International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Original Research Article: Proximate Compositions of Differently Processed Cassava Meals and their Effects on Carcass Quality of *Oreochromis Niloticus*

Ngozi G. Iwuji, Christian N. Anyanwu, Dorathy C. Gbaruko, Dorathy C. Egwuatu, Ekene I. Oguodinma and Donard .I. Osuigwe

Department of Fisheries and Aquaculture Technology, Federal University of Technology Owerri, Nigeria.
E-mail: iwujingozi2@gmail.com / samuel.iwuji@futo.edu.ng

ABSTRACT

This study compared the proximate composition of fish diets formulated by partial replacement of maize with differently processed cassava meals and the carcass quality of *Oreochromis niloticus* fed on these diets. Seven isocalorie and isonitrogennous diets were formulated with sun-dried and fermented gelatinized cassava meals replaced maize at 25%, 50% and 75% levels, respectively. The diet with maize only as energy source served as control. Each diet was randomly assigned to three cages ($1m^3$) stocked with 50 juveniles O. *niloticus* in Otamiri River, Owerri and fed for 56 days. Proximate composition of the diet showed [$p<0.05$] that the crude protein and gross energy values were similar in all diets. Generally, fish fed on fermented gelatinized cassava (25%) diet had similar flesh (carcass) quality as those fed the control diets (maize). The results showed that the nutritional values of diets prepared with maize and cassava are relatively the same but the carcass quality of fish fed on 25% inclusion level of fermented gelatinized cassava had relatively higher values of gross energy content (GE), crude protein (CP), ether extract (EE), ash and moisture contents but lower nitrogen free extract (NFE) and fibre content than the carcass of Nile Tilapia cultured on other processed cassava meals. This may necessitate the replacement of conventional fish energy source (maize) with lower cassava inclusion levels and the supplementation of the higher cassava inclusion diets with protein and lipid-rich ingredients.

Key words: Cassava meals, Proximate composition, Carcass quality, *Oreochromis niloticus*, fish feeds

INTRODUCTION

By 2032 (an *El Niño* year), aquaculture production is projected to account for 55% of total fish production. [1] Aquaculture has been described as a means of augmenting capture fisheries to boost fish food production.[2] Farmed fish account for almost half of the fish consumed worldwide. [3] [4]. Tilapias (*O. niloticus*) were reported as the world's second most important fish species for fish farming, after the carp. [5] However, with intensification in aquaculture, the major problem is what to feed the fish since the same feed ingredients are used in human and livestock feed resulting in increased prices of the conventional feedstuffs. This has implications that feed alone takes over 60% of the operating costs aquaculture.[6]

Maize is one of the major sources of metabolizable energy in most compounded diets as it is readily digestible by fish. [7] Maize, which is predominantly used for human consumption in Nigeria, is not provided in sufficient quantities.[8] The increasing prohibitive cost and scarcity of maize have necessitated the need to search for underutilized energy feed ingredients.[9] Therefore, there is an urgent need to step up aqua feeds research and production if Nigeria must attain self-sufficiency in terms of fish production. [10-16]

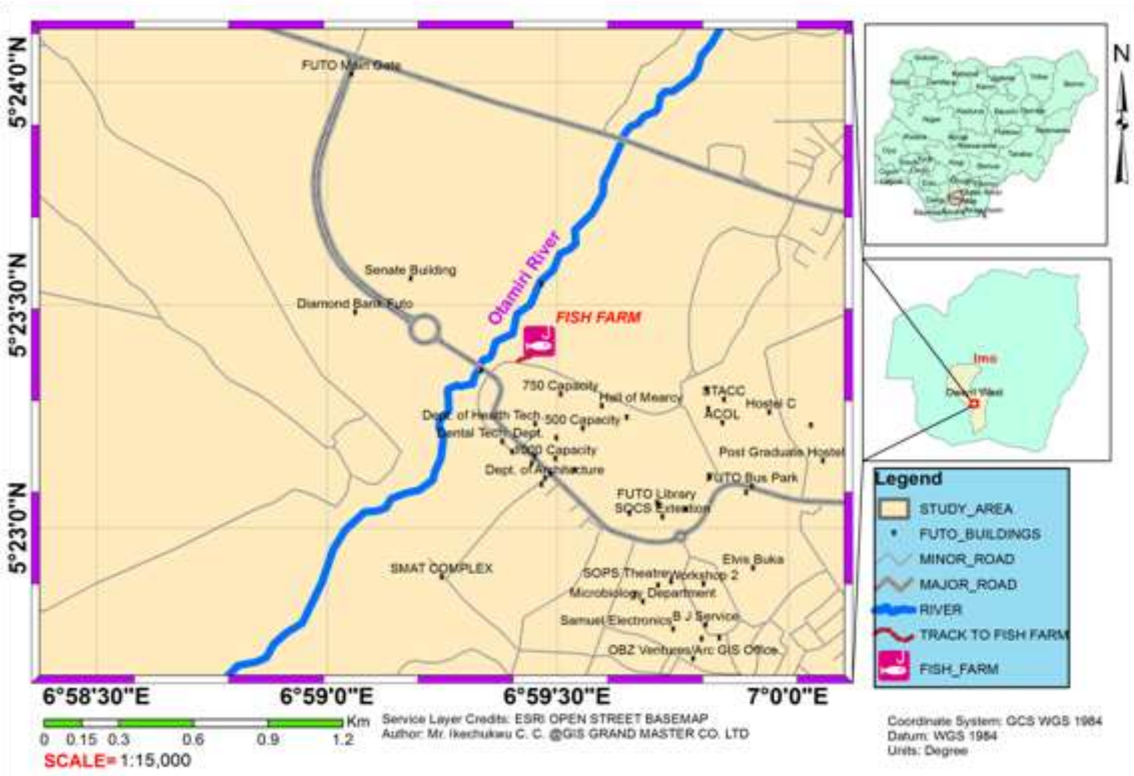
Utilization of carbohydrates by tilapia is within a range of 35-40% of the digestible portion depending on certain factors such as the size of the species, including of feeding, origin of carbohydrate and presence of other ingredients. [17] Cassava is one of the energy sources that have great potential as an alternative to maize. Nigeria is regarded as the greatest producer of cassava in the world today with production estimate of about 33 million metric tonnes per annum. [8]

There could be possible differences in the nutritional composition of sundried and fermented gelatinized cassava that may cause various effects on the carcass quality of fish cultured in cages in the rivers. In this study, herbivorous O. *niloticus* juveniles cultured in cages were fed on graded levels of differently processed cassava diets in order to determine their effects on their carcass quality.

MATERIALS AND METHODS

Study area:

The research was conducted in part of Otamiri River in Federal University of Technology Owerri, Imo State, Nigeria. Otamiri River is a major water source for the population of Imo State, Nigeria. [18] The geographical area of the project site was located using the Hand-Held Global Positioning System (GPS) Receiver (Garmin Montana 680T, USA) with the assistance of Prof. E. U. Onweremadu of Institute of Erosion Studies and Mr. C.C. Ikechukwu both in Federal University of Technology Owerri. The Project fish farm coordinate is Latitude N5.390318 and Longitude: E6.991008 (as shown below)



LOCATION MAP OF OTAMIRI RIVER STUDY AREA IN FUTO NIGERIA

The cages were installed in a water body created by sand mining along the bank of Otamiri River in FUTO. The depth of the water body there ranged from 0.7-1.55 metres. The flow rate recorded was between 7.05m/ min.

Experimental fish and design:

A total of one thousand and fifty (1050) *O. niloticus* juveniles of average weight of 20g were sourced from a reputable fish farm in Imo State.

The experimental fish were acclimatized and fed with commercial feed for one week. All the fish were starved for 24 hours prior to the commencement of the feeding trial. This was necessary to enable the juveniles to prepare their gastrointestinal tract and adjust to the new diet (Okoye and Sule, 2001) and environment.

Fifty of the experimental juveniles of Nile tilapia were randomly distributed into 1m x 1m x 1m net cage culture. The net cage cultures were covered with mesh nylon screens and lowered into the river.

Fish were fed twice daily morning (08.00-09.00h) and evening (17.00-18.00h) at 5% of their body weight. The weighing was carried out an hour before feeding. Fish from each tank were weighed to the nearest gram at the commencement and subsequently biweekly using weighing scale and corresponding adjustments made in the amount of feed fed. The study period which lasted for 56 days, compared the proximate composition of diets formulated by partial replacement of maize with differently processed cassava meals and the carcass quality of *O. niloticus* fed with the diets.

Experimental method

The proximate analysis of the diets and carcass followed the AOAC method. [20]

Experimental foodstuff and the diet:

Fresh bitter cassava (*Manihot esculata*) roots were procured from a local farm in Obinze, Owerri West LGA of Imo State, Nigeria.

The cassava roots were washed with water to remove any possible dirt and then peeled. The peeled cassava roots were mashed and divided into two portions, one portion was used to prepare fermented gelatinized cassava root meal while the other portion was used for sundried cassava root meal.

Processing of Fermented Gelatinized Cassava Meal

The peeled and mashed roots were fermented for 4 days in plastic vats under ambient temperature. The fermented cassava roots were then put in sacs, pressed to reduce water content and then sundried.

The dusty cassava products were then subjected to gelatinization. Gelatinization involved mixing the meal in water in a pot seated on fire at the rate of 1kg of the meal to 1litre of water and the mixture stirred until it sufficiently gelatinized into *fufu*, the form of cassava meal which is usually prepared and eaten locally.

The products were taken bit by bit and flattened on polyethylene sheets and sun-dried for a given period. The flakes were considered adequately dried when they become crispy to the touch and when they snap at bending.

The flakes were milled in a hammer mill with 2mm mesh size sieve to produce peeled, fermented and gelatinized cassava root meal [21].

Processing of Sundried Cassava Meal

The peeled and mashed cassava roots were de- watered and sun dried to form sundried cassava root meal.

Eight isocaloric and isonitrogenous diets were formulated and designated as; Diets (FG (0%), FG (25%), FG (50%), FG (75%), SD (0%), SD (25%), SD (50%) and SD (75%)) table 3.4. Diets FG (0%) and SD (0%) are the control and had maize as the main source of energy. In Diets (FG (25%), FG (50%) and FG (75%)), maize was substituted with fermented gelatinized cassava and in Diet (SD (25%), SD (50%), and SD (75%)) maize was substituted with sundried cassava. Both were substituted at graded levels of 25%, 50% and 75%, respectively. Maize and the processed cassava were the major energy sources; fishmeal and soybeans in the ratio of 1:2 were the protein sources; the fixed ingredients which include wheat bran, fish premix, bone meal, cassava starch, cod liver oil, common salt, palm oil, methionine lysine and vitamin C made up the 11.5% by weight of respective experimental diets. These ingredients were ground into fine texture. The ground ingredients were mixed in dry form before addition of water at 0.5 L kg-1 of mixture. Water used was at a temperature of 70^{o}C. This enabled dough formation before pelleting was carried out using a 2 mm dice. The pelleted diets were sundried for three days and packed in plastic air tight containers and kept in a refrigerator prior to use.

RESULTS AND DISCUSSION

Gross composition of experimental diets

The seven isocalorie and isonitrogenous diets were formulated with sun-dried and fermented gelatinized cassava meals replaced maize at 25%, 50% and 75% levels, respectively. The gross composition of these experimental diets is shown in Table 1. The diet with maize only as the energy source served as Control.

Table 1: Gross Composition of Experimental diets

INGREDENTS	FG 0%	SD 0%	FG 25%	FG 50%	FG 75%	SD 25%	SD 50%	SD 75%
Fish meal	19.39	19.39	14.97	16.33	17.66	14.97	16.33	17.66
Soya beans	39.77	39.77	44.20	42.83	41.51	44.20	42.83	41.51
Yellow maize	29.33	29.33	22.00	14.67	7.33	22.00	14.67	7.33
Cassava meal	0.00	0.00	7.33	14.67	22.00	7.33	14.67	22.00
Wheat bran	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Vitamin C	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Lysine	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Methionine	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Palm oil	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Fish premix	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Salt	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Bone meal	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Cassava starch	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Cod liver oil	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00

Comparison of the proximate compositions of the experimental diets

The results in Table 2 are the proximate composition(%) and the statistical comparisons (P<0.05) of moisture, crude protein, Ash, Fibre, Ether Extract (EE), Nitrogen free extract (NFE) and Gross energy (GE) in maize (Control) and differently processed cassava diets.

Table 2: Mean proximate compositions of fermented gelatinized and sundried cassava root diets at different inclusion (graded) levels.

PROC_M	**MC (%)**	**CP (%)**	**EE (%)**	**ASH (%)**	**CF (%)**	**NFE (%)**	**GE(kcal/g)**
MZ 0%	6.34±1.02	34.44±1.81	10.18±1.29	10.69±1.56	3.02±0.68	35.33±1.16	437.5±3.18
FG 25%	6.15±1.78	34.32±1.28	10.15±0.13	10.18±0.75	2.42±0.53	36.78±0.75	431.3±2.49
FG 50%	6.39±0.63	34.09±0.92	10.27±0.47	10.20±2.07	2.50±0.02	36.55±2.07	435.9±9.02
FG 75%	6.48±1.28	34.03±1.55	10.23±0.25	10.51±0.44	2.19±0.08	36.56±0.44	435.2±6.86
SD 25%	6.17±0.62	33.93±0.84	10.53±0.18	10.63±0.63	2.85±0.13	35.88±0.63	434.8±2.27
SD 50%	6.18±0.70	33.85±1.64	10.48±0.91	11.08±0.76	3.08±0.42	35.16±0.94	432.5±2.39
SD75%	6.58±2.00	33.40±2.09	10.89±0.19	11.28±0.53	3.18±0.01	34.67±0.65	430.2±12.65
LSD (0.05)	2.60	3.16	1.59	2.24	0.89	2.24	14.94

Keys: PROC_M = Processing method; INC= Inclusion level; FG =Fermented gelatinized cassava root diet; Sundried cassava root diet; MC= Moisture; CP=Crude protein; EE = Ether extract (crude fat); CF = Crude Fibre; NFE= Nitrogen free extract; GE=Gross energy; (Least Significant Difference (LSD) is significant when p<0.05)

Common observations showed that fish feed on raw cassava when soaked in the river for fermentation. Man is commonly known to feed on gelatinized cassava called 'fufu'. Cassava gelatinization is a process of breaking down the intermolecular bonds of starch molecules in the presence of water and heat, allowing the hydrogen bonding sites (the hydroxyl hydrogen and oxygen) to engage more water. [22]

The determined proximate compositions of the cassava root meals prepared as fermented gelatinized and the sun-dried cassava root diets fell within the required range promoting good health and growth of *O niloticus*. It also fell within those published in previous studies, yet did not differ markedly between the two processed types. [23 - 26]

The proximate composition of the diet showed that the Crude Protein and Gross Energy values were similar in all diets but the presence of Ash and ether extract content significantly (p>0.05) increased in the diets formulated with sun dried cassava meals.

Seventy five percent sundried cassava meal diet also had the highest Crude Fibre (3.18±0.01%) that is significantly different (p<0.05) from the others. The Nitrogen Free Extracts content in the gelatinized cassava diets were higher and significantly different (p<0.05) from the other diets (37.72%).

3.3 Comparison of the proximate compositions of the carcasses (carcass quality) from O. niloticus fed on different experimental diets

The results in Table 3 are the proximate compositions (%)and the statistical comparisons (P<0.05) of moisture, crude protein, Ether Extract (EE), Ash, Fibre, Nitrogen Free Extract (NFE) and Gross Energy (GE) contents in carcasses of *O. niloticus* fed on maize (Control) and differently processed cassava diets.

Table 3: Comparing the carcass qualities of O. *niloticus* fed on formulated feeds with graded levels sun-dried and fermented gelatinized cassava roots.

PROC_M	MC	CP	EE	Ash	CF	NFE	GE
PROC X INC							
MZ 0%	72.44±0.18	19.26±0.25	3.32±0.53	4.68±0.07	0.18±0.06	0.12±0.02	140.57±0.45
FG 25%	72.31±0.15	19.47±0.17	3.41±0.18	4.49±0.02	0.20±0.00	0.12±0.02	142.72±0.24
FG 50%	72.47±0.12	19.40±0.48	3.33±0.29	4.39±0.19	0.25±0.05	0.16±0.01	141.74±0.03
FG 75%	74.59±0.14	18.06±0.03	3.05±0.02	3.87±0.21	0.25±0.04	0.18±0.03	131.60±0.27
SD 25%	73.71±0.08	18.47±0.16	3.26±0.13	3.56±0.10	0.25±0.08	0.75±0.04	138.25±0.06
SD 50%	74.35±0.36	17.77±0.06	3.26±0.12	3.73±0.15	0.18±0.06	0.71±0.01	134.12±0.03
SD 75%	74.50±1.13	17.33±0.10	3.10±0.34	3.96±0.15	0.25±0.04	0.860.01	130.74±0.1
LSD (0.05)	0.17	0.24	0.21	0.51	0.03	0.22	2.26

Keys: PROC_M =Processing method; INC=Inclusion; MZ =Maize; FG =Fermented gelatinized cassava root diet; Sundried cassava root diet; MC= Moisture CP=Crude protein; EE = Ether extract (fat); CF = Crude Fibre; NFE= Nitrogen free extract; GE=Gross energy.

The control diet (MZ0% = 72.44%) had higher moisture content than cassava at higher inclusion levels (FG75% = 74.59%; SD75% = 74.50%) probably because alternative energy sources with lower protein and fat levels tend to result in higher carcass moisture contents. [27] The higher moisture content at 75% inclusion may indicate a trade-off between protein and lipid deposition, which inversely correlates with water retention. The lower inclusion levels of fermented gelatinized cassava diets (FG25% and FG50%) maintained moisture levels comparable to the control maize, suggesting improved nutrient utilization. This is consistent with the fact that fermentation enhances nutrient digestibility and reduces anti-nutritional factors like cyanogenic glycosides. [28]

The decline in carcass crude protein at higher cassava inclusion levels of both processing methods reflects the lower protein content of cassava root meals relative to maize and it is coherent with. [29] However, fermented cassava performed better than sun-dried cassava at moderate replacement levels, perhaps due to improved amino acid availability after fermentation. [30]

Higher cassava-based diets despite the processing methods had much lower ether extract (lipid) deposition compared with the control maize diet. This trend is underscored by the results that carbohydrate-rich diets, such as cassava based, often result in reduced lipid deposition due to the preferential utilization of carbohydrates for energy. [31] However, the slightly higher lipid retention in fermented cassava diets at lower inclusion levels (FG25%) supports claims that fermentation improves carbohydrate digestibility and spares lipid for deposition. [32]

There is reduced ash deposition (mineral) in fish fed cassava-based diets at 75% inclusion levels perhaps due to the lower mineral content in cassava compared to maize. [7] Also, fermented cassava diets resulted in slightly higher ash content at lower inclusion levels (FG25%) compared to sun-dried cassava (SD25%), which may reflect improved mineral availability due to the breakdown of phytic acid and other mineral-binding compounds during fermentation.

The crude fiber content remained relatively stable across diets (0.18–0.25%) reflecting the low fibre content of cassava and showing that cassava inclusion does not significantly impact fiber levels in fish carcass composition. [33] The minimal variation suggests that processing methods had little effect on fiber digestibility and utilization.

The carbohydrate-rich diets (at 75% inclusion levels) promoted higher carbohydrate storage (Nitrogen-free extract (NFE) content) in fish tissues. [34] Fermented gelatinized cassava diets resulted in slightly lower NFE values than sun-dried cassava at comparable inclusion levels, likely due to enhanced carbohydrate metabolism during digestion. It is however noteworthy that the increase in NFE at the expense of protein and fat deposition indicates a shift in carcass composition, which may affect the nutritional quality of the fish for human consumption.

The reduced carcass energy content in fish fed higher-carbohydrate diets (FG75% = 131.60 kcal/100g; SD75% = 130.74 kcal/100g compared to the control MZ0% = 140.65 kcal/100g) reflects the lower energy density of cassava. [35] The fermented gelatinized cassava diets at lower inclusion levels (FG25% = 142.72 kcal/100g) had relatively higher energy content probably because fermentation improves the energy value of cassava by reducing fiber and anti-nutritional factors. [36]

The optimal inclusion levels (FG25% and FG50%) yielded carcass quality closer to that of control maize diet. This implies that 25–50% levels of inclusion is a practical range for incorporating cassava root meal into Nile tilapia diets as supported by [37] Fermentation enhances cassava's nutritional profile [32] [38-39] which could cause its higher carcass quality than the sundried cassava meal.

At higher cassava inclusion levels, both processing methods resulted in significant reductions in protein, fat, and energy contents depicting the limitations of cassava as a primary feed ingredient. Consequently, there is need for supplementation with protein- and lipid-rich ingredients [30] at 75% inclusion levels of cassava.

CONCLUSION

The triplicates of experimental diets were prepared with differently processed cassava roots and compared with the maize (Control) as the energy source to O. *niloticus* cultured in cages. This work showed that the nutritional values of diets prepared with maize and cassava were relatively the same but the carcass quality of fish fed on 25% inclusion level of fermented gelatinized cassava had relatively higher values of crude protein (CP), ether extract (EE), ash and gross energy (GE) contents but lower moisture, fibre and nitrogen free extract (NFE) content than O. niloticus cultured on other processed cassava diets. This necessitates the replacement of conventional fish energy source (maize) with lower cassava inclusion levels and the supplementation of the higher cassava inclusion diets with protein and lipid-rich ingredients.

REFERENCES

1. https://doi.org/10.1787/08801ab7-en © OECD/FAO 2023
2. Nwanna, L and Oladipupo, M. (2018). Evaluation of the Effect of Replacing Maize with Cattle Rumen Waste Meal in Feed for Production of Nile Tilapia, *Oreochromis niloticus*. *J. Appl. Sci. Environ. Manage*. 22 (3): 391 –394. https://www.ajol.info/index.php/jasem http://ww.bioline.org.br/ja

3. Fry, J. P., Love, D. C., MacDonald, G. K., West, P. C., Engstrom, P. M., Nachman, K. E., and Lawrence, R. S. (2016). Environmental health impacts of feeding crops to farmed fish. *Environment International*, *91*, 201–214. https://doi.org/10.1016/j.envint.2016.02.022

4. Food and Agriculture Organization (2018). The State of World Fisheries and Aquaculture (SOFIA); FAO: Rome, Italy: p. 227.

5. El-Sayed AM (2002) Effects of Stocking Density and Feeding Levels on Growth and Feed Efficiency of Nile Tilapia (*Oreochromis niloticus*) Fry. *Aqua Res.* 32: 621-625.

6. Nwanna, LC; Ogundowole, OE; Nwanna, EE (2014).Use of Plantain (Musa paradisiaca) peels in low costs diets for enhancement of growth and carcass quality of African catfish, J. Appl. Aquacult, 26 (1): 1-10

7. Olurin, K B; Olujo, E; A,Olukova, OA (2006). Growth of African catfish *Clarias gariepinus* fingerlings, Fed Different Levels of Cassava. World J. Zoo (1):54-56.

8. Food and Agriculture Organization (2005). *A synthesis of formulated animal and aqua feed industry in sub-saharan Africa*. Moel J. and Halwart M (eds). CIFA Ocassional Paper No 26 61p.

9. Jimoh W. A., Sodamola M. O., Ayeloja A. A., Oladele-Bukola M. O. and Shittu M. O. (2014).The influence of replacing maize with *Chrysophyllum Albidum* seed meal on growth response and nutrient utilization in *Clarias Gariepinus. Agrosearch. 14(1):54-61* http://dx.doi.org/10.4314/agrosh.v14i1.6

10. Osuigwe, D.I. (2014). Growth response of *Heterobranchus longifilis* (*Valenciennes*, 1840) fingerlings fed raw and boiled *Mucuna cochinchinensis* seed meal

11. Tacon, A.G.J. and Metian, M. (2015). Feed matters: satisfying the feed demand of aquaculture. Rev. Fish. Sci. Aquacult. 23, 1–10, http://dx.doi.org/10.1080/23308249.987209.

12. Solomon, G. S., Victor, T.O., Samson, O. O. **(2017).** Nutritional value of toasted pigeon pea, *Cajanus cajan* seed and its utilization in the diet of *Clarias gariepinus* (Burchell, 1822) fingerlings. *Aquaculture Reports* 7:34–39

13. Udo, I. U. and Umanah, S. I. (2017). Current Status of the Nigerian Aqua Feeds Industry: A Review. International Journal of Innovative Studies in Aquatic Biology and Fisheries (IJISABF). Volume 3, Issue 1, 2017, PP 14-22. DOI: http://dx.doi.org/10.20431/2454-7670.0301003. www.arcjournals.org

14. Anyanwu, C.N., Osuigwe, D.I., Njoku, D.C., Adaka, G.S. and Nwaka, D.E. (2018). Evaluation of Haematology and Challenge Test of *Enterococcus faecum* on Clarias Gariepinus at Different Inclusion Levels. *Futo Journal Series* (FUTOJNLS). Volume-4, Issue-1, pp- 358 – 367. www.futojnls.org

15. Tugiyono, Indra Gumay Febryano, Yuwana Puja and Suharso, 2020. Utilization of fish waste as fish feed material as an alternative effort to reduce and use waste. Pak. J. Biol. Sci., 23: 701-707.

16. Chinh Thi My Dam, Mark Booth, Igor Pirozzi, Michael Salini, Richard Smullen, Tomer Ventura and Abigail Elizur (2020). Alternative Feed Raw Materials Modulate Intestinal Microbiota and Its Relationship with Digestibility in Yellowtail Kingfish Seriola lalandi Fishes. 5, 14; doi:10.3390/fishes5020014. www.mdpi.com/journal/fishes

17. El-Sayed A. F. M., (2006). Tilapia culture. CABI International, pp. 106–107.

18. Nmecha, M.I., Okereke, C.D., Egwuonwu, C.C. and Okorafor, O.O. (2024). Assessment of water quality of Otamiri River along selected reach using drone technology. Curr. Res. Env. Sci. eco. Letters. 1 (1): 01-19.

19. Okoye, F.C. and Sule, O.D. (2001). Agricultural Byproducts of Arid-Zone of Nigeria and their Utilization in Fish Feed. In: Fish Nutrition and Fish Feed Technology in Nigeria, Eyo, A.A. (Eds.). NIOMR, Lagos, Nigeria, pp: 8-13.

20. AOAC (2016). Official Methods of Analysis of the Association of Official Analytical Chemists

21. Enyenihi, G. E., Esiegwu, A. C., Esonu, B. O., Uchegbu, M. C. and Udedibie, A. B. I. (2013). Gelatinization of fermented cassava tuber meal and its nutritive value for broilers. Nigerian Society for Animal Production Nigerian Journal of Animal Production: 91-99.

22. Masakuni, T., Yukihiro, T., Takeshi, T. and Yasuhito, T. (2014). The Principles of Starch Gelatinization and Retrogradation. Food and Nutrition Sciences, 2014, 5, 280-291. (http://www.scirp.org/journal/fns).

23. Emenalom, O. O., Udedibie, A. B. I., Esonu, B. O. and Etuk, E. B. (2005). Evaluation of processed valvet bean (*Mucuna pruriens*) as a feed ingredient in starter diets for broiler chickens. *The Journal of Poultry Science*. 42: 301-307

24. Bichi, A. H. and Ahmad, M. K. (2010) Growth performance and nutrient utilization of African catfish (*Clarias gariepinus*) fed varying dietary levels of processed cassava leaves. *Bayero Journal of Pure and Applied Sciences.* 3(1): 118- 122.

25. Obasa, S. O., Babalola, E. O., Akinde A. O., Idowu A. A., Ojelade, O.C., Nwekoyo V. E. and Oyetade Y. O. (2021). Impact of Processing on Cassava Root Tuber and Use as a Replacer of Maize in the Diet of Nile Tilapia, *Oreochromis niloticus*. Mal. J. Anim. Sci. 24(2): 39-49

26. Abu, O. M. G., Lazarus, et al. (2021) Effect of Graded Level of Whole Cassava Root Meal as a Replacement for Maize on Growth Performance of *Clarias gariepinus* Fingerlings. IOSR *Journal of Agriculture and Veterinary Science* (IOSR-JAVS), 14(2), 2021, pp. 09-13. DOI: 10.9790/2380-1402010913.

27. Aanyu, M., Wullur, S. and Mugo-Bundi, J. (2018). Effect of alternative feed ingredients on water quality, growth and carcass composition of Nile tilapia (*Oreachromis niloticus*). Aquaculture Research, 49(2), 657-664.

28. Olagunju, F.I., Adesiyan, I.O and Ezekiel, A.A.,(2007). Economic viability of catfish production in Oyo State, Nigeria. J. Hum. Ecol, 21: 121-124

29. Adeparusi, E. O., Jimoh, W. A. and Olusola, S. E. (2001). Growth performance and nutrient utilization of African catfish [*Clarias gariepinus*) fed diets containing cassava peels and leaf meals. *Journal of Agricultural Science and Technology*, 5(1), 75-85.

30. Aderolu, A. Z. and Sogbesan, A. O. (2010). Evaluation and potential of cocoyam as carbohydrate source in catfish diets. *African Journal of Agricultural Research*, 5(6), 453-457.

31. Ng, W. K. and Wee, K.L. (1998). The nutritive value of cassava leaf meal in pelleted feed for Nile tilapia. *Aquaculture,* 83 (1-4), 45-58.

32. Ubalua, A. O. (2007). Cassava waste: Treatment options and value addition alternatives. *African Journal of Biotechnology*, 6(18). 2065-2073.

33. Effiong, B. N., Fakunle, J. O. and Ikpi, G. U. (2009). Effect of partial replacement of fish meal with cassava leaf meal on the growth and feed utilization of Nile tilapia *(Oreochromis niloticus). Nigerian Journal of Fisheries*, 6(1), 16-24.

34. Eknath, A. E., Hulata, G. and Liti, D. (2007). Breed improvement and growth performance of Nile tilapia: implications for aquaculture development. *Aquaculture International*, 15(1). 1-18.

35. Falaye, A. E. (1992). Utilization of agro-industrial wastes as fish feedstuffs in Nigeria. *Proceedings of the 10th Annual Conference of Fisheries Society of Nigeria,* 47-57

36. Obasa, S. O., Alegbeleye, W.O., and Olurin, K. B (2013). Effects of fermentation on the nutritional composition and anti- nutritional properties of cassava root meal and its utilization by African catfish (*Clarias gariepinus). Aquaculture Nutrition*, 19(4), 430-437.

37. Eusebio, P. S., Coloso, R. M. and Golez, N. V (2004). Nutritional evaluation of cassava meal in fish diets Aquaculture Research, 35(9), 849-857

38. Sogbesan, C.A., Ugwumba, A.A., Madu, C.T., Eze, S.S.and Isa, J. (2007). Culture and utilization of earthworms as animal protein supplement in the diet of *Heterobranchus longifillis* fingerlings. Journal of Fisheries and Aquatic Science. 2(6):375-386.

39. Adeparusi, E.O. and Jimoh, W. A. **(**2002). Digestibility coefficient of raw and processed lima bean- diet for Nile tilapia. *Journal of Applied Aquaculture* 12(3): 89-98.