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RESEARCH ARTICLE

Economic Analysis of Locally Produced Aquaculture Feeds with Complements of Plant-based Ingredients in Kainji Lake Basin, Nigeria

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Abstract: Optimization through cost minimization is a key strategy aquaculture feed producers adopt to ensure a continuous supply of fish in the global market. In light of this consideration, the study analyzed the economics of locally produced aquaculture feeds by complementing fishmeal with plant-based sources of ingredients. Specifically, the study estimated the cost and returns, socio-economic determinants of net income, and challenges of local feed production. Using a survey design, a case study approach was used to collect data from 36 aquaculture feed producers/millers. The data were presented using descriptive statistics, budgetary techniques, and two-stage least squares regression analysis. Key findings established that the majority (78.12%) of aquaculture local feed producers were men, and 43.75% had tertiary educational qualifications with a good number of years of experience. The profitability indicators show that aquaculture local feed production is profitable with 3.24% net returns on investment. The result further indicates that the incorporation of plant-based sources of ingredients reduced the utilization of Fishmeal (Clupeids) by 50%. Also, the regression analysis shows that the years of experience and initial capital investment were statistically significant ($p < 0.05$) determinants of net income while the major challenges in aquaculture local feed production were lack of perfect substitute for Fishmeal ($\bar{x} = 2.94$), government regulations on the harvest of Clupeids used for Fishmeal ($\bar{x} = 2.91$), poor access to capital ($\bar{x} = 2.88$) and high cost of machine spare parts ($\bar{x} = 2.88$). Based on the findings, it is recommended that fish nutritionists should intensify research on the production of fish feeds with a sole plant source of ingredients.

Keywords: Aquaculture; Feed; Plant; Fishmeal; Economics

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1. Introduction

The contribution of aquaculture to fish-food production has been on a steady increase over the past decades while capture fisheries production has remained stagnated [1-3]. This is because fish is a primary source of protein, essential amino acids, fats, minerals and vitamins which necessitates the increase in demand for fish in response to a rising population growth [1]. It is estimated that this demand will continue to rise by more than 20 million tons over the next few decades in order to keep a constant per capita consumption [4]. According to FAO [1], aquaculture is seen as the solution to the rising demand for fish. However, the success of aquaculture depends on the availability, affordability and formulation of aquafeeds (fish feeds) that contain the required level of protein and energy necessary for the growth of stocked fish [5].

It is estimated that approximately 70% of farmed fish in Asia is raised with feed while the remaining 30% is raised through traditional unfed systems which rely on fertilization [1,3]. Fishmeal (FM) tends to be the most reliable source of feed for cultured fish because it is considered to be a highly digestible source of bioavailable nutrients for cultured fish. However, the exploitation of Fishmeal poses a serious economic and environmental concern. In Kainji lake basin, Nigeria, the use of beach seine nets for the harvest of Clupeids, a major fishmeal ingredient in fish feed has attracted both national and international condemnation because of the obnoxious method used by fishers in its harvest. Furthermore, from the an economic point of view, the rising cost of Fishmeal as a result of an increase in the demand for fish has made the cost of feed for aquaculture a concern for the industry [1]. For example, the harvests of marine ingredients by foreign vessels in West Africa have limited the access and affordability of marine resources for local consumption by the poor and vulnerable communities [6,7]. For this reason, an alternative source of protein and energy mainly from the plant was proposed. Soybean meal combined with other sources such as rice bran, wheat bran and corn flour along with fish waste to produce low-cost pelleted fish feeds using indigenous machinery (pelletizer, crusher, mixer, etc.), was found to be a close substitute for Fishmeal. However, such an alternative is known to have a lower nutritional value than Fishmeal [8].

Plant-based sources of feeds for cultured fish are readily available in the global market and have shown to have suitable nutritional profiles as they possess the ability to compete with Fishmeal [9-12]. This is because the availability of local ingredients attracts labour from the household at a lower opportunity cost, thus reducing the overall cost of production and increasing the resulting profit margins [5]. This was supported by Mmanda et al. [13] that in an attempt to reduce the cost of production, fish farmers relied on locally available feed ingredients to supplement the diets of farmed fish. Hence, the identification and use of cheap, locally available ingredients would improve the long-term sustainability of aquaculture. However, Blanchard et al. [14], Froehlich et al. [15], Malcorps et al. [16], Roberts et al. [17] reported that the transition towards the use of plant resources in combination with the rise in aquaculture output could potentially add more pressure on the necessary agricultural resources with resultant socioeconomic and environmental impacts. For example, according to World Bank [18], the exploitation of soya beans for both human and animal needs has resulted in a two-fold increase in the global market price for soya beans between 2000 and 2018. However, irrespective of this resultant price surge, the use of plant sources for fish feed formulation remains the closest alternative to the high cost of Fishmeal.

The cost related to fish feed remains a major issue, especially among small-scale fish farmers in the aquaculture industry [19]. This is because feed accounts for over 70% cost of producing a table-size fish [20,21]. However, to maximize profit through cost minimization, there has been a substantial improvement in the technology of processing locally pelleted fish feeds in recent years. The use of hand mixing has been replaced with a well-modernized model of indigenous machinery comprising a crusher, pelletizer, mixer, etc. This technology can be set up at the fish farm sites, while the composition of the mixed ingredients and the size of the pelleted feed can be changed considerably depending on the age and specie of farmed fish.

In light of these considerations, this study is limited in economic analysis of locally produced aquaculture feed used in Kainji Lake Basin. Jewel et al. [5] analysed the economic return among different low-cost feed types while Rashid and Kurt [19] carried out a techno-economic analysis of extruded aquafeeds. Nwabeze et al. [22] on the other hand, analysed the profitability of fish production in Kainji Lake Basin; hence, the need to evaluate the socio-economic determinants of net income by this study used a two-stage least square technique. It is based on this background the study analysed the economics of locally produced aquaculture feeds in Kainji Lake Basin Nigeria. Specifically, the study:

i. Examined the socio-economic characteristics of the local fish feed producers;

ii. Estimated the cost and returns in local fish feed production;

iii. Evaluated the effects of the socio-economic factors on net income; and

iv. Identified the challenges of local fish feed production.

2. Materials and Methods

2.1 Study Area

Kainji lake basin is situated within Latitudes 9°50' and 1°55' North and Longitudes 4°23' and 4°51' East Niger and Kebbi State, Nigeria [23]. The area has huge potential for aquaculture development with Catfish and Tilapia species the dominant aquaculture species cultured in the area [23,24]. Kainji lake comprises about 316 fishing communities demarcated into 3 strata namely: upper stratum (northern basin), middle stratum (central basin) and lower stratum (southern basin). However, aquaculture activities actively take place in the lower stratum (southern basin) which in turn, promotes the activities of other value chains such as feed milling, processing and marketing.

2.2 Procedure for Data Collection and Analysis

A case study approach was used in this study. Due to the limited number of feed millers in the area, a census was conducted and 36 feed producers or millers formed the population of the study. These feed millers were concentrated in three (3) communities which include Wara, New Bussa and Monai communities. From the communities identified, 18 feed millers from New Bussa, 16 feed millers from Monai and 2 feed millers from Wara Communities made up the respondents of the study. Primary data were collected with questionnaires that were administered through an interview schedule. Data collected were presented using descriptive statistics such as mean, percentages and bar charts. The budgetary technique was used to estimate the profitability indices in the feed while a two-stage least square regression analysis was used to evaluate the socioeconomic determinants of net income. The models are specified as thus.

2.3 Profitability Indices

Net Income after Tax (NIAT)

$$\text{NIAT} = \textit{Revenue-Total expenses} \quad (1)$$

Net Profit Margin

$$\text{Net Profit Margin} = \frac{Profit\ after\ tax}{Revenue} * 100 \quad (2)$$

where, Revenue=Unit Price* Quantity sold.

Return on Investment

$$\text{Return on Investment} = \frac{Net\ income\ after\ tax}{Total\ Expenses} * 100 \quad (3)$$

2.4 Two-stage Least Square Regression Analysis

A two-stage least-square regression analysis was used to address the failure of the structural equation in ordinary least-squares regression to give consistent parameter estimates. The failure is a result of the violation of an essential condition of regression analysis, i.e. the error term must be uncorrelated with the independent variables.

The structural equation is specified thus:

$$Y = \beta o + \beta_1 X_1 + b_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \varepsilon \quad (4)$$

where, Y = net income (₦), X_1 = Years in school (Years), X_2 = Experience (Years), X_3 = age (Years), X_4 = initial capital (₦), X_5 =household size (Number) and ε = error term.

However, X_1 is endogenous because it correlates with an immeasurable variable "ability" that is accounted for by ε. An instrumental variable "parents' income" was uncorrelated with ε; hence, used for the estimation of the reduced form of the equation using two-stage least square regression analysis as specified thus:

$$X_1 = \pi_o + \pi_1 Z_i + \pi_2 X2 + \pi_3 X_3 + \pi_4 X_4 + \pi_5 X_5 \quad (5)$$

where, Z_i = parents' income and $\pi_1 \neq 0$.

2.5 Liker-type Rating Scale

A 4-point Likert-type scale rating technique was employed to achieve part of objective (iv) in this study. Respondents gave qualitative responses which were rated as Very Serious Challenge (VSC), Serious Challenge (SC), Mild Challenge (MC) and Not Serious Challenge (NSC) with corresponding values of 4, 3, 2, and 1 respectively. The mean score of the respondents based on the 4-point rating scale was computed as specified below:

$$\frac{4+3+2+1}{4} = 2.50$$

A 2.50 cut-off point using the interval scale of 0.05 was adopted; the upper limit cut-off point was 2.50 + 0.05 = 2.55 while the lower limit cut-off point was 2.50 – 0.05 = 2.45. Based on this, any score below 2.45 (MS < 2.45) was taken as a weak factor and not considered while those with a mean score of above 2.55 (MS > 2.55) were taken as strong factors and considered.

3. Results and Discussion

3.1 Socio-economic Characteristics of Aquaculture Local Feed Producers

The result of the socio-economic characteristics of aquaculture local feed producers is presented in Table 1. From the results of the analysis, 53% of the feed producers were within the age bracket of 31-40 years, while 43.75% and 3.13% were between the age of 41-50 and 21-30 years respectively. The mean age was 39.78, which indicates that the majority of the feed producers were within the economically active age group that a good sign for the further development of the fish in the feed producing-industry. Omeje, Sule and Aguihe [20] reported that entrepreneurs within the economically active age possess the potential to expand their businesses for higher income. This result is similar to the result of Nwabeze et al. [22] that fish feed producers in Kainji Lake Basin had a mean age of 41 years. Hence, one can see that the aquaculture local feed producing industry has witnessed an influx of young people who have taken up the responsibility of investing in local feed production.

The result shows that the majorities (78%) of the feed millers were men, 3.13% were women and 18.75% were male youths. This clearly shows that the feed-producing industry in Kainji Lake Basin is dominated by men. This is in consonance with the result of Nwabeze et al. [22] that the majority (89.7%) of fish feed producers were male. Although the representation of the youths in the industry is quite commendable, the women on the other hand, had a low representation in the industry probably due to the high capital and labour-intensive nature of the operation.

The result for experience shows that 56.25% of the feed producers had an experience of 1-5 years, 34.38% and 9.37% had been in the aquaculture feed-producing business for 6-10 and 11-15 years respectively. It's interesting to note that feed producers with longer years of experience will capitalize on their wealth of knowledge and skills gained for the sustainability of their enterprise and profitability. This supports the report of Onyekuru et al. [21] that a long year of experience is a necessary prerequisite for high productivity. Also, good years of experience in networking with other actors in the value chain can be an added advantage with respect to participation and benefiting from any form of intervention in the value chain.

The result for years in school and level of education shows that the majority (59.38%) of the feed producers spent between 11-15 years in school with 40.63% and 43.75% attaining the secondary and tertiary level of education respectively (Table 1). This shows that the feed producers have attained a good level of education to read, understand and take an informed decision which can be a positive factor in adopting new techniques in the feed-producing industry. This agrees with the statement of Ogunmefun and Achike [25] on the relevance of a high level of education in the adoption of new techniques. In addition, a good level of education is an asset to support learning and training to acquire technical knowledge and skills to improve the efficiency of production.

3.2 Estimation of Cost and Returns in Aquaculture feeds

The result for the estimates of cost and returns is presented in Table 2 and Table 3. The result showed that an estimated initial cost of ₦5,482,644 was incurred by the local feed producers with a total operational expense of ₦11,686,580.9 per month while the average revenue was ₦12,065,455 per month. The net income received was ₦378,874.1 per month which indicates that the local aquaculture feed producers receive a higher return in excess of operation cost. This indicates that the business of local fish feeds production is profitable as supported by the result of Nwabeze et al. [22] that fish feed enterprises make profits per unit Kg of fish feed produced. Also, profitability indicators show that the net profit margin was 3.14% which implies that for every ₦1 received as revenue, the aquaculture feed producers received 3.14 kobo as profit while the Return on Investment (ROI) of 3.24% indicates that for every ₦1 invested in the local fish feed business; 3.24 kobo was received as Return on Investment. The Benefit Cost Ratio (BCR) was 1.03, indicating that the business of local fish feed production is viable. Jewel et al. [5] affirmed that a BCR of > 1 is an indication of viability in fish feed, thus implying that local fish feed producers operate a viable business through innovation and utilization of local ingredients for feed formulation and production.

Table 1. Socio-economic characteristics of aquaculture local feed producers (N = 36).

Variable	Percent	Mean
Age (years)		
21-30	3.13	
31-40	53.12	
41-50	43.75	39.78
>50	0.00	
Gender		
Men (male > 35 years)	78.12	
Women (female > 35 years)	3.13	
Youths (male/female < 35 years)	18.75	
Experience (years)		
1-5	56.25	
6-10	34.38	
11-15	9.37	
>15	0.00	6.41
Years in School (Years)		
6-10	25.00	
11-15	59.38	
16-20	15.62	
>20	0.00	12.58
Level of Education		
Primary	15.62	
Secondary	40.63	
Tertiary	43.75	

Source: Field survey, 2020.

In addition, the analyzed data show that the use of plant-based sources of ingredients as complements of Fishmeal has reduced the cost of using Fishmeal as the sole protein source of ingredients by 50%. This means that there is a trade-off between the use of these ingredients in order to ensure the sustainability of aquaculture as well as the protection of natural bio-resources. Hence, giving credence to Hassaan et al. [9], Davies et al. [10], El-Husseiny et al. [11], Goda et al. [12] that plant sources of ingredients have suitable nutritional profiles as they possess the ability to compete with Fishmeal.

3.3 Socio-economic Determinants of Net Income in Aquaculture Local Feed Production

The socio-economic determinants of net income are presented in Table 4. The OLS estimates showed that the variables: years in school, experience and Initial capital investment were positive and statistically significant determinants of net income at a 5% level of significance. However, due to the presence of endogeneity with the variable "Years in School" which was assumed to be correlated with an immeasurable variable "ability", a two-

Table 2. Fixed cost schedule in aquaculture local feed production.

Item	Average quantity	Cost (₦)	Lifespan (Years)	Salvage Value (₦)	Depreciation (₦)
Land	1 plot	887878.79	-	-	-
Building	1 bungalow	2545454.55	20	750000	89772.73
Hammer Mill	1.03	489393.94	18	150000	18855.22
Crusher	1.15	375757.58	15	150000	15050.51
Pelletizer	1.21	1148456.06	15	550000	39897.07
Bowls	5.23	3727.27	5	500	645.45
Spreading Mats	4.16	28727.27	3	1500	9075.76
Rakes	2.54	3248.48	3	500	916.16
Total		5482644			174212.90

Source: Computation from field survey, 2020.

Note: Straight Line Method of Computing Depreciation = (Total Cost-Salvage Value)/Lifespan.

Table 3. Cost and return analysis of aquaculture local feed production.

Item	Mean Number	Mean Unit Price/ ton (₦)	Total Price/Cost (₦)	Share of Total Cost (%)
Revenue (₦)				
a. Working days/Month	24.00			
b. Tons/day	2.1			
c. price/Ton		239393.94		
TR/M = (c*b*a)			12065455.00	
Expenses/Month				
Groundnut cake (GNC)	50.4	34000.00	1713600.00	14.66
Soybean	50.4	35500.00	1789200.00	15.31
Fishmeal(Clupeids)	50.4	114545.45	5823490.68	49.83
Energy (maize or millet)	50.4	34212.12	1724290.85	14.75
Ascorbic	50.4	1936.36	97592.54	0.84
Methionine	50.4	2293.94	115614.58	0.99
Premix	50.4	3000	151200.00	0.04
Electricity bill	1	5151.52	5151.52	0.004
Levy	1	515.15	515.15	0.02
Water	50.4	218.18	2520.00	1.49
Depreciation	1	174212.90	174212.9	1.29
Labour	4.2	21236.36	89192.71	0.76
Total			11686580.93	100
Net income = Revenue-Total expenses			378874.07	
Net Profit Margin			3.14%	
Return on Investment (ROI)			3.24%	
Benefit Cost Ratio (BCR)			1.03	

Source: Computation from field survey, 2020.

Note: Total price=Mean unit price * Mean numbers.

stage least square (2sls) regression analysis was conducted with an instrumental variable (IV) "parent's income". This is because the higher the income of the respondents' parents, the more likely they will spend more years in school *ceteris paribus*. The resultant analysis of the 2sls shows that experience was positive and statistically significant ($p < 0.05$) on net income. This means that an increase in the years of experience will increase the net income of aquaculture local feed producers. Similarly, Onyekuru, Ihemezie and Chima [21] reported that individuals with long years of experience are expected to be more productive than those with shorter years of experience. This is because exposure to product management through the years is an indication of mastery, technology adoption and utilization of scarce resources for profitability.

Also, the variable for Initial Capital investment was positive and statistically significant ($P < 0.05$) on the net income of aquaculture local feed producers. This implies that the higher amount invested in fixed and variable assets will result in an increase in the net income of aquaculture local feed producers. The amount invested as initial capital is an indication of the level of capacity the firm can manage at a specific period of time. Eke and Effiong [26] posited that capital accumulation is a positive determinant of output, hence implying that enterprises with a higher investment in initial capital will generate more revenue with a resultant net income than firms with lower investment in initial capital.

The R-square was 0.8022 which means that the socio economic variables used in this analysis account for about 80% of the variation in the net income of aquaculture local feed producers.

3.4 Challenges in Aquaculture Local Feed Production

The challenges in aquaculture local feed production are presented in Figure 1. From the result of the Likert-type scale analysis, the lack of a perfect substitute for Fishmeal ($\bar{x}$ =2.94), government regulations on the harvest of Clupeids used as Fishmeal ($\bar{x}$ =2.91), poor access to capital

Table 4. Socio-economic determinants of net income.

	OLS estimates		2sls estimates	
Variable	Coefficients	T	Coefficients	T
Years in schools	0.2175	2.19*	0.4123	1.56
Experience	0.2584	3.80**	0.2602	3.60**
Age	0.3326	1.40	0.2373	0.88
Initial Capital	0.1671	2.71*	0.1500	1.97*
Household size	0.0221	0.42	–0.0731	–1.05
Constant	8.1339		8.4701	
R-squared	0.8091	8.51**	0.8022	8.76**
Prob>F	0.000		0.000	

Source: Computation from field survey, 2020.

*significant at 0.05, **significant at 0.01.

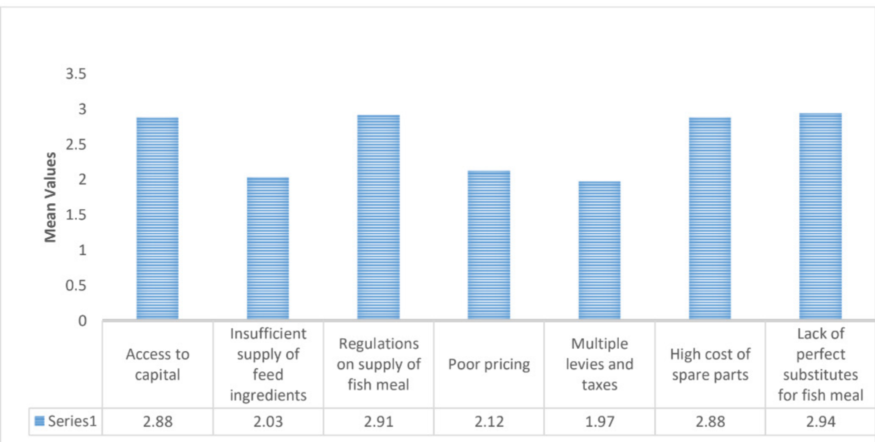

Figure 1. Challenges of aquaculture local feed production.

Source: Computation from field survey, 2020.

Note: >2.5 = serious challenge.

($\bar{x}$ = 2.88) and high cost of machine spare parts ($\bar{x}$ = 2.88) were found as serious challenges in aquaculture local feed production. Although the use of plant sources has been largely used in local feed production, the feed producers still consider the incorporation of Fishmeal (Clupeids) a very important ingredient in aquaculture local feed production. This is because of the nutritional components of Fishmeal and fish oil in addition to its high level of digestibility for cultured fish [1]. Furthermore, regulations by the government in the conservation of fish species in Kainji Lake Basin have placed local feed producers in disarray of finding a perfect substitute for Clupeids. This calls for extensive research on the production of fish feed with plant sources as sole ingredients. Also, Nwabeze et al. [22] reported that poor access to credit facilities and the high cost of replacing worn-out machine parts were among the leading challenges encountered by fish-feed producers. Generally, significant capital is required to operate a feed mill [27], this is because the feed mill components such as pelletizers, silos, crushers, hammer mills, etc are quite expensive to procure. In addition, these implements are mostly imported, hence necessitating the need for local fabrication of worn-out parts for the sustainability of aquaculture local feed production.

4. Conclusions and Recommendations

The study established that the majority of aquaculture local feed producers were men, who had tertiary educational qualifications with a good number of years of experience. The profitability indicators show that aquaculture local feed production is profitable with high net returns on investment. Also, the result shows that the use of plant-based sources of ingredients reduces the utilization of Fishmeal in feed production by 50%. Furthermore, the results of the regression analysis indicate that the years of experience and initial capital investment were significant determinants of net income while the major challenges in aquaculture local feed production were the lack of a perfect substitute for Fishmeal, government regulations on the harvest of Clupeids used for Fishmeal, poor access to capital and high cost of machine spare parts. From the findings of this study, it is recommended that fish nutritionists should intensify research on the production of fish feeds with a sole plant source of ingredients. Also, local fabrication of feed mill components should be encouraged through the training of technical engineers and local fabricators.

Authors Contributions

Omeje, J.E. (35%): Conceptualization, Research Design, Data Collection and reporting. Achike, A.I. (20%): Supervision. Nwabeze, G.O. (15%): Data Collation. Ibiyo, L.M.O. (15%): Supervision. Jimmy, S.P. (15%): Data analysis.

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Data Availability

The data used for this study are available on request from the corresponding author.

Conflict of Interest

There was no conflict of interest at every stage of this research.

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