b	59.85±11.56^c	68.47±27.20^c
D_3 265.12±0.38^b	87.62±2.13^c	102.34±1.22^b	35.53±0.09^b	1.20±0.04 ^{a}	2.45±0.10 ^{b}	50.87±0.76^b	55.93±3.48^c	62.56±38.98^c

Means within the same column with different superscript are significantly different (P<0.05) a higher value of 13.14±2.43 were recorded at diet D2. The values of protein retention (PR) obtained in the experimental fish varied significantly (P<0.05) among the dietary treatments, with the highest value (59.85±11.56) observed in diet D2. And the lowest (31.62±7.97) observed in diet D0. Also, the values of FR obtained in the experimental fish varied significantly (P<0.05) among the dietary treatments, with the highest value (68.47±27.20) observed in diet D2., while the lowest (16.47±7.41) was observed in diet D0. Comparative values of protein increase (PI) in *C. gariepinus* fed with fed with different levels of *Ipomea batatas* inclusion dietary treatments over eight weeks is shown in Fig. 1. The values of PI increased as the experimental period increased. In all dietary treatments. The highest value of 42.70 obtained in diet D3 at week 8. While the lowest (25.90) was observed at diet D0 at week 2. Comparatively, the values of FCR in *C. gariepinus* fed with fed with different levels of *Ipomea batatas* inclusion dietary treatments over eight weeks are presented in Fig. 2. The values of FCR reduced as the experimental period increased in all dietary treatments. With the highest value of 3.29 obtained in diet D3 at week 2, while the lowest (1.04) was observed at diet D2 at week 8. The comparative values of PER in *C. gariepinus* fed with fed with different levels of *Ipomea batatas* inclusion dietary treatments over eight weeks is shown in Fig. 3. The values of PER increased as the experimental period increased. In all dietary treatments. The highest value of 2.86 obtained in diet D3 at week 2. While the lowest (0.87) was observed at diet D0 at week 2.

The comparative values of feed intake (FI) in *C.gariepinus* fed with different levels of *Ipomea batatas* inclusion dietary treatments over eight weeks is shown in Fig. 4. The values of FI increased as the experimental period increased, in all dietary treatments. The highest value of 122.00 obtained in diet D3 at week 8. While the lowest (75.3) was observed at diet D0 at week 2. However, dietary treatment D0 consistently recorded the lowest value among all the dietary treatments in all experimental periods.

4. DISCUSSION

4.1 Proximate Composition of Experimental Diets

The results for the physiochemical parameters (Table 1) were similar to that of Ukwe and Deekae (2024), who stated that they were conducive for aquaculture practice. Ukwe and Abu (2016) reported that water qualities such as temperature, dissolve oxygen and pH determines to a large extend the growth and health of fish in aquaculture. The growth, health and reproduction of commercial fish and other aquatic animals are primarily dependent upon an adequate supply of nutrient, both in terms of quantity and quality, irrespective of the culture system in which they are grown. Therefore, supply of inputs (feeds, fertilizers etc.) must be ensured so that the nutrients and energy requirements of the species under cultivation are met and the production goals of the system are achieved (Gabriel et al. 2007). Nowadays formulated and commercial fish feeds are widely used for more yield in aquaculture. The protein requirement of commercial fish is influenced by various factors such as commercial fish size, water temperature, feeding rate, availability and quality of natural foods and overall digestible energy content of diet (Storebakken and Refstie 2000). In this study, the crude protein content of the experimental diets analysed were within the acceptable range recommended for commercial fish (Shiau et al. 1990). Soliman (2015) reported that most of the commercial fish feeds for example catfish feeds contain 32% crude protein. Agani et al. (2004) estimated the protein requirement for tropical catfish to be 35-40, 25-35 and 28-32% for fry, grow-out and brood stock respectively. However Atteh and Ologbenla (2015) observed that fish production increased through the utilization of high amounts of protein i.e., 35% and above in their diet and dietary protein have been reported to improve the quality of fish flesh (Kuo et al. 2022).

Lipids are primarily included in formulated diet to maximize their protein sparing effect (Hassan 2001) by being a source of energy. The observed lipid values were in line with that of Agani et al. (2004) who reported that 10-20% of lipid in most freshwater fish diets gives optimal growth rates without producing an excessively fatty carcass. On the other hand, Wilson (2000) reported that lipid level in catfish feeds should be 5 to 6%. Moreover, Atack et al. (2019) and Luquet (2000), also stated that dietary lipid levels of 5 to 6% are often used in tilapia diet. In this study, the lipid content of the experimental diets (D1 – D3) were lower, this may be due to the fact that *Ipomea batatas* leaves extract is low in fat content (Oyin 2006), it could also be that the phytochemicals in *Ipomoa batatas* leaves facilitated the reduction of the lipids in the diets.

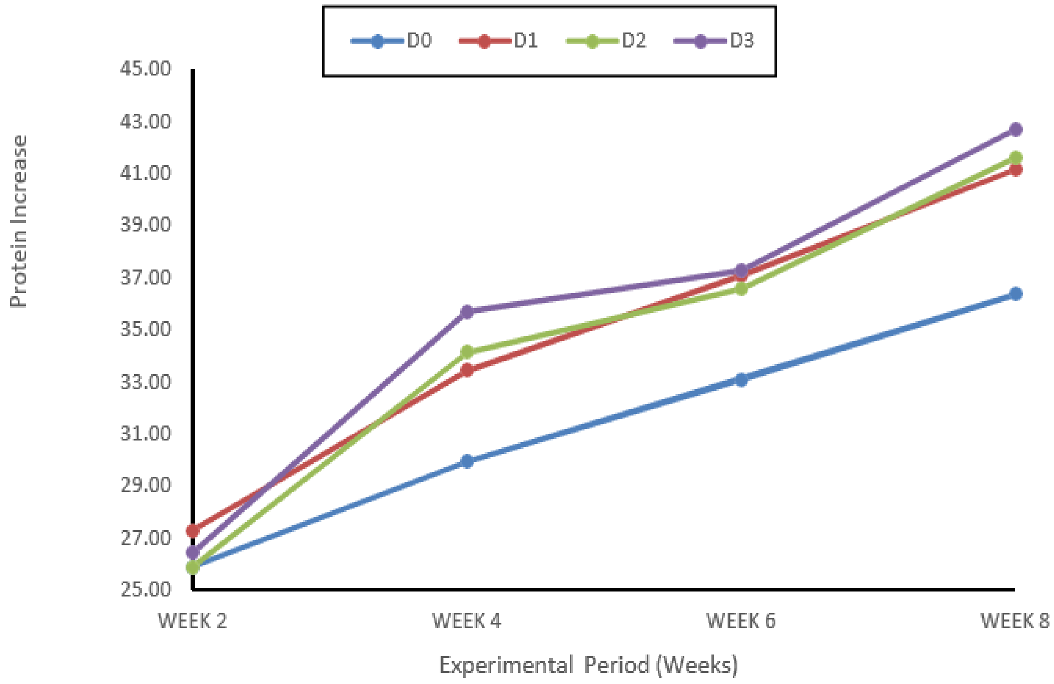

Fig. 1. Comparative values of Protein Increase in *C.gariepinus* fed with dietary *Ipomea batatas* leaf extracts for eight weeks

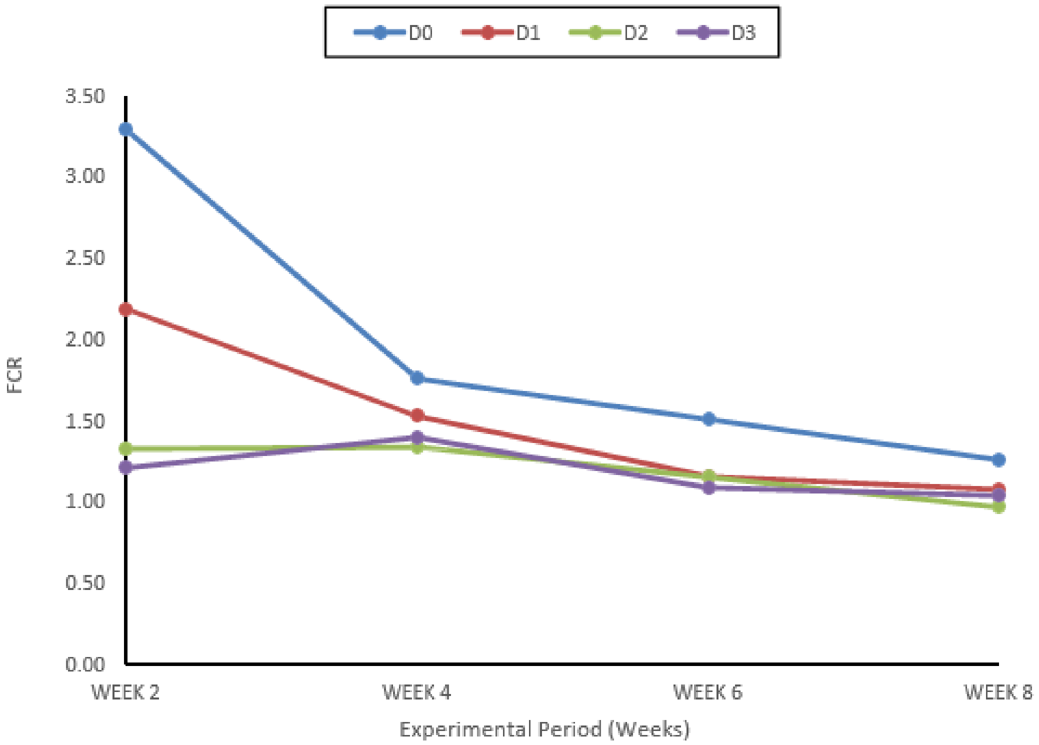

Fig. 2. Comparative values of Feed Conversion Ratio in *C.gariepinus* fed with dietary *Ipomea batatas* leaf extracts for eight weeks

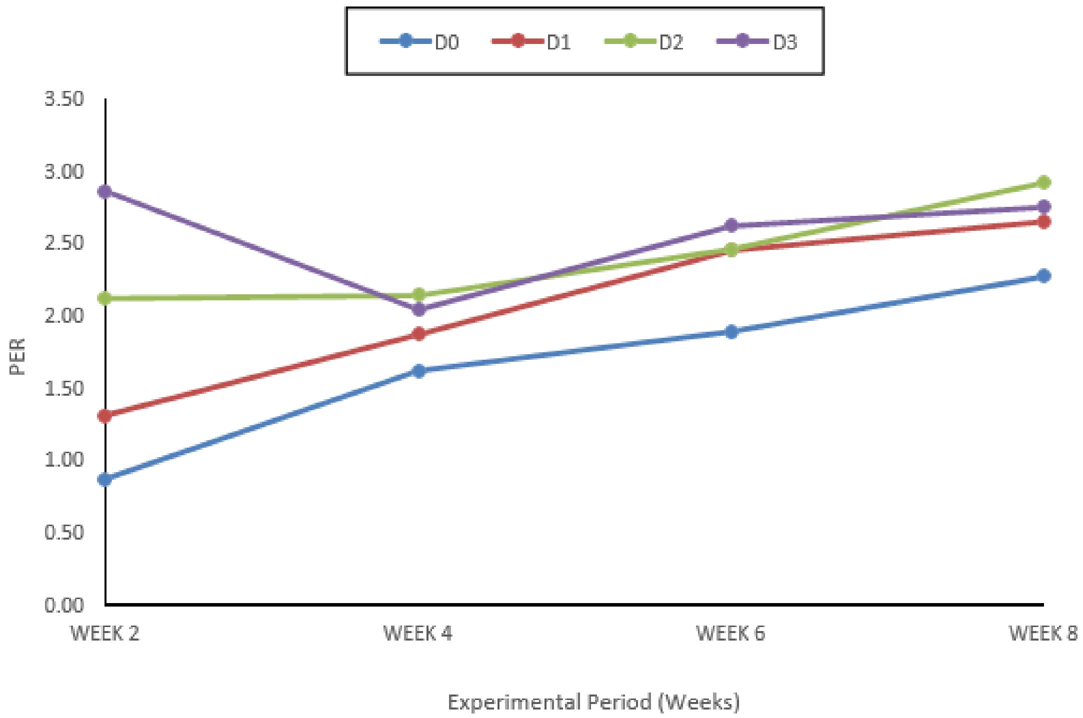

Fig. 3. Comparative of Protein Efficiency Ratio (PER) in *C.gariepinus* fed with dietary Ipomea batatas leaf extracts for eight weeks

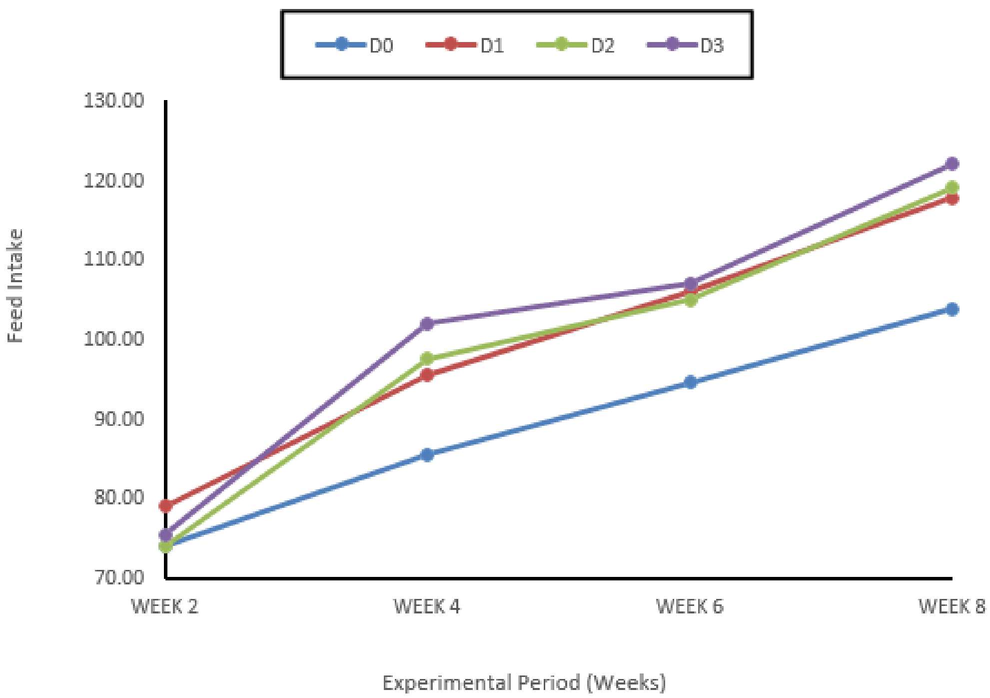

Fig. 4. Comparative values of Feed intake in *C.gariepinus* fed with dietary Ipomea batatas leaf extracts for eight weeks

All plant ingredients contain a certain amount of fibre, and fibre provides physical bulk to the feeds. Adequate quantity of fibre in feed permits better binding and moderates the passage of feed through the alimentary canal. However, Awoniyi et al. (2011) noted that it was not desirable to have a fibre content above 8-15% in diets for animals, as the increase in fibre content would consequently result in the decrease of the quality of nutrient in the diet. (Ukwe et al. 2020) also stated that high fibre content in feeds tends to increase the energy content in the feeds, with the resultant effects of poor growth. The analysed crude fibre content of all the diets under study were within the safe dietary limit for fish.

4.2 Proximate Composition of Experimental Fish Flesh

The moisture and carbohydrate content of the experimental fish fed D1 – D3 after the feeding trial were elevated above the control values. While the ash and fibre content of the fish were within same range across the diets. This result agrees with the findings of Oresegun and Alegbeleye (2001) in the flesh of *C. gariepinus* fed with cassava leaves. The result of the proximate composition of the experimental fish shows higher protein and fat values in fish fed diets D1- D3 compared to the fish fed Do and the values before the commencement of the experiment. Similar result was recorded in Yilmaz et al. (2012) when sea bass (*Dicentrarchus labrak)* was fed dietary Thyme, but Rosemary and Fenugreek in the same experiment showed no significant difference in the protein content of the experiment fish, and Adewolu (2008) who reported improvement in the protein content and reduction in the fat content when *Ipomoea batatas* leaf meal was administrated to *Tilapia Zilli.* Oludayo (2010) also reported increase in both protein and fat content when African catfish was fed with 40% *Ipomoea batatas* leaf meal for fourteen days. The deviation in the fat content of *Tilapia Zilli* sited above compare to the present result could be as a result of the life stage of the fish. The increase in the protein and fat content of the fish fed D1-D3 could be as a result of the bio-active compounds and minerals contain in *Ipomoea batatas* leaves extracts (Olamiposi and Tolulope 2018) that enhanced the digestion and absorption of the protein and fat in the diets. Minerals such as calcium, phosphorous, potassium etc contain in *Ipomoea batatas* (Olamiposi and Tolulope 2018) are known to improve fish flesh quality (Wu et al. 2017, Bell et al. 2013). Overland et al. (2008) reported the positive effects of plant phytochemicals such as astaxanthin and carotene on the flesh quality of Atlantic salmon.

4.3 Organoleptic Assessments of the Experimental Fish

Fishes are great source of highly valuable protein that is premium in human nutrition (Nargis 2006), with its irregular water and fat content (Pal et al. 2018). The crude protein content of the fish is also affected by the quantity of salt and water-soluble protein in the diets (Chomnawang et al. 2007), and the presence of endogenous enzyme and bacteria influencing deterioration during the processing period (Hultman and Rustard 2004).

Eating healthy is a prerequisite to a good and sustainable live, and people are more concern with what they eat (Oriakpono et al. 2011). One factor that influences organoleptic assessment in fish is acceptability of available feed by the fish. Farmer et al. (2000) postulated that the overall acceptability and sensory characteristic of the fish is correlated to the quality of the water body, and Fawole et al. (2018) also reported difference in taste when *Sardinella spp* and *M. pontasson* from different locations within the South-West Nigeria were organoleptically accessed. Despite that several methods have been used to evaluate the flesh quality and freshness of fish, sensory evaluation remains the valuable and trusted means of obtaining the best result (Fatma and Mohamed 2011). Shiau et al. (1990) reported a positive correlation between body composition and sensory quality, whereas Ochang et al. (2007) observed no significant differences in the sensory evaluation of fresh fish fed different diets. In this study, fish fed diets D1-D3 were significantly superior to those fed the control diets (Do) in the organoleptic assessment.

The superiority of the fish fed D1-D3 in the organoleptic assessment could be as a result of the bio-active compounds present in the diets, that enhanced bioavailiability of the nutrients in the diets. This assertion is supported by Parada and Aguilera (2007) who postulated that the quantity of nutrient delivered to the blood steam for use is more relevant than the quantity present in the feed. Some of the bioactive compounds found in *Ipomoea batatas* leaves includes phenolic compounds, flavonoids, carotenoids, dietary fibres, dietary protein etc (Nguyen et al. 2021; Awol 2014) and essential minerals and trace elements such as iron, calcium, zinc, copper among others (Frankic et al. 2009; Awol 2014). *Ipomoea batatas* leaves have been proven to have high digestibility for proteins/amino acids (Leon, 2023) and digestibility enhances absorption of nutrients (Kuoshik and Mraz, 2021). (Frankic et al. 2009) also reported that herbs stimulate the secretion of pancreatic enzymes which facilitates nutrients digestion and assimilation.

The noticeable changes in the catfish aroma, colour and taste are the main criteria that qualify catfish at table size (Muin et al. 2014). It was demonstrated in this study that feeding catfish with different levels of *Ipomea batatas* leaves inclusion diet enhanced the typical characteristics of fish; taste, aroma, texture, and appearance in catfish flesh and did not yield any off odour or flavour, and this can be attributed to the higher lipid content in the fish fed D1-D3 (Table 3). The observation was similar to previous reports which suggested that the lipid in fish flesh affects the sense of flavour and the general sensation of cooked fish in the mouth as well as aroma (Muin et al. 2014). Ramezani (2009) also noticed the effect of inclusion of the supplemental plant-based protein in the diet of brown trout on taste, texture, and acceptability. On the contrary, Khan et al. (2012) observed that no effects of dietary treatments were found to affect taste, texture and aroma of the Indian major carps fed with different plant based dietary treatments.

4.4 Nutrient Utilization of the Experimental Diets

Plants and plants products have been utilized as additive or supplements in fish feeds due to their ability in the maintenance of fish health and enhancing digestibility/absorption of nutrients in feed (Dawood et al. 2022). Plants and plants products are preferred to synthetic drugs as growth enhancers in aquaculture (Ghafoor et al. 2020), and have been proved to be growth promoters, anti-bacteria, environmentally friendly and are not immunospecific (Ukwe and Gabriel 2019). Some of the bioactive compounds in plants and plant products that facilitates the above qualities includes; polyphenols, flavonoids, saponines, tannins, essential oils etc. (Ukwe and Deekae 2022, Ukwe and Deekae 2024), and *Ipomoea batatas* leaves extracts contains these bio active compounds (Nguyen et al. 2021; Awol 2014; Ukwe and Deekae 2024).

Some of the valuable indices used to determine the effectiveness of how an experimental fish utilizes its diet are: the feed conversion ratio (FCR) which is the expression of how the fish converts feed to flesh; the protein efficiency ratio (PER) which expresses the effectiveness of the fish to utilize protein in the diet for growth; the protein intake (PI) which states the quantity of protein taken from the injected feed by the fish, and the feed intake (FI) which expresses the quantity of feed injected by the fish (De et al. 2018; Qi et al. 2012).

There were difference in the PI, FCR, and PER in the fish fed Do – D3, with the value increasing as the concentration of *Ipomoea batatas* leaves extracts in the diets increases. The result of this research shows that the PI and FI increases as the period of feeding increases in fish fed D1-D3 compared to the fish fed Do. This result is similar to the report of Lawal et al (2021) when *Clarias gariepinus* was fed dietary *Terminalia catappa, Chromolaena odorata* and *Psidium guajava.* The increase in the feed intake (FI) and protein intake (PI) in the fish fed D1-D3 could be as a result of the presence of the bioactive compounds in *Ipomoea batatas* leaves extract, that enhanced the palatability of the diets or having direct bactericidal effects on the digestive system of the fish fed D1-D3 thereby enhancing protein digestion and absorption (Citarasu 2010). Polyphenols, flavonoids, calcium, phosphorus, and potassium are some bioactive compounds and minerals found in *Ipomoa batatas* and have the ability to enhance palatability and digestion of feed (Zhang et al. 2020). The feed conversion ratio (FCR) reduced as the period of the experiment increases and were lower in the fish fed D1-D3 compared to the fish fed Do (Fig. 2). Feed utilization by the fish determines the FCR (Ekanem et al. 2010). This result depicts the fact that the I. batatas leaves extract enhance feed utilisation in fish.

The reduction in the FCR is an indication that the fish made a good conversion of feed to flesh, and the reduced values in D1-D3 depicts that the biochemical compounds in *Ipomoea batatas* enhanced digestion and absorption of the feed compared to fish fed Do (Koushik and Mraz 2021, Leon 2023).

The protein efficiency ratio (PER) increases as the period of the experiment increases in the fish fed D1-D3 showing better performance (Fig. 3). Protein efficiency ratio is the ability of the fish to use the protein absorbed from the ingredients for growth. The increase in the PER in fish fed D1-D3 depicts the fact that there were enhance digestion and absorption of the protein components of the diets compared to the fish fed Do. This could be as a result of the phytochemicals in *I. batatas* (Ukwe and Deekae, 2024), which have been reported to enhance protein digestiability and absorption in fish (Leon 2023). Other authors have reported results similar to these findings: (Ashry et al. 2023) when striped catfish was fed dietary ginger and Lawal et al (2022) when African catfish was fed dietary *Terminalia catappa.*

After the eight (8) weeks feeding period, the NPU, PR and FR increased with increase in *Ipomoea batatas* inclusion in the diet, with significant increase in PR and FR (Table 5). The increase of these parameters (NPU, PR, and FR) in the fish fed D1-D3 compared to Do suggests the fact that the *Ipomoea batatas* enhanced nutrient utilization, and it is as a result of the stimulating effect of *Ipomoea batatas* leaves extracts on the secretion of pancreatic enzymes that facilitates digestion and absorption of nutrients (Frankic et al. 2009).

Though the PR and FR were higher in the fish fed D1 – D3 the values for PR were higher compared to FR as the *I. batatas* leaves extract increases in their diet (D0 – D3). This depicts the fact that more fat was utilized for energy while more protein was utilized for growth, and as a result led to increase in the quantity of protein deposited in the fish flesh (NPU) which is a measure of digestibility. This position is supported by Yilmaz et al. (2012) and Robb et al. (2002).

5. CONCLUSION

The present study shows that application of *Ipomea batatas* leaf extract can be utilized in fish feed for optimal performance of fish, as it enhances bioavailability, digestion and absorption of nutrients. It was demonstrated that feeding catfish with different levels of *Ipomea batatas* leaf extract inclusion diet improved the typical characteristic of fish such as flesh color, flavour and aroma in catfish fillet and did not yield any off odour, which connotes the fact that what the fish consume as feed affects the quality of the fish flesh. The result of the study shows that 100 – 150 ml/kg dietary inclusion level of *Ipomea batatas* leaves extract produced fish of better flesh quality and composition than the control.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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