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Article

DEVELOPMENT OF FISH FEED PRODUCTION TECHNOLOGY IN NIGERIA

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ABSTRACT

Objectives: Assessment of the development of local fish feed production technology in Federal College of Freshwater Fisheries Technology, Baga, Maiduguri, Borno State, Nigeria for the formulation and implementation of appropriate policy that would ensure sustainable fish feed production technology for the development of the fisheries sub-sector of the economy in the study area.

Methods: Data for the study were obtained from both primary and secondary sources while qualitative and quantitative methods with descriptive techniques were employed in the analysis of data.

Results: The study reveals that there exists underutilization of fish feed production capacity due to zero utilization and underutilization of some input ingredients for production. Thus, the development of fish feed production technology is low as the technological practice of fish feed production has a low cumulative mean percentage impact.

Conclusion: Technology has a positive effect on fish feed production practices in the study area. The study recommends that efforts should be intensified at all levels of governance through collaboration, creativity, and innovation focusing on the development of fish feed production technology at a sustainable level in the study area.

Keywords: Development, Fish feed, Production, Technology.

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INTRODUCTION

Aquaculture fish farming is the world's fastest-growing food production sector. However, the key ingredients in commercial fish feed – fishmeal and fish oil – come from an unsustainable source: small fish, such as anchovies and herring, near the base of ocean food webs. A high–performing, fish-free aquaculture feed that replaces these traditional ingredients with several types of microalgae – abundant single-celled organisms that form the very bottom of the food chain in fresh and saltwater ecosystems around the world. This approach was tested by developing feed for Nile tilapia – the world's second-most-farmed fish, exceeded only by carp. The result showed that tilapia fed our fish-free diet grew significantly better, achieving 58% higher weight gain than tilapia fed conventional feed. The resulting cost per kilogram of tilapia raised on our feed was lower than for fish raised on conventional commercial feed. Moreover, the feed yielded a higher level of a key fatty acid that is important for human health, DHA omega-3, in the resulting tilapia fillets [1].

Fish feed represents almost 65–70% of the fish culture inputs. Research has been done to find innovative sources of fish feed with the right nutritional values that can replace or augment conventional aquaculture or fish feed. Some environmentalists have voiced concerns about the consequences of bioengineered fish escaping into the wild, breeding with their wild relatives, and creating a hybrid that could out-compete other fish in the marine ecosystem. Quite rightly, these are serious concerns that require proper attention and strong mitigation plans [2]. Feed determines to a large extent the sustainability in aquaculture since the survival and growth of the larvae depend on the quality of feeds used. Quality fish feed production in aquaculture is one of the major determinants of significant growth, efficiency in feed utilization, and flesh quality of the fish produced [3].

About 19 million tons of wild fish – some 20% of the total quantity caught around the world – are rendered into fish meal and fish oil every year, even though 90% of these harvested fish are fit for human consumption. Analysts project that aquaculture feed demands for fish meal and fish oil outstrip the supply of small forage fish, also known as prey or bait fish, by 2037. If this happens, it could have disastrous consequences for human food security and marine ecosystems. Aquaculture feeds can also contain soy and corn ingredients from industrial farms on land that generate large amounts of water pollution. Fish cannot fully digest these ingredients, so they end up in aquaculture wastewater. Just like wastewater from cattle or poultry farms, effluent from fish farms can be a serious pollution source. What's more, these crops could be used for direct human consumption. Developing fish-free feed is a key leverage point for reforming aquaculture so that it helps conserve natural ecosystems instead of damaging them. Reducing pressure on forage fish will strengthen global marine fisheries [1].

In Africa, the sector of aquaculture is driven by the private sector, with feed and seed provided by private businesses. Due to recent significant investments of private capital and renewed political will to empower the private sector in the area of aquaculture development, Nigeria is the largest aquaculture producer in sub-Saharan African and this importance is steadily increasing. From 21,700 tons in 1999, aquaculture production has grown steadily to 3,16,700 tons in 2015. Catfish, typically grown in ponds and tanks, is the most farmed species in Nigeria, constituting over half of the total aquaculture production by volume [4].

The aquaculture initiative was launched in Borno state on April 2019, under a comprehensive response program to restore agriculture-based livelihoods in the state, designed to build the technical capacity of fish actors on safe and sustainable aquaculture. The initiative has boosted fish availability in the state especially around the benefitting communities such as Zabarmari, Gongulong, Dusman, Alau and Gamboru in Jere, Konduga and Maiduguri Metro-Polytan Council local government areas of the state. This has improved food

Table 1: Nutritional value of some local fish feed ingredients (required standard set) and actual formulation of 100 kilogram (Kg) of 40% crude protein (CP) of Catfish feed based on the following quantity of ingredients in the study area

S. No.	Ingredients	Crude protein in percentage (%) Required Standard Set 1	Crude fat in weight percentage (%) Required Standard Set 2	Actual composition Kilogram (kg) 3	Crude protein (CP) Actual Formulation 4	Crude protein in percentage (%) Actual Formulation 5
1.	Maize (White)	9.3	5.0	4.8	8.20	0.4
2.	Maize (Yellow)	10.8	3.4	-	-	-
3.	Millet	9.0	5.0	-	-	-
4.	Guinea Corn	11.2	2.5	-	-	-
5.	Rice Bran	6.9	4.4	-	-	-
6.	Fish Meal	65.69	-	30	62	18.6
7.	Soya Beans (toasted)	48.1	23.9	21.9	44	9.6
8.	Groundnut Cake	40.6	23.4	8.4	42	3.5
9.	Blood Meal	86.0	0.7	-	-	-
10.	Palm Kernel Cake	19.1	7.6	-	-	-
11.	Cassava (*Alabo*)	-	-	2	5.20	0.1
12.	Wheat Offal	-	-	50	17.20	8.6
Total Actual Composition and Formulation				117/100 kg		40%

S. No	Ingredients	Crude Fat weight Actual Formulation 6	Crude Fat weight Percentage (%) Actual Formulation 7	Zero/ Underutilization of Protein Nutritional Value Per Input Component 8	Zero/ Underutilization of Fat Nutritional Value Per Input Component 9	Zero/Underutilization of Fish Feed Production Capacity Per Input Component Kilogram (kg) 10
1.	Maize (White)	4.0	0.2	8.9	4.8	113 – 4.8 = 108.2
2.	Maize (Yellow)	-	-	10.8 (Zero Utilization)	3.4 (Zero Utilization)	Zero Utilization
3.	Millet	-	-	9.0 (Zero Utilization)	5.0 (Zero Utilization)	Zero Utilization
4.	Guinea Corn	-	-	11.2 (Zero Utilization)	2.5 (Zero Utilization)	Zero Utilization
5.	Rice Bran	-	-	6.9 (Zero Utilization)	4.4 (Zero Utilization)	Zero Utilization
6.	Fish Meal	09	2.7	47.09	2.7 (Alternative Introduction)	105.95 – 30 = 76
7.	Soya Beans (toasted)	0.80	0.2	38.5	23.7	114.52 – 21.9 = 92.62
8.	Groundnut Cake	6.20	0.5	37.1	22.9	96.7 – 8.4 = 88.3
9.	Blood Meal	-	-	86.0 (Zero Utilization)	0.7 (Zero Utilization)	Zero Utilization
10.	Palm Kernel Cake	-	-	19.1 (Zero Utilization)	7.6 (Zero Utilization)	Zero Utilization
11.	Cassava (Alabo)	1.20	0.02	0.1 (Alternative Introduction)	0.02 (Alternate Introduction)	No Standard Set for Contrast
12.	Wheat Offal	5.10	2.6	8.6 (Alternative Introduction)	2.6 (Alternate Introduction)	No Standard Set for Contrast
Total Underutilized Fish Feed Production Capacity			6%			365.12

Source: Field Survey, 2023

security and malnutrition considered major challenges, especially for millions of women and children affected by insurgency in the state, and promoted sustainable water management for income generation in the state [5].

Problem Setting and Research Objective

The increasing rate of global demand for aquatic food as a result of the need for the consumption of healthy food has enabled a rapidly growing aquaculture sector in several countries of the world. The problem of high cost and the scarcity of some aqua feed ingredients, specifically fishmeal and fish oil are major areas of concern. These ingredients are considered vital components for fish feed production as a result of their excellent nutritional value, including their good profile of essential amino acids, high digestibility, and composition of essential fatty acids. Although they are extremely valuable ingredients for animal diets, these raw materials are mainly sourced from wild fisheries, which are subject to seasonal fluctuations, sometimes with negative environmental impact.

Thus, the need for alternative aqua feed ingredients, adequate technical know-how, and the machinery for production to meet the nutritional requirements of aquatic animals, at a lower cost, with less environmental damage at a sustainable level to meet the continuing growth and development of aquaculture systems. Increasing production alone is not enough, enhancing training and capacity technically to meet adequately the dietary demand and the food security needs of the populace is also very important.

The production from capture fisheries in the area is increasingly diminishing; threatening livelihoods, food security, and the economy in general without a proportionally corresponding increase in the

Table 2: Percentage distribution of respondents according to their level assertion on the impact of fish feed production technology in feed production practices in the study area

S. No.	Fish Feed Production Technology Practices Assertion Criteria in the Study Area	Strongly Agree	Agree	Disagree	Strongly Disagree	Mean% impact High/Low		Level of Technological Development
1.	The technological level of fish feed production enable nutritious feed production?	12	30	20	03	27*	15	High
2.	The cost of fish feed ingredients constitute a high percentage of the total cost of production?	30	20	09	06	33	10*	Low
3.	The fish feed produce does not meet the required standard?	29	08	03	25	24.1	18.2*	Low
4.	The fish feed produce has negative effect on the output level?	10	25	27	03	22.8	20*	Low
5.	The type of fish feed produce is artificial?	43	-	16	06	28*	14.3	High
6.	Fish feed production takes place in the farm mill?	29	11	18	07	26*	16.3	High
7.	The fish feed produce serves different purposes?	38	13	05	04	33.2*	5.9	High
8.	Inadequate local fish feed ingredients?	65	-	-	-	42.3	00*	Low
9.	Inadequate capital for advanced technology?	65	-	-	-	42.3	00*	Low
10.	Inadequate source of funding?	21	13	09	22	22	20.2*	Low
11.	The feed production procedure is advance method?	-	-	23	42	Zero	42.3*	Low
12.	The produce feed met the standard specification of quality feed?	-	-	19	46	Zero	42.3*	Low
13.	Adequate feed storage and handling facilities?	-	-	49	16	Zero	42.3*	Low
Cumulative mean percentage impact						114.2	195.3*	Low

Source: Field Survey, 2023.

Indicate high observation recorded per observation, thus cumulative mean percentage impact of fish feed production technology in feed production practices is rated (195.3) low in the study area.

Table 3: Impact of fish feed production technology on feed production practices in the study area

Subject (Theme descriptions)	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (|O/STDEV|)	p values
Fish Feed Production Technology -> Feed Production Practices	0.950	0.955	0.042	22.675	0.000

Source: Field Survey, 2023

Table 4: R-square and R-square adjusted

Subject (Theme descriptions)	R-square	R-square adjusted
Feed Production Practices	0.903	0.897

Source: Field Survey, 2023

aquaculture production coupled with a growing population of the region dependent on its fisheries resources with an overall increasing tendency toward an over-exploited status of inland fisheries resources. Lack of management actions has resulted in an increasing tendency of depletion of fisheries resources, tremendous waste of the value, and income from these resources in the region. The consequences are most devastating for the fisheries sub-sector of the economy. Appropriate measures that embarking on aquaculture production should be considered where fish feed production and technological requirements are fundamental components inevitably to be pursuit, which also necessitates technological development.

Although, the aquaculture industry in Nigeria has been very promising as a result of the natural resource endowment of water bodies and institutional commitment and high demand for fish among others. However, the country's aquaculture is bedeviled with constraints such as; inadequacy of appropriate technologies, inadequate information on aquaculture technology, inadequate infrastructure, irregular electricity supply, poor finance, unfavorable environmental conditions, inadequate training and technical support, land acquisition, high price of the input, Poor extension services, inefficient or unsustainable production of fishmeal and fish oil, inadequate technical know-how, in the availability of extension agents, are critical in meeting the requirement of fish feed production as well technological advancement in the study area. Partly as outlined as the country Nigeria's aquaculture development constraints [6].

In view of the above, this research work has been undertaken with the main objective to assess the development of fish feed production technology in the Federal College of Freshwater Fisheries Technology Baga, Maiduguri, Borno State, Nigeria for the formulation and implementation of appropriate policy that would ensure quality sustainable fish feed production technology in the study area.

The output of this research work may be useful in the decision-making process that may require improvement in the method of fish feed production technology as well as in yielding high- and better-quality fish feed as might be revealed by the result of the study. Where there exists technological underdevelopment the research output may enable the government and other policymakers to initiate appropriate action based on the result for the transformation of the system to highly developed fish feed technology and remedy all other accompanied deficiencies identified to embark on a more efficient and effective

Table 5: Construct reliability and validity

Subject (Theme descriptions)	Cronbach's alpha	Composite reliability (rho a)	Composite reliability (rho c)	Average variance extracted (AVE)
Feed Production Practices	0.964	0.965	0.974	0.883
Fish Feed Production Technology	0.991	0.994	0.993	0.974

Source: Field Survey, 2023

Figure 1: Feed pelleting in progress in the study area
Source: Field Survey, 2023

Figure 2: Sun drying of local fish feed in the study area
Source: Field Survey, 2023

Figure 3: Mixing the mixture of ingredients in the study area
Source: Field Survey, 2023

Figure 4: Sinking pelleted feed (finished product) in the study area
Source: Field Survey, 2023

method of fish feed production technology. Policymakers may use the research outcome for planning purposes in the area of training and capacity building and financing the institution to cope with the technological development required.

METHODS

The study area was the Federal College of Freshwater Fisheries Technology, Baga, located on the shores of the Nigerian portion of the Lake Chad Basin, relocated to National Institute for Freshwater Fisheries Research (NIFFR), New Bussa, Niger State, Zonal Office in Maiduguri, Borno State, Nigeria in the year 2014 as a result of insecurity emanated from Boko Haram Insurgency. The College was established by the proxy of the Federal Research Institutes Degree of 1975 (supplement to official gazette Number 61 Volume 63 of 1975) which established Lake Chad Research Institute, Maiduguri, Borno State of Nigeria. As a result of the nationwide reorganization of Federal Research Institutes between 1988 and 1989, the supervision of the College was transferred to the National Institute for Freshwater Fisheries Research, New Bussa, Niger State of Nigeria, under the supervision of the Agricultural Research Council of Nigeria (ARCN) Abuja, the apex body of all the Agricultural Research Institutes in the country, Nigeria. The College concentrates on the training of fisheries personnel leading to the award of a Pre-National Diploma in Science and Technology, Vocational Certificate in Fisheries Technology, National Diploma in Fisheries Technology, Higher National Diploma in Fisheries Technology, and short-term Skill Acquisition Program on an annual basis and rendering Consultancy Services to fish farmers in the study area fishing communities. The institution is having five (5) departments and eleven (11) units; the Department of Fisheries Technology, Basic Science, General Studies, Administration, and Finance and Accounts Department. The units include; the Gear Technology Unit, Feed Mill Unit, Works Unit, Gear Technology Unit, Hatchery Unit, Library, Information and Documentation Unit, Clinic Unit, Fish Processing Unit, Information, Communication and Technology Unit, Student Affairs Unit, and Examination and Record Unit (Field Survey, 2023). Data collection for the research work was carried out from "1st to 31st October 2023" the period Federal College of Freshwater Fisheries Technology (FCFFT, Baga) Maiduguri, Borno State, Nigeria in collaboration with the Federal Ministry of Agriculture and Rural Development (FMARD) Abuja, Nigeria through the Agricultural Research Council of Nigeria (ARCN) Abuja, Nigeria organizes a National Training Workshop annually on Aquaculture Entrepreneurship Development for unemployed youths in the country.

The targeted population for this study consisted of five hundred and fourteen (514) teaching staff, non-teaching staff, students, and trainees from the study area. Sixty-five (65) respondents were selected and used for the study. Data for the study were obtained from both primary and secondary sources. Primary data were obtained through face-to-face interviews, demonstrative participatory technique, and the use of checklist, whereas secondary data were also obtained with the use of checklist with the aid of a table showing the nutritional values of some local fish feed ingredients and standard set for the formulation of 100 Kilogram (Kg) of 40% crude protein (CP) to elicit information from the respondents. Multi-stage sampling procedure was adopted for the selection of respondents for the research work. In the first stage, the Federal College of Freshwater Fisheries Technology, Baga, Maiduguri, Borno State, Nigeria was purposely selected out of the science and technology-based tertiary institutions in Borno State, Nigeria. The second stage involved selection of five (5) respondents from teaching and non-teaching staff of each of the five (5) departments, two (2) respondent from student of each of the five (5) academic programs, two (2) respondent from staff of each of the eleven (11) departmental units except the Feed Mill Unit "the

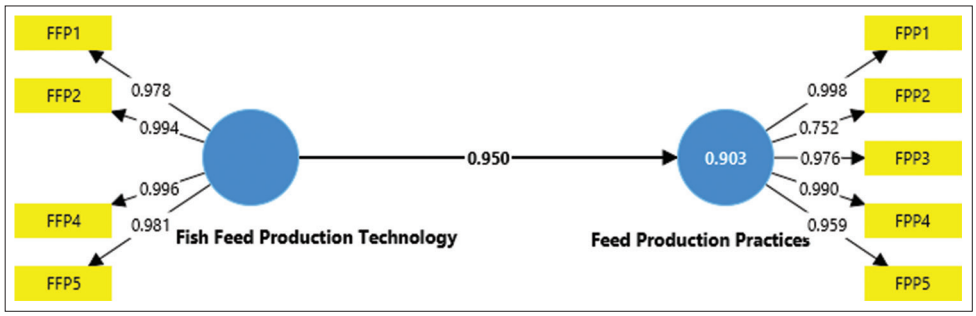

Figure 5: Path coefficient showing the impact of fish feed production technology on feed production practices in the study area
Source: Field Survey, 2023

subject matter of the research" from which five (5) respondents was selected and three (3) respondents were selected from each of the five (5) classes of unemployed youth trainees grouped for the purpose of the training workshop. Accordingly, making a total number of sixty-five (65) respondents from four (4) sample groups for the study.

Both qualitative and quantitative methods with descriptive techniques were employed in the data analysis of the study to determine actual composition in kilogram (kg) of each ingredient used for the production of the total output, level of utilization of protein nutritional value per input component, level of utilization of fat nutritional value per input component and the level of utilization of fish feed production capacity and evaluation of the level of mean percentage impact of fish feed production technology in feed production practices and application of "Structural Equation Modeling – Partial Least Squares (SEM-PLS)" for justification of the reliability and validity of the analysis of the impact of the Level of Technological Development in Feed Production Practices in Federal College of Freshwater Fisheries Technology Baga, Maiduguri, Borno State, Nigeria.

RESULTS AND DISCUSSION

The application of the method of fish feed formulation for the production of local fish feed is based on trial and error but the nutritive value of some of the local fish feed ingredients is set as standard for the ascertainment of percentage nutritional requirement for the production of quantities of fish feed required in kilograms (kg) in the study area (Table 1).

In the process of formulation, the total requirement of ingredients is proportional to the production of 117kg but on completion of the production stages, the ingredient's total output is 100kg as a result of wastages encountered in the process of palletization and packaging. On completion of the production, one (1) bag of fish feed is equivalent to fifteen (15) kg; therefore, the total bags of fish feed produced are 100kg/15kg equal to seven (7) bags. Moreover, it is important to note that not all the ingredients presented as a basis for the formulation given as a guide (set standard) have been applied in the study area. Items 2, 3,4,5,9, and 10 were not used as an input ingredient in the production process, although item 6 was partly used, and items 11 and 12 stand as substitutes and were not experimented as a basis for formulation in the study area.

The value of the actual composition of ingredients in kilogram (kg) is determined based on the crude protein (CP) actual formulation and crude protein in percentage (%) required standard set for each component which shows production capacity of 100kg in the study area. The level of utilization of protein nutritional value per input component is obtained by determining the differences in the values of crude protein in the percentage (%) required standard set and crude protein (CP) actual formulation for each component. The level of utilization of fat nutritional value per input component is obtained by determining the differences in the values of crude fat in weight percentage (%) required standard set and crude fat (Weight) percentage (%) actual formulation for each component. The results of both show underutilization or zero utilization of ingredients and alternative introduction of ingredients. The level of utilization of fish feed production capacity per input component in kilogram (kg) is determined based on the value of crude protein (CP) actual formulation and the value of crude protein in percentage (%) required standard set and "x" stand for the unknown value of the level of utilization of fish feed production capacity per input component in kilogram (kg) which is calculated with the application of simultaneous equation elimination method. Accordingly, the result shows a total underutilization of fish feed production capacity of 365.12 kilogram (kg) in the study area.

The Development of Fish Feed Technology

The respondents view fish feed as an essential input in fish production as it provides nutritious food in enough quantity to enable the fish to grow and attain big sizes in a short period of time under culture conditions. The cost of acquisition or production of fish feed constitutes about 60% to 80% of the total cost of fish production as a result, the fish producer uses low-quality ingredients in fish feed production which also results in the production of fish feed with inadequate nutrition. This results to negative effects such as poor growth, water pollution, high level of infectious diseases, and high mortality rates. Regardless of the poor quality of the fish produced the price of fish attracts high prices to enable the producers to maximize profit for sustainable fish production in the study area (Table 2).

This result shows consistency with the findings of Soliman *et al.* [2].

The type of fish feed produce is artificial feed prepared and given to the fish although the nutrients in the feed are not well balanced to meet the nutritional requirements of the fish. The feed is prepared on a farm-made basis as the feed is made in the Federal College of Freshwater Fisheries Technology, Baga, Maiduguri, Feed Mill. The mode of production has been mixing ingredients into powder and or dough, pelleted and after sundried the fish is served directly. The feed produced is not only for the college fish farm utilization but also for student practical, entrepreneurship youth empowerment training, and commercial purposes.

This study confirms that of Pallab [1].

In the study area, feed ingredients, such as soya beans, groundnut cake, and cotton seed cake as local ingredients substitutes are inadequate in most cases for energy feedstuffs deficiencies of feedstuffs containing less than 20% crude protein most importantly that of plant origin as cassava, wheat offal, rice bran except that of maize, guinea corn and others where available. Furthermore, local ingredients substitutes are inadequate for protein supplement deficiencies of feedstuffs containing 20% crude protein or more derivable from both animal and plant materials such as bone meal, blood meal, soya beans meal, groundnut cake, cotton seed cake particularly when embarking on fish culture. The inadequacy of the substitutes is a result of a lack of capital and other sources of external funding but not as a result of fertile land for

the cultivation of plants as well as for grazing of animals to acquire the required ingredients as the area is endowed with fertile land.

This result shows inconsistency with the findings of Jamabo *et al.* [3].

The Federal College of Freshwater Fisheries Technology, Baga, Maiduguri, Borno State, Nigeria has qualified and skillful personnel requirement to engage in fish feed production, but the personnel are not adequate in contrast to the high demand of professionals in the sector as expansion is required for industrialize large production. The material requirement is not adequate as the machines are not technologically sophisticated and lack adequate funding for sustainable use of such technologically advanced equipment and other standard feed production ingredients (Fig. 1).

This result is in line with the findings of Abegurin *et al.* [7] the major problem of the Nigeria's aquaculture has been the inadequacy of appropriate technologies, inadequate information on aquaculture technology, inadequate technical know-how, in availability of extension agents, unfavorable environmental conditions, inadequate training, and technical support.

According to the respondents, the major procedures undertaken in fish feed production involves feed formulation, which encompasses; nutrient requirements for fish such as protein, energy, calcium, and others. Selection of ingredients based on cost implication, availability, chemical composition, calculation based on nutrient requirement, and composition of ingredients. Other stages include feed milling which involves grinding and mixing of ingredients, pelletizing which also concerns binding with starch and drying under the sun and or with the application of an oven but in the study area the practice has been drying by the sun. Thereafter, bagging with the use of a sack ensures that quality is controlled and finally storing and distribution. Although, the respondent's complaint of inadequate funding and lack of other logistics to meet up with the nutrient requirement of the feed produce which may have a negative effect on the maintenance of the product generally (Fig. 2).

This result corroborates with the findings of Ajani *et al.* [8] the natural resources available in the country have shown that Nigeria has all it will take in achieving sustainable fish production. If the available resources are properly harnessed to ensure that aquaculture attains its full potential in Nigeria's fish production system which requires modern aquaculture practices and fish farming technology.

In the study area, the first step involved in the production of the fish feed is grounding the ingredients for making the fish feed finely with the application of a milling machine so that the feed will be transformed to be more digestible. The powdered ingredients are then mixed in a certain proportion with the use of a manual mixer taking into consideration small fish require high protein levels, starting at 40% protein and gradually reducing at 30% level as applicable. Thereafter, the mixed ingredients are pelletized with the use of pellet-making machine and dry the pelleted feed under the sun. The process requires feed are well packaged and sealed to prevent wastages.

This result shows inconsistency with the findings of Abegurin *et al.* [7].

There are no technological devices in the study area for the dictation of the problem associated with the nutritional value of the feedstuff and for remedying the dictated problem. Thus, fish feed formulation and production in the study area is carried out with consciousness because protein is the most limiting nutrient, most expensive, and best indicator of diet quality to avoid any substance that will alter the nutritional value of the feedstuff. Consequently, best-buy techniques, trial and error method, and or pearson's square method are applied in the fish feed formulation techniques as a deterrent factor.

This result confirms that of Jega *et al.* [9] pointed out the constraints in Nigeria, which work against increased aquaculture production and fisheries growth in Nigeria and the unavailability of locally produced high-quality extruded feeds at reasonable prices using local raw material. Other constraints include a lack of cage culture training, lack of processing and routes to developed markets in some countries, traditionally low prices and quality of wild fish in the region, lack of potential investors willing to take long-term investment risk in Nigeria, and lack of expertise in disease identification and management.

The respondents emphasize on important aspects of fish feed production exhibited in the study area; first, they identify all the feeding stuff that will be used for the purpose of fish feed, development of a formula that will meet the nutritional requirement of the fish species that will be cultured based on the identified ingredients, use of separate bags for keeping grinded mill of each feedstuff. The respondents ensure each feed ingredients are weighed according to the established formula in a container with the application of a scale or hand palm method. Depending on the quantity of feed that will be produced, the producers apply a hand and or a spade in mixing the mixture and to enable pelletize the feed mash thus, they thoroughly mix the feed (Fig. 3).

Sinking pelleted feed is produced in the study area. It sinks and stays at the bottom of the pond if not consumed by the fish as it has low water stability. The producers in the study area produce this type of feed because of economic factors compared to other types of feed called floating feed which requires machinery for its setting up thus floating feed production is very costly as it is classified as capital-intensive form of production (Fig. 4).

This result shows consistency with the findings of Zettl *et al.* [10] several new initiatives have come up regarding the incorporation of alternative aqua feed ingredients. Feeding trials using fish pellets made with plant-based ingredients, including soya bean protein, canola meal, and camelina meal, are being conducted to guide aqua feed producers in the selection of feed containing agricultural products. The challenge of alternative feed ingredients is to reduce or replace fish meal and fish oil while maintaining nutritional requirements, improving feed conversion, and lowering costs.

Regarding feed storage and handling in the study area; there is no appropriate specific place in the form of a house or building for feed storage. The temporary spaces provided where feed is stored have not been free from other items. Other regulations such as ventilation, stacking, waterproof, and security are not adequately maintained. The respondents are of the view; that the shortage of storage facilities is a result of the Federal College of Freshwater Fisheries Technology running its activities in temporary sites unlike when the College was sited in its permanent site where facilities and services are better compared to the current temporary status of the college.

This result is in line with the findings of Igoche *et al.* [6].

Application of "Structural Equation Modeling – Partial Least Squares (SEM-PLS)".

This result highlights the impact of fish feed production technology on feed production practices in the study area. The original sample shows a strong baseline performance at 0.950, while the sample mean increases slightly to 0.955, indicating a positive effect of the technology on practices. The standard deviation of 0.042 suggests that the responses are closely clustered around the mean, reflecting consistent outcomes across the sample.

The T statistic of 22.675 reveals a statistically significant difference between the original sample and the mean, underscoring the robustness of the technology's impact. In addition, the P value of 0.000 confirms that the results are highly significant; suggesting that adopting fish feed production technology can meaningfully enhance feed production practices (Table 3 and Fig. 5).

This analysis shows the path coefficient matrix with a strong positive relationship between "Feed Production Practices" and "Fish Feed Production Technology," with a coefficient of 0.950. This indicates that improvements in feed production practices are likely to significantly enhance fish feed production technology.

Such a strong correlation suggests that stakeholders in aquaculture can benefit from focusing on optimizing their feed production methods, which could lead to advancements in technology. However, it's important to consider the broader context, including environmental factors and market conditions, which may also impact this relationship. Understanding these dynamics can help tailor effective strategies and interventions in the industry. Overall, leveraging better feed production practices could lead to meaningful improvements in fish feed technology, ultimately benefiting aquaculture productivity.

This result reveals the R-square and adjusted R-square values for Feed Production Practices. The R-square value of 0.903 indicates that approximately 90.3% of the variance in Feed Production Practices can be explained by the model, suggesting a strong fit. The adjusted R-square, at 0.897, accounts for the number of predictors in the model and adjusts the R-square value accordingly. This slight decrease indicates that even after considering the number of predictors, the model remains highly effective in explaining the variance. Overall, these statistics demonstrate that the model effectively captures the dynamics of Feed Production Practices, reinforcing the reliability of any conclusions drawn from it (Table 4).

This result presents strong evidence for the reliability and validity of two constructs: Feed Production Practices and Fish Feed Production Technology. Both constructs exhibit high Cronbach's alpha values, indicating excellent internal consistency, with Feed Production Practices at 0.964 and Fish Feed Production Technology at 0.991. Similarly, the composite reliability values (0.965 for the first construct and 0.994 for the second) reinforce their strong reliability, as both exceed the commonly accepted threshold of 0.70. In terms of validity, the Average Variance Extracted (AVE) values are also impressive, standing at 0.883 for Feed Production Practices and 0.974 for Fish Feed Production Technology. These values indicate that both constructs capture a substantial amount of variance in their respective items, well above the recommended threshold of 0.50 for convergent validity. Overall, the metrics suggest that both constructs are highly reliable and valid, ensuring that any analyses or interpretations based on them are robust and trustworthy (Table 5).

CONCLUSION

The concern of the study is the development of fish feed production technology in the Federal College of Freshwater Fisheries Technology, Baga, Maiduguri, Borno State, Nigeria. The finding of the study reveals the underutilization of fish feed production capacity due to zero utilization and underutilization of ingredients for production. Thus, the development of fish feed production technology is low as a technological practice of fish feed production has a low cumulative mean percentage impact as evident by the production cost of fish feed constitutes about 60–80% of the total cost of production, this results to the production of fish feed with inadequate nutrition with the attendant problem of infectious disease and high mortality rate as well high price of fish output to recoup the cost of production to make a profit and sustain production. There exist qualified personnel with the application of required procedures and principles to produce standard fish feed but constraints by lack of adequate funding, technologically advanced machineries, and other ingredients for quality fish feed production. Sinking pelleted type of local fish feed is produced because of economic factors as its production does not require advanced machinery. Thus, the study reveals technology has a positive effect on fish feed production practices. The study recommends:

1. The need for government and non-governmental organizations integration with community-level involvement to find ways for easy access to input requirements for local fish feed production in a sustainable manner.
2. Empowerment of the local fish feed producers to engage in large-scale production with the support of adequate funding and technologically advanced mode of production in the study area.
3. Modern storage facilities should be in place that covers storage rightly from the collection of production ingredients up to the final stage of channel of the distribution (final consumer).
4. Efforts should be intensified through collaboration, creativity, and innovation focusing on the development of fish feed technology in the study area through training, research, and development.

CONFLICTS OF INTERESTS, AUTHORS CONTRIBUTION AND FUNDING

Contribution, Conceptualization, writing original draft preparation, writing review, and editing by Babagana Zanna. The author has read the manuscript and agreed for onward vetting, corrections, guidance for further consideration and approval and subsequent publishing of the final version of the manuscript accordingly. The research work was carried out by Babagana Zanna without any financial support from any agency or individual and finally, the research work has no any conflict of interest.

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