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Bio-economic Assessments of Novel Aquafeed Software on Nile Tilapia (*Oreochromis niloticus)* Raised in Recirculatory Aquaculture System

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ABSTRACT

This research evaluated the bio-economic feasibility, nutritional adequacy and growth performance associated with the incorporation of non-conventional protein sources in the formulation of aqua feed for *Oreochromis niloticus* (Nile tilapia) using the novel FUTA Aquafeed formulation software for optimizing the various blends of the ingredients. The creation of software for fish feed formulation is evolving as a result of developments in computer technology. Nile tilapia fingerlings were raised in a Recirculatory Aquaculture System (RAS) for eight weeks. A total of 750 fingerlings with an average weight of 12.00± 0.40g were randomly distributed across 15 fiber tanks measuring 1m×1m×1m, with 50 fish per tank in triplicate treatments. The fingerlings were fed twice a day, between 8.00 hrs. to 9.00 hrs. and 17.00 hrs. to 18.00 hrs GMT for eight weeks under a recirculatory aquaculture system. The control treatment utilized Pearson square feed formulation, while the first treatment used WINFEED. The study measured various zootechnical parameters, including standard growth rate, final weight gain, feed conversion ratio, feed efficiency ratio, and mortality rate. The feed efficiency ratio was significantly higher in the fish fed WINFEED and AQUAFEEDAPP compared to those fed the control diet (Pearson square feed formulation). The cost index also showed significant differences ($p \geq 0.05$), with the AQUAFEED treatment having the lowest mean value, followed by WINFEED and the control diet. The carcass proximate composition of the fish was observed, with only moisture showing a significant difference. In summary, there were no significant differences between the control, WINFEED, and AQUAFEEDAPP treatments in terms of standard growth rate, final weight gain, feed conversion ratio, feed efficiency ratio, and mortality rate. However, the AQUAFEEDAPP software demonstrated its potential as a low-cost feed formulation method without compromising feed quality, based on its significantly lower cost index value

Keywords:
Winfeed, Aquafeed App, Pearson Square Feed Formulation, Nile tilapia, Cost Index

Introduction

Fish is highly nutritious and plays a crucial role in the sustenance and well-being of the global population. It possesses significant economic, nutritional, medicinal, industrial, aesthetic, and religious values, while also providing employment opportunities for millions of people worldwide. Fish contributes to food security in numerous regions by serving as a valuable supplement for diverse and nutritious diets (FAO,2020). Nigeria, the most populous country in Africa, with over 215 million inhabitants, holds the distinction of being the largest fish consumer on the continent. Annually, the

country consumes approximately 3.2 million tons of fish, accounting for 40% of its protein intake. On average, each person in Nigeria consumes about 13.3 kg of fish per year. Nigeria faces a trade deficit in fish, with about 45% of its fish consumption being imported from other countries. This translates to an annual trade deficit of 1 billion USD. To address this issue, aquaculture emerges as a viable alternative to meet the domestic demand for fish. Nigeria takes the lead as the primary aquaculture producer in sub-Saharan Africa, contributing to 52% of the region's production. It also ranks as the second-largest aquaculture producer on the entire African continent, with Egypt holding the top spot. Over the past 35 years, Nigeria's aquaculture production has witnessed a steady growth rate of 12%, although this growth has slowed in recent years (Maguregui ,2022).

Nigeria's aquaculture primarily focuses on extensive inland operations. The country's annual aquaculture production reaches 313,000 tons, with African catfish (*Clariasgariepinus*) and Nile tilapia (*Oreochromisniloticus*) being the most commonly produced species. Nigeria's significant population and high fish consumption demand, coupled with its prominence in aquaculture production, highlight the critical role of aquaculture in bridging the domestic fish supply gap and reducing reliance on imports (Maguregui ,2022).

The economic production of healthy and high-quality animal products relies heavily on good nutrition. In the context of aquaculture, nutrition plays a vital role as feed expenses typically account for around 50% of variable production costs. Recent years have witnessed significant advancements in fish nutrition, particularly with the introduction of balanced commercial diets that optimize fish growth and ensure their well-being (Fasakin*et al.,* 2000).Amidst rising foreign exchange rates and inflation in Nigeria, which heavily relies on imported protein and protein raw materials, this project aims to identify alternatives to conventional proteins used in fish feed formulation using a novel fish feed formulation software to meet the dietary requirements of Nile tilapia – the second most cultured fish species in Nigeria and globally.

Materials and Methods

Experimental Site

The research was conducted in 4 concrete tanks that were already constructed at the department of Fisheries and Aquaculture Technology Teaching and Research farm, Federal University of Technology, Akure.

Experimental Fish

Healthy juveniles of *Oreochromisniloticus* was obtained from reputable source. Upon purchase the fish was acclimatized to experimental condition for a period of 2 weeks at the Department of Fisheries and Aquaculture Technology Teaching and Research Farm, Federal University of Technology, Akure, Ondo-State. The fish were not fed for 48 hours to maintain a uniform stomach condition and to induce their appetite prior to the time of study.

Preparation and formulation of experimental diet

Components of feed formulated consist of soybean meal, fish meal, groundnut cake, yellow maize, vegetable oil, starch and vitamin-mineral premix. The feed was formulated using Pearson square, Winfeed software and Aquafeed software. The Winfeed software and Aquafeed software were procured from Aquafeed formulation vendors. Various ingredients to be used were weighed and grinded into fine powder separately. After grinding the ingredients into fine powder they were measured based on the

percentage composition of the experimental diets and thoroughly mixed together to form a homogeneous mixture. Physico-chemical parameters like temperature, pH and dissolved oxygen were measured weekly, using HANNA Instruments.Proximate composition of whole body of fish and feed was determined using the standard methods of the Association of Official Analytical Chemist (AOAC, 2010). The following parameters were determined, moisture content, crude protein, fiber, lipid, ash and nitrogen free extract.

Table 1 Ingredients used for diet formulation

Ingredients	Pearson Square	Winfeed	Aquafeed
Fish meal	17.95	18.00	10.90
Soyabean meal	17.10	25.00	26.00
Groundnut cake	17.90	21.00	20.70
Yellow maize	37.05	26.00	32.40
Vegetable Oil	6.00	6.00	6.00
Vit/Min Premix	2.00	2.00	2.00
Starch	2.00	2.00	2.00

Premix manufactured by Chemiconsult International Limited, Ikeja, Lagos, Nigeria.

Vitamins supplied mg/100g diet: vitamin B1 (Thiamine) 1.2mg; vitamin B2 (Riboflavine) 2.4mg; vitamin B3 (Niacin) 10mg; vitamin B5 (Pantothenic acid) 4.0mg; vitamin B6 (Pyridoxine) 2.0mg; vitamin B7 (Biotin) 0.2mg; vitamin B9 (Folic acid) 0.4mg; vitamin K 2.0mg; vitamin B12 (Cyanocobalamin) 10.0mg; vitamin C (Ascorbic acid) 150mg, chlorine 160mg.

Minerals: Manganese 4.8mg, Iron 150mg, Zinc 30mg, Copper 1.70mg, Iodine 0.50mg, Cobalt 0.3mg, Selenium 0.20mg.

Determination of Proximate Composition

The proximate composition of the feed ingredients and the diets were determined using analytical methods (AOAC, 2010). All measurements were done in duplicates and values presented in percentage.

Aquafeed software algorithm and model

Algorithm: AquaFeedApp

1. ***Set*** *the crude protein requirement of the feed, say CP_req*
2. *Assume* X_i *is the ingredients and* $i \ldots n$ *is the number of ingredients selected for the mix.*
3. ***Initialize****n in order to obtain the grouping for protein supplement and basal feed list*
4. ***Initialize*** *protein supplement and basal feed lists to empty*
5. *If* $CP(X_i) > 20$

1. *Add to protein supplement list*

6. *Else*
    1. *Add to basal feed list*
7. *Determine the length of protein supplement and basal feed list say nProteinSupp_list and nBasalfeed_list*
8. *If nProteinSupp_list == empty*
    1. *Print "Poor selection: Your mix must contain a least on protein source"*
9. *If nProteinSupp_list == 1*
    1. *Set protein_supp= CP of the ingredient*
10. *Else*
    1. *Set protein_supp= harmonic-mean ratio of CP for all the ingredients in nProteinSupp_list*
11. *If nBasalfeed_list == empty*
    1. *Print "Poor selection: Your mix must contain a least on energy source"*
12. *If nBasalfeed_list == 1*
    1. *Set basal_feed = CP of the ingredient*
13. *Else*
    1. *Set basal_feed = harmonic-mean ratio of CP for all the ingredients in nBasalfeed_list*
14. *If protein_supp>CP_req*
    1. *Resultant_basal=protein_supp – CP_req*
15. *Else*
    1. *Resultant_basal= CP_req – protein_supp*
16. *If basal_feed>CP_req*
    2. *Resultant_protein = basal_feed – CP_req*
17. *Else*
    2. *Resultant_protein= CP_req – basal_feed*
18. *Set aggre_mix= Resultant_basal + Resultant_protein*
19. *//Obtain gram mix per group based on 90% to create 10% allowance for oil and other additives*
20. *Gram_basal= Resultant_basal/agrre_mix*
21. *Gram_protein= Resultant_protein/agrre_mix*
22. *Obtain gram mix per ingredients using either CP ratio or high-low cost ratio of each mix*

Determination of zoo-technical parameters

Evaluation of growth performance was carried out using the following factors, weight gain WG specific Growth Rate SGR Feed Conversion Ratio FCR Feed Intake FI Protein Intake PI Protein Efficiency Ratio PER Feed Efficiency Ratio FER according to

$$Weight\ gain\ (g) = Final\ body\ weight - Initial\ body\ weight$$

$$Specific\ Growth\ Rate\ (\%/day)\ = \frac{In\ final\ body\ weight - In\ initial\ body\ weight}{Duration\ of\ feeding}\ X\ 100$$

$$Feed\ Intake\ (g) = Total\ amount\ of\ feed\ given\ (g)\ X\ number\ of\ days$$

$$Feed\ Conversion\ Ratio = \frac{Feed\ intake}{Weight\ gain}$$

$$Feed\ Efficiency\ Ratio = \frac{Weight\ gain}{Feed\ intake}$$

$$Protein\ Efficiency\ Ratio = \frac{Weight\ of\ fish}{Protein\ fed}$$

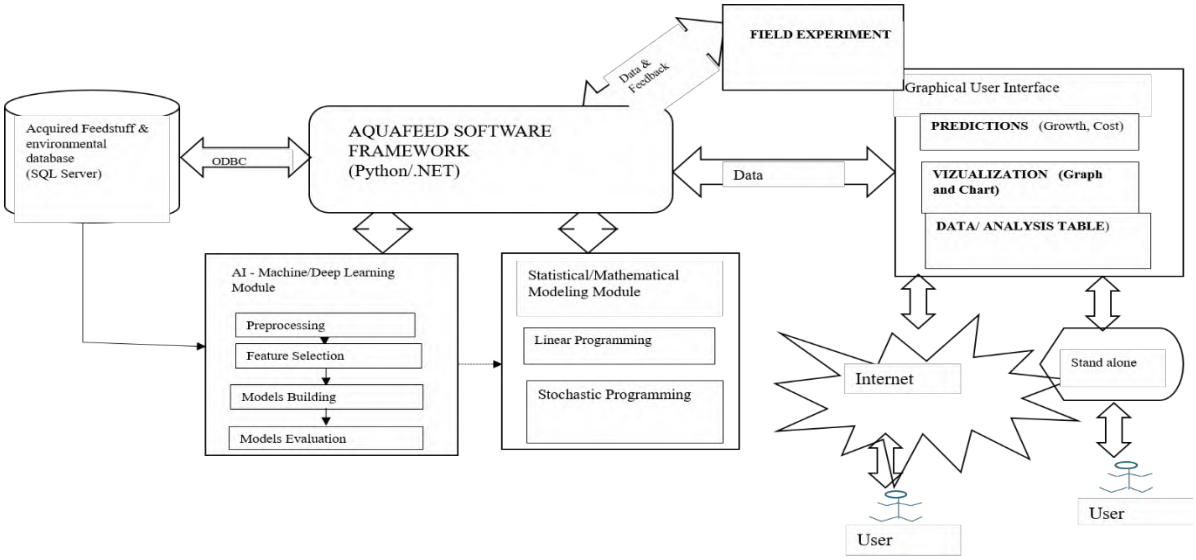

Figure 1: Architecture of FUTA Aquafeed model

Statistical Analysis

Data collected were checked for normality using one-way analysis of variance (ANOVA) and homogeneity of variance using Levene's test to test for significant difference in the means using Statistical Package for Social Sciences (SPSS 22.0 for windows). Where there is significant difference, the means were separated using Duncan's multiple range tests. Mean difference was considered statistically significant with a 95% confidence level and all data were presented as means ± standard errors.

Result and discussion

PROXIMATE COMPOSITION OF FEED (%DM)

Proximate analysis revealed composition of moisture content in all the three feeds formulated by Pearson square, WINFEED and AQUAFEED had the highest amount of water molecule of whichwinfeed has the lowest as shown in Table 2. Protein content ranges from 39.35% inpearson square to 44.01% of aquafeed, this was in concord with Mansour et al. (2022).

Table 2: Proximate Composition of the Experimental Diets (%) for Culturing *Oreochromisniloticus*

COMPOSITION	PEARSON SQUARE	WINFEED	AQUAFEED
Moisture	12.09	11.80	14.43
Crude protein	39.35	43.09	44.01
Lipid	23.42	21.45	19.21
Ash	17.01	17.79	16.15
Fibre	0.63	0.78	1.00
Nitrogen Free Extract	7.50	5.09	5.20

The protein content is the highest among all the feed formulated with a significant difference showing viability of the feeds in fish growth. AQUAFEED hadthe highest percentage of protein while pearson square has the lowest. This is a function of its constituents with low protein content which affected the resultant protein content. Mansour et al.,(2022) had similar result in their research to feed female *Clariasgariepinus*for meat development.

Physicochemical Parameters of Cultured Nile tilapiaFingerlings Water

The result of the physicochemical parameters of water is presented in Table 3. The pH ranged between 7.58 – 7.6, though WINFEED had the lowest pH but did not have any significant impact negatively on the growth of the cultured fish Nile tilapia since all the pH values are in the sphere of neutral on the pH scale Baek *et al*.(2021) corroborate this in their research in African cat fish. Temperature level ranged between 27.03^{o}C – 27.05^{o}C which is still considered within the range of normal or room temperature for fish breeding. The dissolved oxygen (DO) concentration range from 3.1 – 4.7mg/L is still very moderate for the growth of the fingerlings.

Table 3: Physicochemical Parameters of Cultured Nile tilapia Fingerlings Water

PARAMETERS	PEARSON SQUARE	AQUAFEED	WINFEED
Temperature (^{o}C)	27.05±0.03	27.00±0.01	27.03±0.01
pH	7.59±0.02	7.63±0.04	7.58±0.01
Dissolved Oxygen (mg/L)	5.95±0.05	6.10±0.10	6.20±0.00

Mean ± SE, n=3. Values with same superscripts letter(s) in the same row are not significantly different (P>0.05).

Carcass (dry matter) composition of*Oreochromisniloticus*fed experimental diets

Table 4 shows the results of carcass composition for Nile tilapia fingerlings that were fed various experimental diets. The analysis revealed that there were no significant differences in the crude protein content, ash content, and nitrogen-free extract of the fish carcasses among the groups (P>0.05). Among the diets, the highest crude protein content was observed in the AQUAFEED diet 32.18±0.29, while the pearson square diet had the lowest crude protein content. Notably, the initial fish had a significantly

lower crude protein content compared to the fish that were subjected to the experimental diets over the course of the study. In terms of nitrogen-free extract, the AQUAFEED group had the lowest value 22.83±0.78. Zhang et al.(2018) reported similar crude protein and nitrogen-free extract in the initial fish which was significantly higher than the control. There were significant differences in the lipid content and moisture content of the fish among the experimental diet groups, this is in consonance with Zulfahmi et al.(2022). The AQUAFEED group had the highest lipid content, while the WINFEED group had the lowest lipid content.

Table 4: Carcass (dry matter) composition of Nile tilapia fed experimental diets

PARAMETERS	INITIAL	PEARSON SQUARE	AQUAFEED	WINFEED
Moisture	14.87±1.21^{b}	10.72±0.51^{a}	11.52±0.51^{a}	15.41±0.51^{b}
Crude protein	23.98±0.29^{a}	28.84±0.29^{b}	32.18±0.29^{b}	29.62±0.29^{b}
Crude lipid	6.16±1.32^{a}	16.57±0.49^{c}	18.57±0.49^{c}	12.15±0.49^{b}
Ash	16.20±2.55^{a}	19.40±0.47^{a}	15.45±0.47^{a}	17.41±0.47^{a}
NFE	38.78±0.84^{b}	25.01±0.78^{a}	22.83±0.78^{a}	25.94±0.78^{a}

Mean ± SE, n=2. Values with same superscripts letter(s) in the same row are not significantly different (P>0.05).

Growth Performance and Nutrient Utilization of *Oreochromisniloticus*Fingerlings Fed Experimental Diets.

In Table 5, we present the growth and nutrient utilization indices observed in this study. The final mean weight FMW, mean weight gain MWG, and specific growth rate SGR exhibited significant differences (P<0.05) among the groups. The AQUAFEED group showed the highest values for FMW while the WINFEED group displayed the lowest values FMW: The feed conversion ratio (FCR) varied significantly (P<0.05) across the groups, with the best FCR was found in the WINFEED group. Furthermore, the feed efficiency ratio FER and protein efficiency ratio PER also exhibited significant differences (P<0.05) among the groups. These findings collectively demonstrated variations in growth and nutrient utilization indices among the different diet groups in the study. The growth indices in this study revealed significant differences (P<0.05) in the mean weight gain and specific growth rate of fish fed experimental diets. The highest mean weight gain and specific growth rate were observed in the AQUAFEED group, followed by the WINFEED group, while the pearson square group exhibited the least growth. This difference in growth can be attributed to the superior optimisation tendencies of AQUAFEED, Mansour et al.(2022) reported that increasing fish feed intake leads to improved growth. The findings of this study aligned with the research conducted by Shadyeva *et al*.(2022) who observed high growth performance in *Oreochromis niloticus* when fed commercial-based feeds compared to fish fed locally formulated feeds using the pearson square method of formulation. These results emphasize the importance of feed composition and quality in influencing the growth and performance of fish in aquaculture, with commercial feeds like AQUAFEED and WINFEED showing notable advantages in this study.

Table 5: Growth Performance and Nutrient Utilization of *Oreochromisniloticus*Fingerlings Fed Experimental Diets.

PARAMETERS	PEARSON SQUARE	AQUAFEED	WINFEED
Initial Mean Weight	5.31±0.02	6.15±0.08	5.64±0.02
Final Mean Weight	23.02±1.46^{a}	33.49±1.73^{b}	21.22±2.05^{a}
Mean Weight Gain	17.71±1.44^{a}	27.34±1.66^{b}	15.58±2.03^{a}
Specific Growth Rate	1.85±0.08^{a}	2.18±0.05^{b}	1.67±0.12^{a}
Feed Conversion Ratio	2.11±0.15^{ab}	1.67±0.09^{a}	2.29±0.21^{b}
Feed Efficiency Ratio	0.48±0.05^{a}	0.60±0.01^{b}	0.44±0.06^{a}
Protein Efficiency Ratio	0.61±0.06^{a}	0.80±0.07^{b}	0.50±0.08^{a}

Mean ± SE, n=50. Values with same superscripts letter(s) in the same row are not significantly different (P>0.05).

The lowest cost of feed production was associated with the AQUAFEED treatment, while the Control group had the highest cost (Table 6). Groundnut cake costs displayed significant variability (P>0.05) among the treatments, with the highest price recorded in the WINFEED treatment and the lowest in the pearson square treatment. Furthermore, there were significant differences in the prices of yellow maize across the treatments, with the WINFEED and AQUAFEED treatments having the lowest prices and the pearson square treatment having the highest cost.Nankinga et al., (2022) made a similar observation in their research on tilapia feeding.

Table 6: Cost and Benefit ratio of feed

Ingredients	**Pearson Square(₦)**	**WINFEED(₦)**	**AQUAFEED(₦)**
Fish meal	817.55	595.00	455.30
Soybean meal	93.93	111.00	137.40
Groundnut cake	74.60	112.50	108.00
Yellow maize	60.15	45.00	45.00
Vegetable Oil	96.00	96.00	96.00
Vit/Min Premix	50.00	50.00	50.00
Starch	20.00	20.00	20.00
TFP	3400.00	3400.00	3400.00
TOTAL COST BENEFIT RATIO	1: 122.88±23.94b	1 : 95.16±14.74a	1 : 95.06±14.75a

TFP= Total cost of feed preparation

Conclusion

FUTA AQUAFEED software was designed on the principle of algorithms intertwined with deep learning on the basis of artificial intelligence AI. This makes it precision more distinct than pearson square and other arithmetic based methods of formulation. The software combined lower percentage of expensive feed ingredients and higher percentage of cheap feed to enhance high protein content feed than Pearson square methods. The study found that water quality parameters remained within recommended ranges and did not adversely affect the growth of Nile tilapia juveniles. The nutrient composition of the experimental fish carcasses (crude protein, lipid, ash, moisture, and nitrogen-free extract) fell within acceptable levels for this species. Furthermore, utilizing AQUAFEED for feeding Nile tilapia fingerlings improved their growth and nutrient utilization compared to other aquafeed formulating methods. Cost analysis revealed that using AQUAFEED was a cost-effective choice compared to Pearson square and WINFEED methods, reducing expenses while still meeting the nutritional needs of Nile tilapia fingerlings. These findings suggest that employing AQUAFEED software can help reduce the reliance on imported fish feed tailored for tropical fishes like the Nile tilapia. This, in turn, could enhance productivity and profitability in Nigeria's aquaculture industry by optimizing costs and nutrient requirements without compromising feed quality.

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