Asian Journal of Fisheries and Aquatic Research

Volume 27, Issue 11, Page 204-220, 2025; Article no.AJFAR.146006
ISSN: 2582-3760

Survey of Fish Feed Millers and Fish Farmers for Sustainable Aquaculture in Sub-Saharan Africa: A Case Study of Nigeria

Ayo-Olalusi, C.I. [a*], Ibiyo, L. M. O. [b], Obetta C. [c], Lamien N. [d], Yossa, R. [e] and Ahmad Fatan N [e]

[a] *Nigerian Institute for Oceanography and Marine Research (NIOMR), Wilmot point Road, Victoria Island, Lagos, Lagos State, Nigeria.*
[b] *National Institute for Freshwater Fisheries Research (NIFFR), P.M.B. 6006, New Bussa, Niger State, Nigeria.*
[c] *Agricultural Research Council of Nigeria (ARCN), Plot 223D Cadastral B6, Mabushi, P.M.B. 5026, Wuse Abuja, Nigeria.*
[d] *West and Central African Council for Agricultural Research and Development (CORAF), Senegal.*
[e] *WorldFish Headquarters, Penang, Malaysia.*

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/ajfar/2025/v27i111031

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://pr.sdiarticle5.com/review-history/146006

Original Research Article

Received: 22/08/2025
Published: 18/11/2025

ABSTRACT

The objectives of this study were to evaluate the fish farmers and feed millers in the study areas to determine their coping strategies, the types of feeds they use, the ingredients in their formulations, the sources of the ingredients, and any other relevant information that could aid in the scaling of

**Corresponding author: Email: ireti.ayoolalusi@yahoo.com;*

Cite as: *Ayo-Olalusi, C.I., Ibiyo, L. M. O., Obetta C., Lamien N., Yossa, R., and Ahmad Fatan N. 2025. "Survey of Fish Feed Millers and Fish Farmers for Sustainable Aquaculture in Sub-Saharan Africa: A Case Study of Nigeria". Asian Journal of Fisheries and Aquatic Research 27 (11):204–220. https://doi.org/10.9734/ajfar/2025/v27i111031.*

sustainable local ingredients and feeds. Questionnaires were administered in Local Government Areas (LGAs) in 22 States and the FCT cutting across the 6 geopolitical zones (North Central (NC), North-East (NE), North-West (NW), South-East (SE), South-South (SS) and South-West (SW)) of Nigeria from June to December 2023 to obtain information on activities of the feed millers and fish farmers in respect of the use of local ingredients from 2018 – 2022 to improve local feed production, reduce cost and support sustainable aquaculture development. A total of 459 structured questionnaires were administered to 130 feed millers and 329 fish farmers. Majority (65%) of the feed millers produced less than 5 tons per day in all the geopolitical zones across all business age categories (<5 years, 5-10 years and >10 years). Feed sizes of 2mm, 3mm, 4mm, 6mm, 8mm and above were produced at different capacity in all geopolitical zones. The lowest selling price of ₦540 per kg of feed was recorded in the south- west zone while the highest value of ₦1,599.36 was recorded in the South-East zone. Fish farmers in the South-West region have the highest fish production capacity, with 21.28% producing over 1000kg/year, while those in the South-South region have the lowest, with only 0.91% producing between 100-1000kg/year. 78% of fish farmers operate full-time, while only 22% do it part time. Most farmers (47%) use earthen ponds, followed by 24% who use concrete ponds. Some utilize both types, and a few make use of all available facilities. Fish farming and feed milling business can thrive well in Nigeria if favourable factors are considered.

Keywords: Fish feed millers; geo-political zones; fish farmers; structured questionnaire; aquaculture.

1. INTRODUCTION

Fish feed is vital for large-scale aquaculture, as it greatly impacts the growth of fish and the overall expenses of aquaculture operations. Feed is reported to account for 60 to 80% of the total cost of fish production particularly in sub-Sahara Africa (NRC, 1993; Béné et al., 2015, Ragasa et al., 2022). In Nigeria, aquaculture had been largely dependent on imported feeds as locally produced feeds face some challenges such as inconsistency in fish feed formulation and quality. However, in the 21st century, there has been a paradigm shift as fish farmers increasingly utilize farm-made feeds, incorporating ingredients that may be either imported or locally produced. This trend has been observed among fish farmers in the Kainji Lake basin (Julius et al., 2023). Fish feed can provide an essential source of nutrients to boost fish production, and it has been the driving force of the aquaculture sector over the past couple of years (Maulu et al., 2021). According to Assan et al., (2021), feed intake was identified as the primary factor influencing both efficiency and costs in fish farming, playing a crucial role in optimizing production efficiency.

High cost of feed ingredients and aquafeed produced in Nigeria has been a great concern for fish farmers, feed producers, small holder fish farms and other stakeholders. Greater numbers of fish farmers are moving out of business because the input cost outweighs the profit which is attributed to the high cost of conventional feed ingredients such as fishmeal, soybean, groundnut cake, maize, sorghum and millet due to competition. This has led to various research into the use of alternative feedstuffs such as brewers dry grain (BDG), maize bran, wheat bran, rice bran, cassava peel (Mogaji and Ibiyo 2016; Samuel & Shapawi, 2016; Fafioye, 2017, Jatta et al., 2022), soybean, wheat flour and cassava flour (Jatta et al., 2022), duckweed (Ogunshaki et al., 2021), bambara groundnut (Hillocks et al.,(2012), maggot and tadpole (Sogbesan et al., 2005) clupeid fishmeal (Ibiyo et al., 2018). Some feed millers have adopted the use of results from some foregoing research. The objectives of this study were to evaluate the fish farmers and feed millers in the study areas to determine their coping strategies, the types of feeds they use, the ingredients in their formulations, the sources of the ingredients, and any other relevant information that could aid in the scaling of sustainable local ingredients and feeds. This will invariably promote policies that will support local ingredients production and reduce dependence on imports.

2. MATERIAL AND METHODS

2.1 Study Area

Nigeria is a country in West Africa and sub-Saharan Africa, located between latitude 4^{O}N and 14^{O}N of the equator and between longitude 3^{O}E and 15^{O}E of the Greenwich meridian. It is inhabited by more than 200 million people and

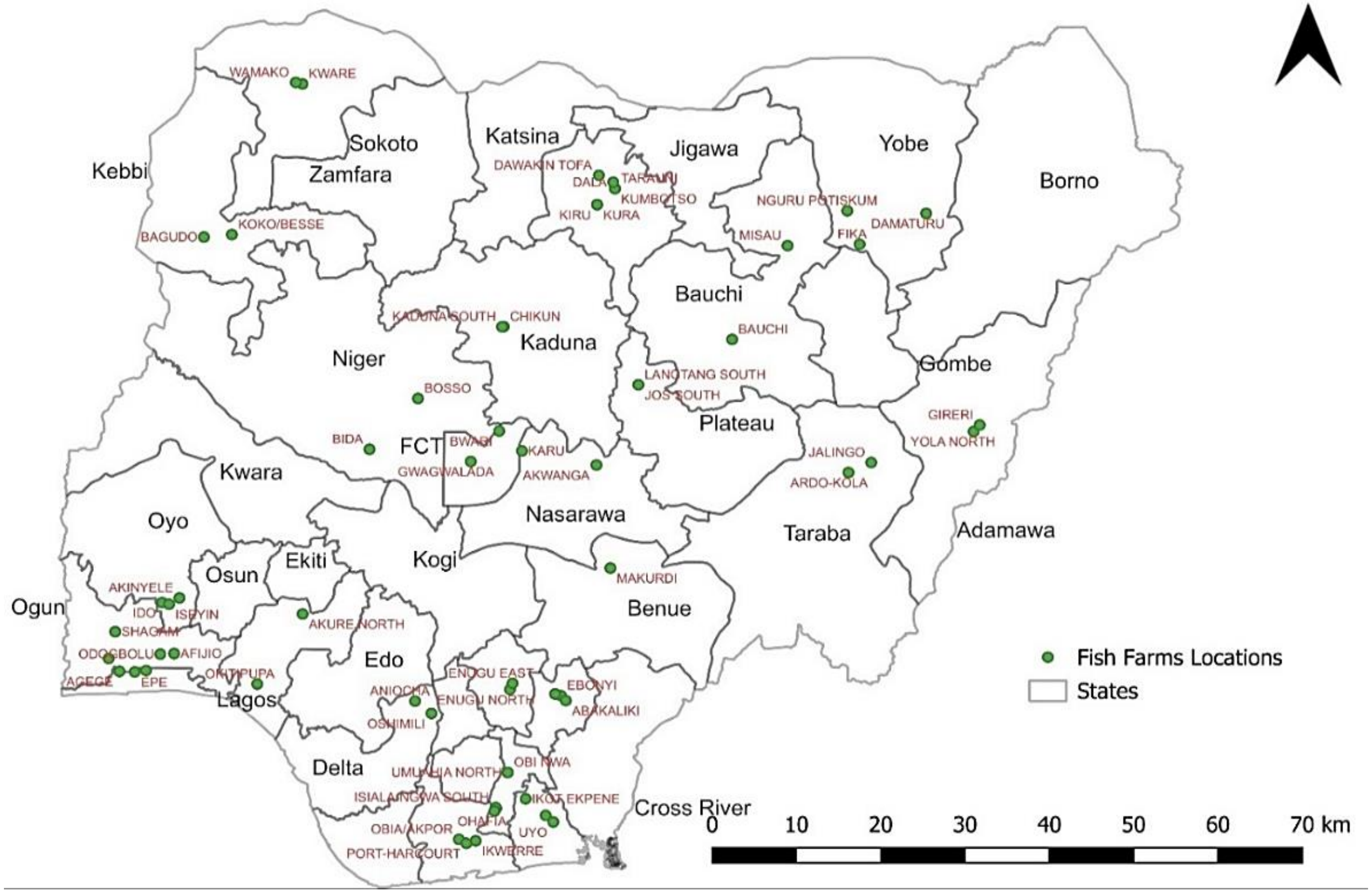

Fig. 1. Map of Nigeria showing the study areas

has a total area of 923,768Km^2 and six geopolitical zones comprising of 36 states and Federal Capital Territory (FCT). Nigeria is Africa's most populous country, bordered to the north by Niger, to the east by Chad and Cameroon, to the south by the Gulf of Guinea of the Atlantic Ocean, and to the west by Benin. The study was conducted in sixty-five (65) local government Areas drawn from twenty-two (22) randomly selected States and the Federal Capital Territory (FCT), making up a total of twenty-three (23) States in Nigeria (Fig. 1).

2.2 Selection, Training of Enumerators and Survey Technique

Enumerators with experience in aquaculture, feed milling, extension work, and field data collection were recommended, trained and selected for the survey. Respondents were interviewed one-on-one in each Local Government Area selected in each state by the enumerators assigned to them. Enumerators were importing questionnaire forms in the Kobo-Collect application using Kobo collect software package and data sent back to toolbox server for collation.

2.3 Feed Millers Evaluations

Feed millers were evaluated in the selected sites in all the six geo-political zones of Nigeria based on their feed produced per day, business age, production capacity, sources of the ingredients used for feed production and experience in the business for each geopolitical zone. The experience was categorized into less than 5 years, between 5 to 10 years and more than 10 years. The selling prices of various feed sizes produced per kg were also recorded in all the six geo-political zones.

2.4 Fish Farmers Evaluations

The fish farmers in the areas of study were also assessed to know what kind of feeds they were using, the ingredients used in feed formulations, sources of the ingredients and any possible valid information that will assist in the scaling of sustainable local ingredients and feeds in the Sub-Saharan region.

2.5 Data Analysis

A total of 459 well-structured questionnaires were administered to feed millers (130) and fish farmers (329) in the sixty-five (65) LGAs across the 6 geopolitical zones of Nigeria. All the data collected were recorded and inputted into a Microsoft Excel spreadsheet. The results were presented in frequencies, charts and percentages.

3. RESULTS

3.1 Feed Millers in the Six Geopolitical Zones

3.1.1 Feed millers' business experience

Fig. 2 shows regional variations in feed millers' business experience across the geopolitical zones. The data reveals that most respondents have been in the feed milling business for more than 10 years with South-West (SW) recorded the highest values of experienced feed millers while North-Central (NC) and North-West (NW) had relatively those who are new in business. In all, irrespective of the geopolitical zones, majority had over five years of experience. Statistically, the result shows that there is no significant difference in the years of experience across the geopolitical zones X^2 (10) =14.24; P>0.05.

3.1.2 Quantity of feed produced per day

Fig. 3 presents the daily feed production across Nigeria's geopolitical zones, categorized by the business age of feed millers. The results indicate an upward trend, with feed millers who have been in business for less than five years generally operating at the lower production rate per day and more established millers recorded higher daily production. Overall, most of the feed millers operated on a small to medium scale producing less than 10 tons per day while a few numbers exceeded 10 tons per day.

3.1.3 Sources of ingredients for feed millers

The result revealed geo-political differences in ingredients sourcing among feed millers. Open markets served as the primary source of feed ingredients across the zones, followed by direct sourcing from farms and, to a lesser extent, factories. The South-South and North-Central zones showed more diversified sourcing patterns, while the North-East and North-West relied predominantly on open market supplies. In all, 25.25% of the respondents sourced their ingredients from farms, 57.07% from Open

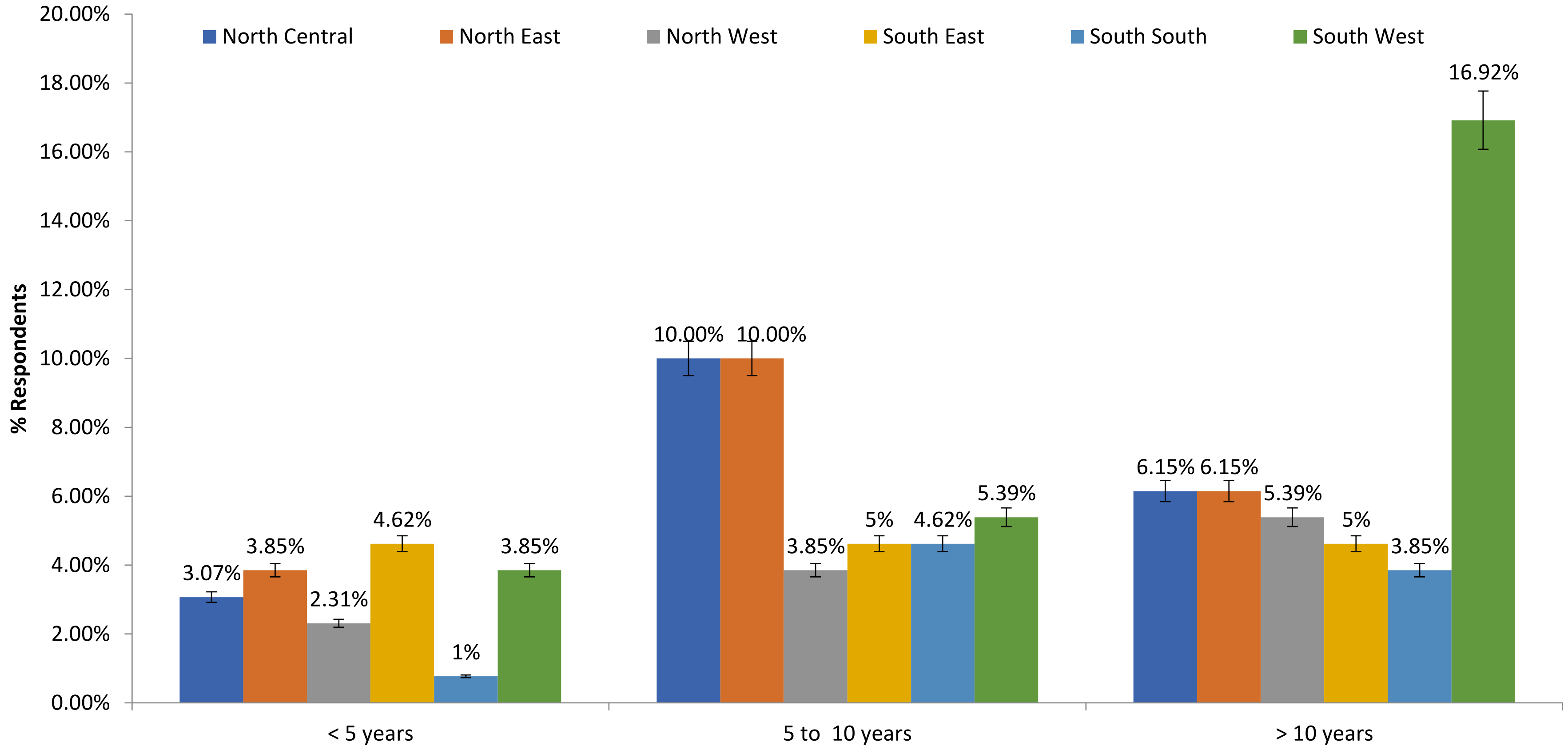

Fig. 2. Duration of Feed Millers in Business

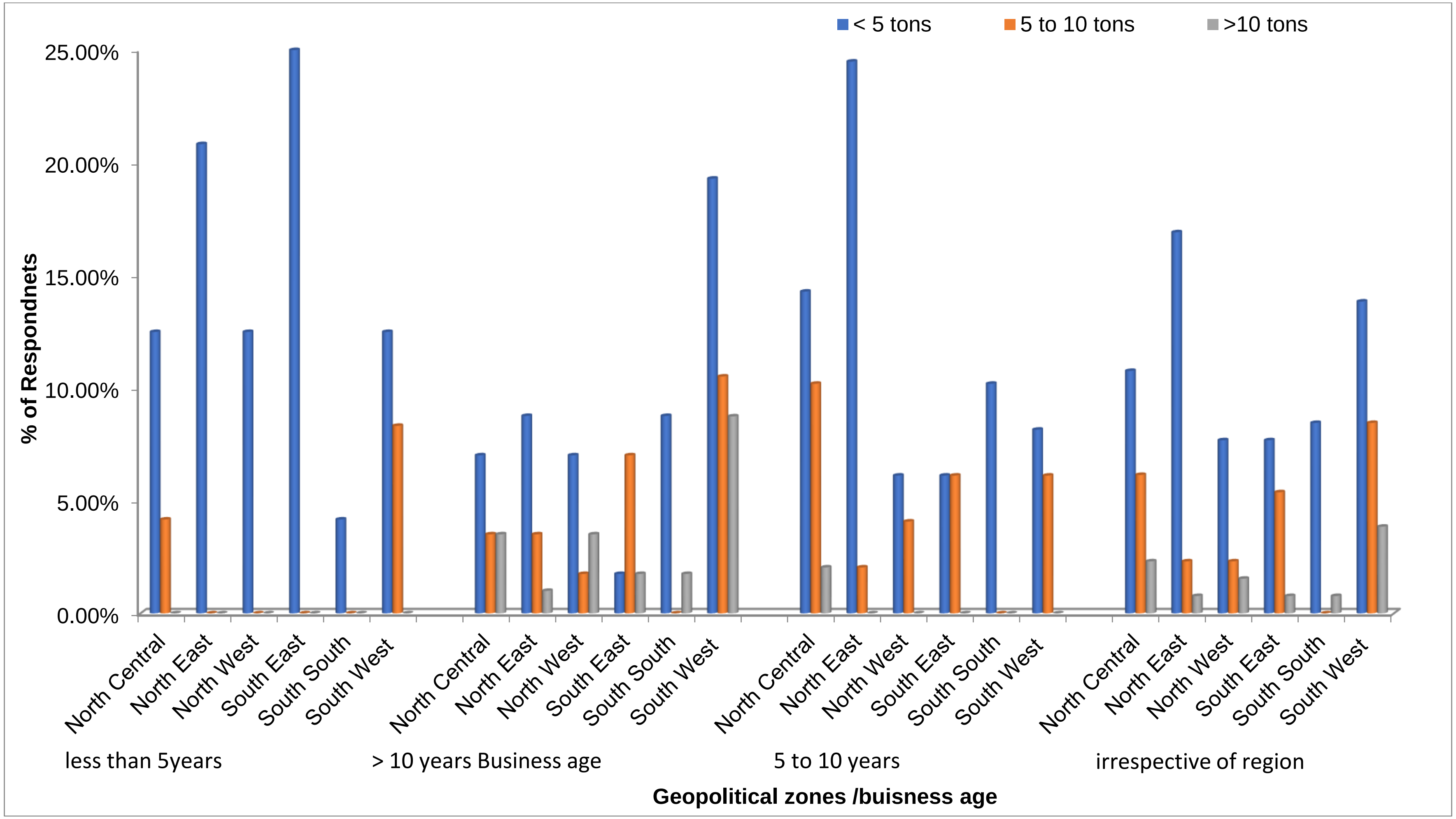

Fig. 3. Tons of feed produced per day based on the business age

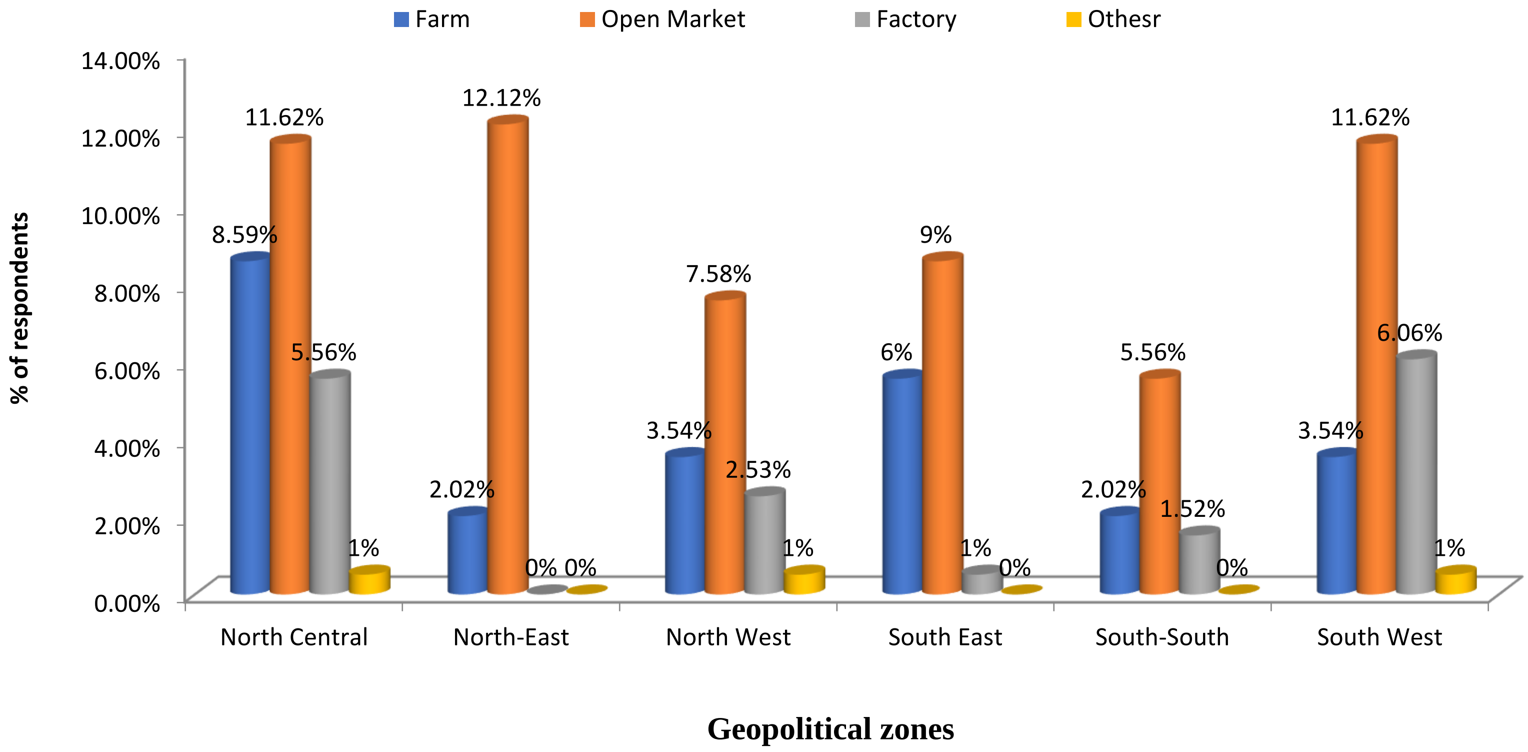

Fig. 4. Sources of Ingredients for Feed Millers in each Geopolitical zone

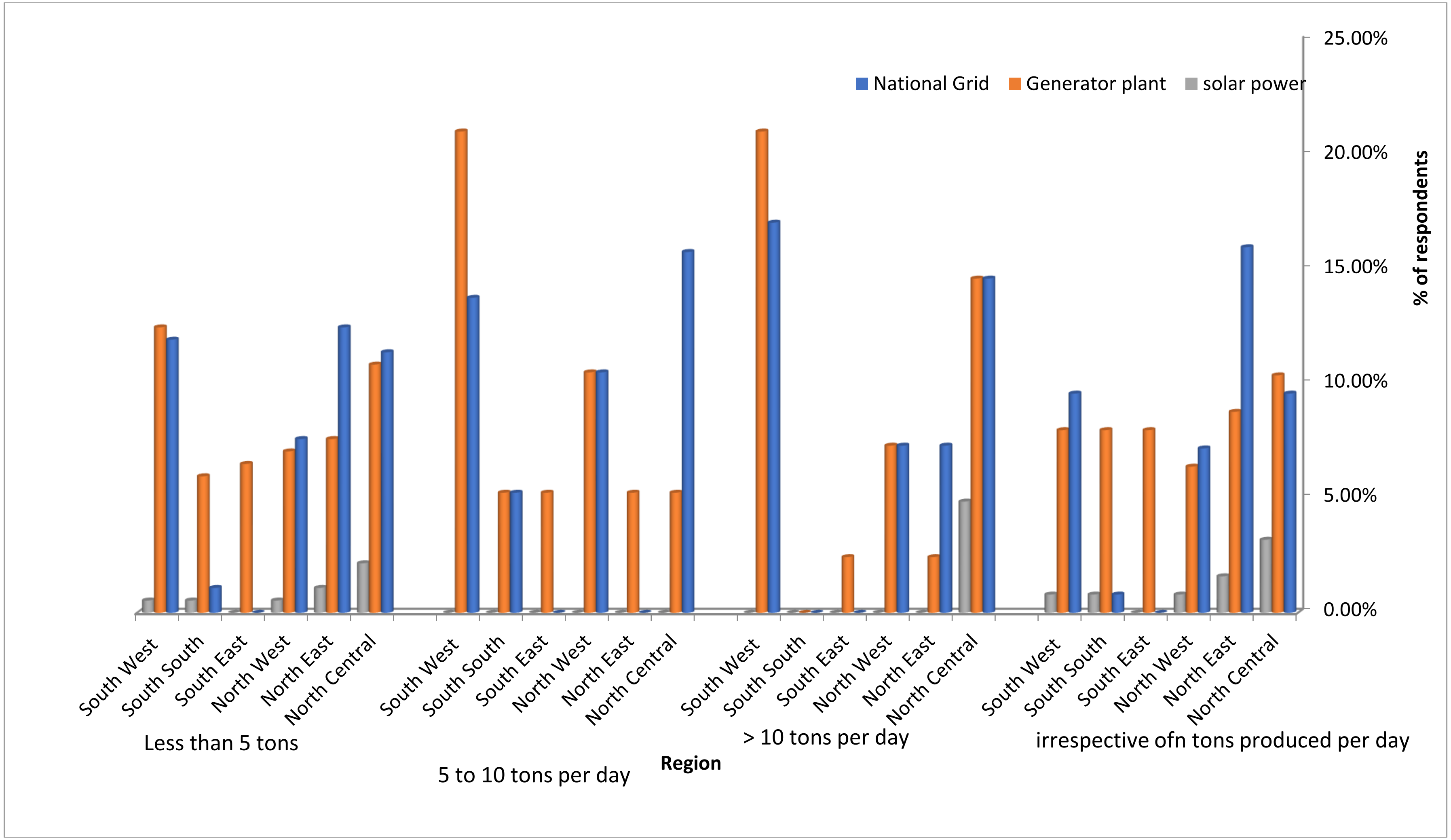

Fig. 5. Source of Power for Millers based on the number of tons produced per day

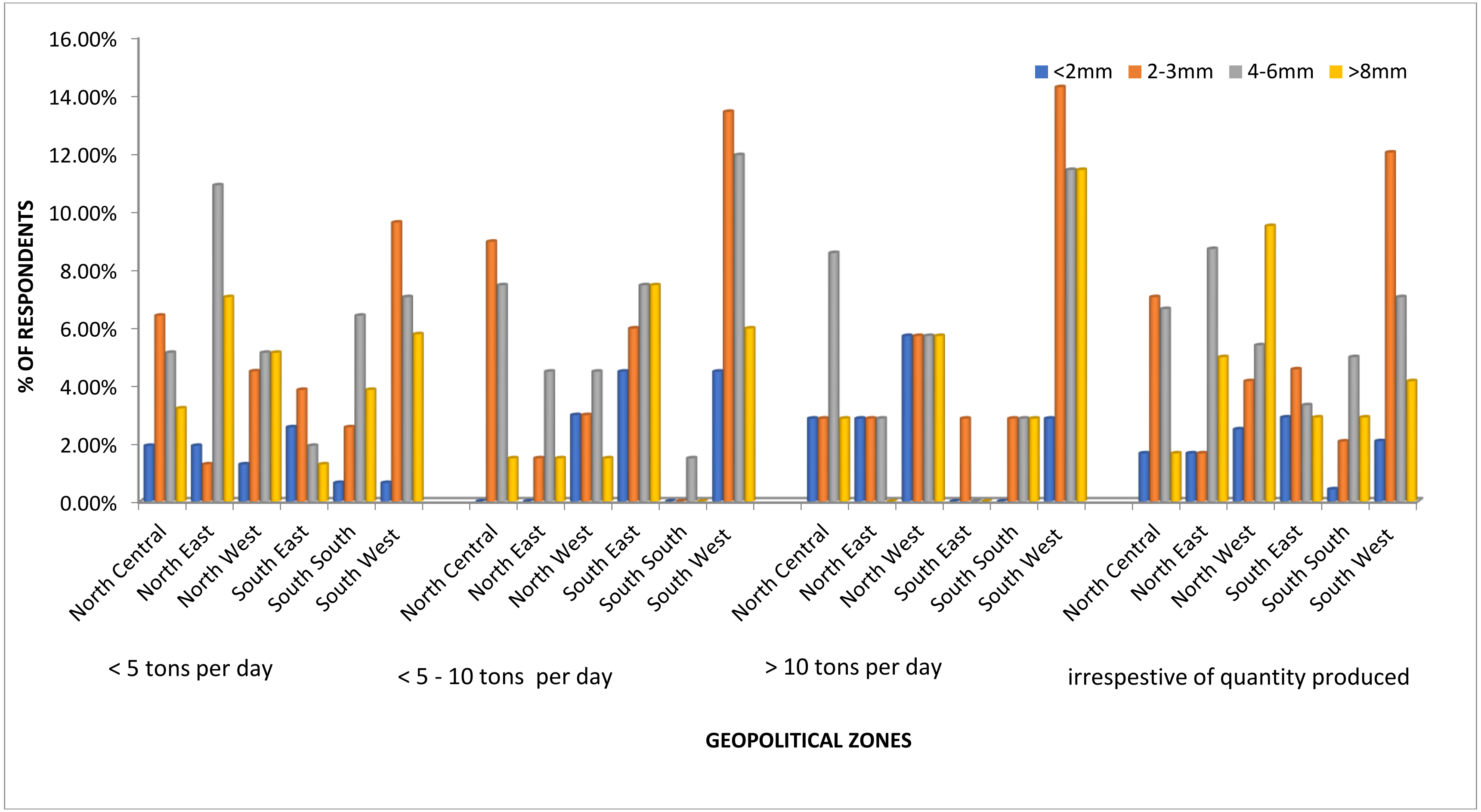

Fig. 6. Sizes of Feed produced, and quantities produced per day in Geopolitical zones

Market, 16.16% from factories and 1.52% from other sources. Summary of these findings is presented in Fig. 4.

3.1.4 Sources of power for feed millers

Interview conducted for the feed millers revealed sources of power being used (Fig. 5). Feed millers who produced less than 5 tons per day, 43.2% were using National grid, 49.6% depended on Generator plant and 7.2% depended on Solar Power. Across all categories, most millers relied on generator plants, followed closely by the national electricity grid, while the use of solar power remained minimal. The Summary indicates that 50.54% depends on Generator plant and 44.57% on National grid and 4.89% on solar power. Overall, Majority of the respondents depended on dual sources of power, which were mostly National grid and Generator plant.

3.1.5 Sizes of feed produced by feed millers

Among feed millers who produce less than 5 tons per day, 36.54% produced feed that was between 4 to 6 mm, 28.21% produced feed 2-3mm in size and 26.28% also produced feed greater than 8mm, only 8.97% produced feed that was less than 2 mm in size. Across all the production levels, feed sizes of 4 to 6 mm were the highest produced. Less than 2mm feed sizes were least produced, while a notable proportion of millers, particularly those with higher production capacity, also produced greater than 8mm.

In all, majority of the millers produced feed of 4 to 6 mm sizes, 31.54% produced feed sizes of 2 and 3 mm; 21.16% produced feed more than 8mm and 11.20% produced feed less than 2mm in size. Sizes of feed produced based on geopolitical zone are presented in Fig. 6.

3.1.6 Selling price of fish feed per kg

Table 1 summarizes variations in the mean selling price of fish feed per kg across Nigeria's geopolitical zones. The results show clear zonal disparities, with SE recorded the highest mean price value of ₦1,599.36 and SW with the lowest mean value of ₦540.00. The feed cost remains relatively high in the regions where ingredients availability and transportation fares are expensive.

3.1.7 Challenges encountered in the feed milling industries visited

Limited capital, lack of funding opportunities from government and private individuals, high cost of raw materials, erratic power supply, high cost of diesel and petrol, lack of effective drying, processing and storage facilities for the grains, high transportation and logistics cost, limited modern milling machines and high cost of maintenance, delay in issuance of certification of NAFDAC Number, lack of price control in the open market, multiple taxation and seasonality of some major raw materials. Others were impact of extreme climatic events (flood and drought) and limited skill labourers to handle complex milling machines.

3.2 Fish Farmers in the Six Geopolitical Zones Assessed

The results of fish farmers are presented as follows:

3.2.1 Production capacity of fish farmers in the geopolitical zones of Nigeria

Fig. 7 shows that production activities occur in all the Geopolitical zones of Nigeria, although at varying scales and capacities. The highest production capacity and largest number of fish farmers were associated with South-West,

Table 1. Selling Price of the feed per kg

Geopolitical Zone	Respondents	Mean (₦/Kg)	Std. Deviation
NORTH-CENTRAL	25	551.60	214.70
NORTH-EAST	26	892.82	370.91
NORTH-WEST	15	704.27	304.72
SOUTH-EAST	18	1599.36	711.98
SOUTH-SOUTH	12	763.63	181.78
SOUTH-WEST	34	540.00	187.71
Total	130	763.64	

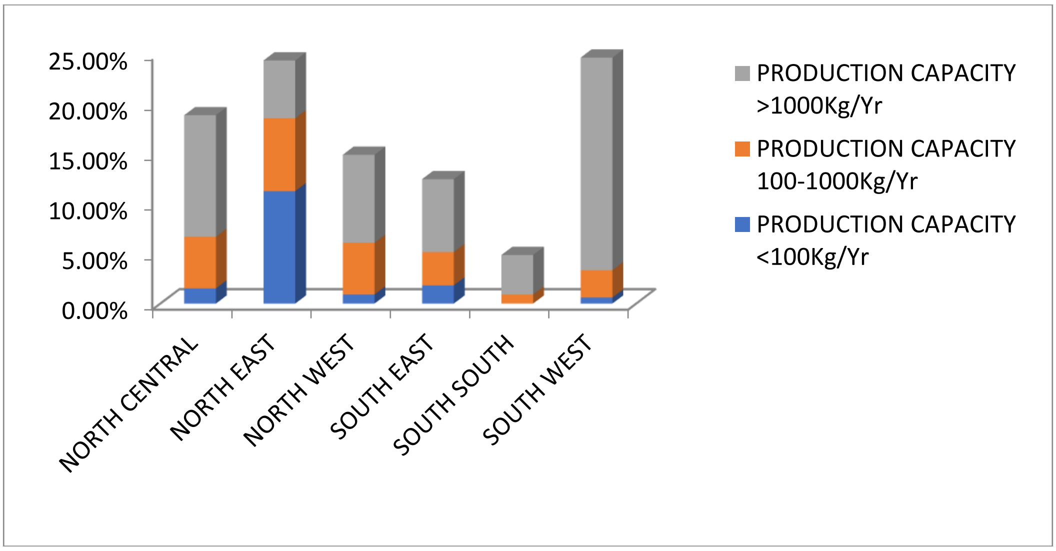

Fig. 7. Production Capacities of Fish Farmers in the Geopolitical Zones of Nigeria

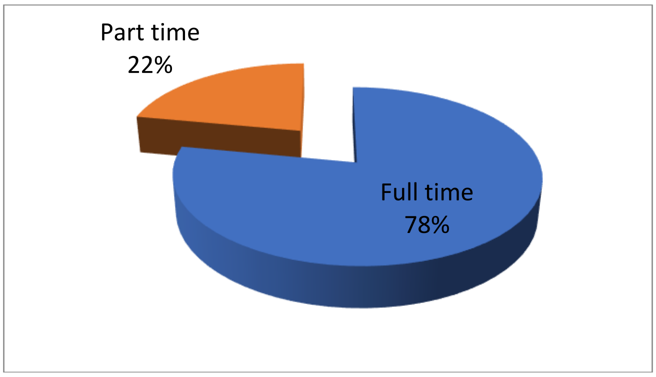

Fig. 8. Farming Status of Fish Farmers in the Geopolitical zones of Nigeria

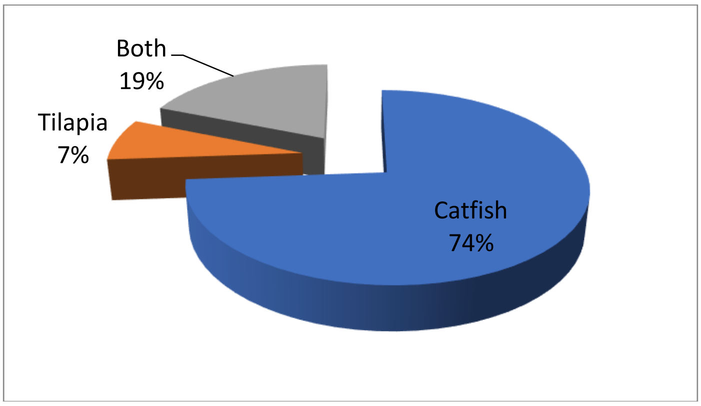

Fig. 9. Type of fish cultured in the Geopolitical zones of Nigeria

followed by North-Central having 21.28% and 12.16% respectively producing greater than 1000Kg/year in the studied areas. Overall, production capacities were generally low across most regions, with most farmers operating below 1000kg/per. The North East and North West recorded relatively higher shares of small-scale producers, while a few fish farmers in South South achieved larger production capacity.

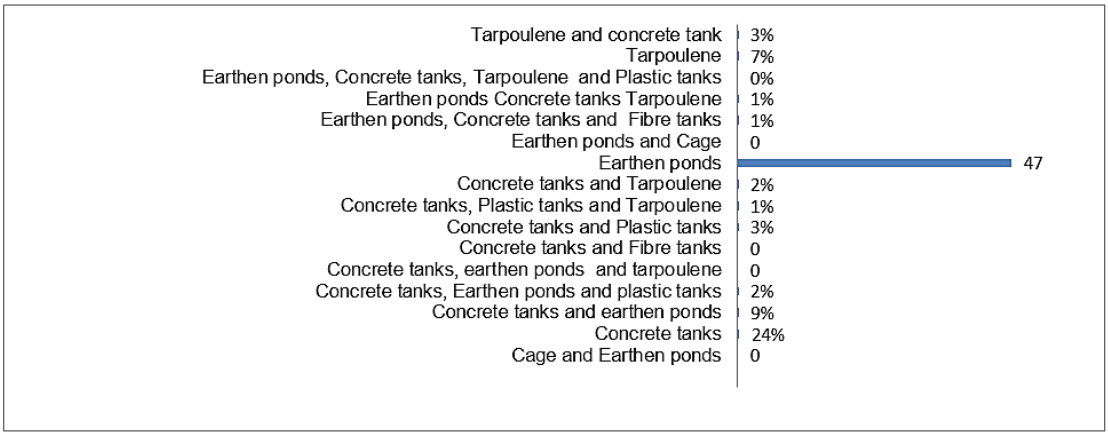

Fig. 10. Types of culture facilities used by Fish Farmers in the Geopolitical zones

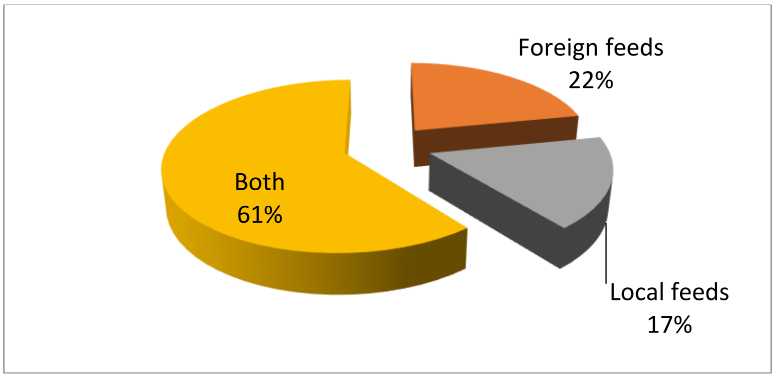

Fig. 11. Types of feed used by fish farmers

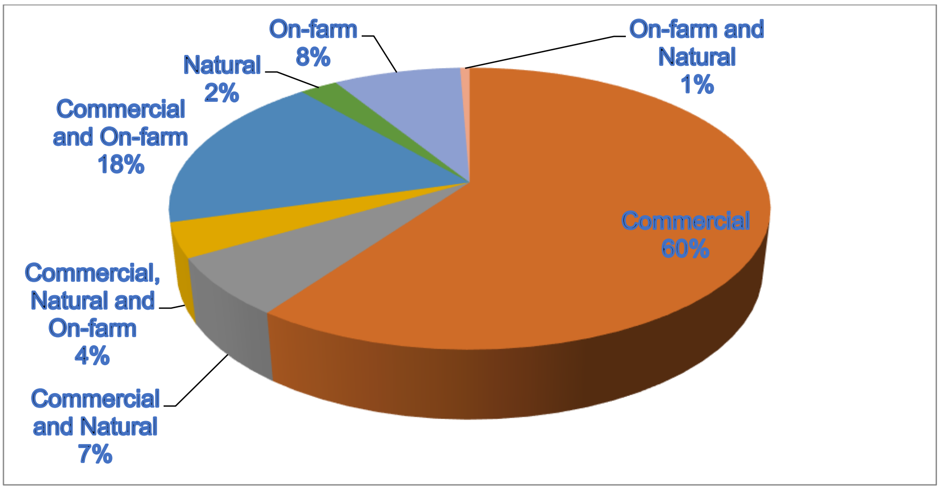

Fig. 12. Sources of feed used by fish farmers in all the Geopolitical Zones

3.2.2 Farming status of fish farmers, type of fish cultured, culture facilities and type of feed used in all the geopolitical zones

Fig. 8 presents the farming status of the fish farmers assessed in all the geopolitical zones, 78% are on full-time fish farming with only 22% doing it on part-time basis. The type of fish culture included catfish and tilapia. Fig. 9 shows that 74% of catfish culture, 19% culture tilapia and 7% culture both species. Fig. 10 shows types of culture facilities used by the fish farmers in all the geopolitical zones of Nigeria. The facilities are shown in the graph with majority of the fish farmers (47%) using earthen ponds and 24% concrete. Some were using both, while a few others were using all the different facilities.

Fig. 11 explained the types of feed used by fish farmers in all the geopolitical zones. As at the time of this survey 22% were using foreign feeds, 17% local feeds while 61% were using both. Fig. 12 displayed the various sources of these feeds, 60% acquired their feed from commercial sources, 8% used on-farm feeds. Some combined commercial feed and natural (7%), others commercial with on-farm and natural (4%), Commercial and on-farm (18%), 2% rely on natural alone while only (1%) on-farm and natural.

4. DISCUSSION

The survey of feed millers and fish farmers revealed significant variation in the feed millers' business experience, quantity of feed produced, sources of feed, production practices and operational experiences of the respondents across Nigeria's' geopolitical zones. Feeds turn out to be one of the major inputs in aquaculture production and fish feed Technology is one of the least developed sectors of aquaculture particularly in Africa and other developing countries of the World. High cost of fish feed was observed as one of the problems hampering aquaculture development in Nigeria (Gabriel *et al*., 2007). As it accounts for at least 60 - 80% of the total cost of production (Ragasa et al., 2022). The capacity of less than 5 tons per day in all the geopolitical zones cutting across all business age is an indication of small-scale dominant operation. The respondents been in the feed milling business for more than 10 years with South West (SW) recorded the highest values of experienced suggest that the experience contributes to scaling up feed milling business, although most of them are still within small to medium scale which enabled the local small scale fish farmers to be able to access feed for feeding fish in their farms. The ingredients used in feed preparation sourced from farm and open market majorly in all zones indicate an agrarian environment which means sourcing the major plant ingredients was not much of a problem but the finance to embark on the venture. The fish farmer with high capacity of production which is concentrated in the South-West and North-Central could be attributed to the advantageous availability of low-cost local feeds which the fish farmers used along with foreign commercial feeds. The high cost of feeds in the south-East explained why majority of the fish farmers were producing at a capacity of less than 100kg and 100 – 1000kg per year. Feed affordability and availability go a long way to encourage productivity of fish farmers.

The use of National Grid, Generator and Solar across the geopolitical zones as mixed power sources for feed production machines and water pumps for water supply to ponds revealed the inconsistency of the National Grid alone to provide source of power for the business of feed production and fish farming. Electricity was a critical infrastructure for feed production in Nigeria. All the zones suffer chronic power shortage. Many feed millers reported high costs due to irregular grid supply, forcing reliance on generators for production which affected both small- and large-scale operators and invariably limiting fish farmers' production capacity. The irregularity of National Grid power source was a big problem noticed with the feed millers which requires a national attendance to solving the issue.

All sizes of feed produced in all geopolitical zones, though at different capacity explain why fish production is being carried out in all zones. The concentration of fish farmers and extent of fish production in each zone determined the quantities and sizes of feed produced. The prices of feed per kg identified on the field vary from one zone to the other. The selling price of feed in the south-west was ₦540 with North-Central being ₦551.60 while selling price was as high as ₦1,599.36 in the South-East at the time of data collection. The significantly high selling price of feed in the South-East compared to North Central could be attributed to the availability of feed ingredients in the North-Central zone. South-East relies on the supply from the Northern zones as most of the ingredients are not produced in the South-East and South-South at large scale. The North-Central also had advantage of the availability of clupeid fishmeal in the zone which was used as an alternative to foreign fishmeal, and it helped to reduce cost of production. The use of clupeids as substitute to foreign fishmeal could also be exploited in other zones. The only major constraint is the availability which demands having supply from North-Central or North-East. To enhance the availability of clupeid fishmeal, the possibility of introducing freshwater clupeids (*Pellonula leonensis* and *Sierathrissa leonensis)* to water bodies where they do not exist or are not found could be explored. They were noted to be a highly prolific freshwater sardine that can easily establish in water bodies and having a nutrient profile like Danish fishmeal (Ibiyo et al., 2018).

The low selling price of feed in the South-West lower than the country's average of ₦763.64 was due to alternative feed ingredients such as Black Soldier fly larvae meal, biscuit waste and indomine wastes meal used for feed production in some part of the South-West zone to reduce high cost of on-farm feeds in Nigeria. The concentration of fish farmers in the Southwest and North Central suggest that water availability influences aquaculture. The predominance of earthen ponds in these zones can be attributed to favourable soil conditions that support pond construction. The dominance of Catfish in the type of fish reared in all the zones emphasized the easy handling and hardy nature of catfish compared to other species.

The high percentage (78%) of fish farmers operating on full time basis indicated the advantage of aquaculture in provision of self-employment, livelihood and wealth creation to most individuals who would have been out of job due to unemployment problems in the nation. Reducing the cost of aquaculture production remains essential for improving profitability and sustainability of fish farming.

Lower production costs would enable feed millers and farmers to increase their income, invest in feed and fish farming businesses, thereby strengthening the aquaculture sector. Aquaculture fish production has the capacity to meet the needs of the population if encouraging factors like low-cost sustainable feed are made available and utilized effectively. This aligns with observation of Igoni-Egweke (2018), who reported that over 600,000t of fish were imported to meet the demand of the growing population.

5. CONCLUSION

This study revealed that feed production in Nigeria remains dominated by small-scale operators facing challenges of high input cost and unstable power supply. Sustainable aquaculture growth will require promoting local feed ingredient production, supporting cooperative feed mills, and improving electricity infrastructure. Further research should assess nutrient quality and economic viability of alternative local feed ingredients.

ETHICS APPROVAL

The survey was carried out with approval (project number CMUL/HREC/03/23/1169) obtained from the Health Research Ethics Committee of College of Medicine, University of Lagos, Nigeria.

DISCLAIMER

This paper is an extended version of a preprint document of the same author.

The preprint document is available in this link: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=5078687
[As per journal policy, preprint can be published as a journal article, provided it is not published in any other journal]

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

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

ACKNOWLEDGEMENT

The authors express gratitude to the Norwegian Agency for Development Cooperation (NORAD) and WorldFish for generously sponsoring this noteworthy research endeavor. We extend special thanks to the Agricultural Research Council of Nigeria (ARCN) and the Nigerian Institute for Oceanography and Marine Research (NIOMR) for their invaluable support in hosting the project. We are grateful to NIOMR and National Institute for Fresh water Fisheries Research (NIFFR) for human resources to execute the project. We are grateful to Dr. Mathew Owen for reviewing the manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

Assan D, Huang Y, Mustapha UF, Addah MN, Li G & Chen H (2021): Fish Feed Intake, Feeding Behavior, and the Physiological Response of Apelin to Fasting and Re feeding. *Front. Endocrinol*. 12:798903. doi: 10.3389/fendo.2021.798903 REVIEW published: 15 December 2021doi: 10.3389/fendo.2021.798903

Béné, C., Barange, M. & Subasinghe, R. (2015). Feeding 9 billion by 2050- putting fish back on menu. Food Sec. 7, 261-274. https://doi.org/10.1007/s12571-015-0427-z

Fafioye, (2017): Effect of fermented wheat Bran on the African Mud catfish (*Clarias gariepinus). Continental of Agricultural Sciences* vol 11(1): 18-30

Gabriel, U.U., Akinrotimi, O.A., Bekibele, D.O., Onunkwo, D.N. & Anyanwu, P.E. (2007): Locally produced fish feed: potential for aquaculture development in Sub-Saharan Africa. *African Journal of Agricultural Research*. 2(7): 287-295.

Hillocks, R. J., Bennett, C. & Mponda O. M. (2012): Bambara nut: A review of Utilization, Market potential and crop improvement. *African Crop Science Journal* Vol. 20 No. 1, pp 1-16.

Ibiyo, L. M. O., Kayode, R. M. O., Oresegun, A., Olugbenga B. O. & Joshua, F. O. (2018): Chemical composition of clupeid fish as alternative replacement for foreign fishmeal in fish feeds in West Africa region. *Journal of Animal Husbandry, Dairy and Veterinary Science* Volume 2(4): 1 – 3.

Ibiyo, Lenient M. O., Rowland M. Kayode, A. Oresegun, Oluwaseyi Mogaji & Felicia O. Joshua (2018). Evaluation of clupeids and Danish fish meal based diet on the growth of African catfish *Clarias gariepinus* fingerlings. *Archive of Food and Nutr Sci.* 2018; 2: 031 – 037 https://doi.org/10.29328/journal.afns.1001014

Igoni-Egweke, Q. N. (2018): Analysis of value addition in commercial catfish (*Clarias gariepinus, Heterobranchus* Spp.) productionin Rivers State, Nigeria. Federal University of Technology, Owerri. *Food and Nutrition Bulletin* 27(4):327- 34.

Jatta S., Fall, J. Diouf, M., Viet Le D. & Sheen S.S. (2022): The Effects of Substituting Soybean Meal, Wheat Flour and Cassava Flour with Groundnut Cake, Poultry By-product Meal, Brewery Waste and Rice Bran on Growth and Body Composition of Tilapia Fry. *European Journal of Agriculture and Food Sciences*4(3):30-34. DOI:10.24018/ejfood.2022.4.3.320.

Julius E. O., Achike A. I., Nwabeze G. O., Ibiyo, L. M. O. & Samuel P.J. (2023): Economic Analysis of Locally Produced Aquaculture Feeds with Complements of Plant-based Ingredients in Kainji Lake Basin, Nigeria. *World Agricultural Economy Journal* Vol. 4(01): 54 – 61.

Maulu S., Hasimuna O.J., Haamibiya L.H., Monde C. Musuka, C.G., Makorwa T.H., Munganga B.P., Phiri K.J. & Nsekanabo J.D. (2021). Climate Change Effect on Aquaculture Production: Sustainability Implications, Mitigation and Adaptations. *Front. Sustain. Food Syst.*5:609097. Doi10.3389/fsufs.2021.609097.

Mogaji, O. Y. & Ibiyo, L. M. O. (2016): Growth performance of *Oreochromis niloticu*s fed Brewer’s Dry Grain (BDG) base NIFFR feed supplemented with Xylanase enzyme. *International Journal of Fisheries and Aquatic Studies.* 4(3): 220 – 222.

National Research Council (NRC) (1993) Nutrient requirements of fish. National Academy Press, Washington DC.

Ogunshakin, R.Y., Takim, F.O., Birnin-Yauri, Y.A., Mbagwu, I.G., Enodiana O.I. & Mogaji. O.Y. (2021) Utilization of Duckweed Species as a Sustainable Alternative Source of Crude Protein for Poultry and Aquaculture feeds in Nigeria – A Review. Proceedings of 48th Annual conference of Weed Science Society of Nigeria (WSSN) PP 36-42.

Ragasa, C., Osei-Mensah, Y., & Amewu, S. (2022). Impact of fish feed formulation training on feed use and farmers’ income: evidence from Ghana. Aquaculture,558 Article738378,10.1016/j.aquaculture.2022.738378

Samuel & Shapawi (2016). Effect of different inclusion levels of rice bran in the diets of African catfish (*Clarias gariepinus*). juveniles. *Malaysian Applied Biology*, *45*(2), 17-22.

Sogbesan, O.A., Ajuonu, N.D., Ugwumba, A.A.A. & Madu, C.T. (2005). Cost benefits of maggot meals as supplemented feed in the diets of *Heterobranchus longifilis* x *Clarias gariepinus* (Pisces-Clariidae) hybrid fingerlings in outdoor concrete tanks. *Journal of Industrial and Scientific Research*, 3(2): 51-5

APPENDIX

Appendix 1: Feed Millers Survey

Note for interviewer: Data should be collected by interviewing knowledgeable individuals. Respondents should be informed that they were chosen by random selection and that the information obtained will be confidential. They should also know that their participation is voluntary, and they are free to withdraw at any time without giving reasons.

Name of Interviewer: ___________________ Phone number: ___________
Date of interview: ______________
Geopolitical zone: ____
State: ____
LGA: ____
Ward: ___________________
Address of respondent: _________________ Phone number _____________
GPS Coordinates _________________

Variable Response (Use codes)

C1: Name of respondent
C2: Gender 1 = Male, 2 = Female
C3: Marital Status 1 = Single, 2 = Married, 3 = Separated, 4 = Divorced, 5 = Widowed
C4: Age 1 = < 18yrs; 2 = 18 to 40yrs; 3 = 41 to 60yrs; 4 = > 60yrs
C5: Level of Education 0 = None, 1 = Primary; 2 = Secondary, 3 = Tertiary, 4 = Adult literacy, 5 = Other, specify
C6: Main Occupation 1 = Farming, 2 = Wage labour, 3 = Formal employment, 4 = Small scale business, 5 = Others (specify)
C7: Name of Company/date of establishment
C8: Source of ingredients 1= farm; 2= Open market, 3= factory.
C9: Type of feed ingredient used
C10: Where do you buy each ingredient?
C11: Price/kg of each ingredient listed
C12: Production capacity of your feed mill 1= 1 ton/day, 2=5 tons/ day, 3= 10 tons/day, others (specify)
C13: Sources of power 1= public electricity, 2=generator plant; 3= solar
C14: Sizes of feeds 1 = <2, 2 = 2-3mm 3 = 4-6mm; 4 = >8mm
C15: Selling price of feed/kg
C16: Quantity sold /day
C17: To Whom?1= wholesaler; 2= retailers 3= Direct to farmers
C18: Challenges encountered
C19: Duration of Business 1= less than 5 years, 2= 5-10 years, 3= above 10 years

Appendix 2: Fish Farmer Survey

Note for interviewer: Data should be collected by interviewing knowledgeable individuals. Respondents should be informed that they were chosen by random selection and that the information obtained will be confidential. They should also know that their participation is voluntary, and they are free to withdraw at any time without giving reasons.

Name of Interviewer: ___________________ Phone number: ___________
Date of interview: ______________
Geopolitical zone: ____
State: ____
LGA: ____
Ward: ___________________
Address of respondent: _________________ Phone number _____________

GPS Coordinates _______________

VariableResponse (Use codes)

D1: Name of respondent
D2: Gender 1 = Male, 2 = Female
D3: Marital Status 1 = Single, 2 = Married, 3 = Separated, 4 = Divorced, 5 = Widowed
D4: Age 1 = < 18yrs; 2 = 18 to 40yrs; 3 = 41 to 60yrs; 4 = > 60yrs
D5: Level of Education 0 = None, 1 = Primary; 2 = Secondary, 3 = Tertiary, 4 = Adult literacy, 5 = Other, specify
D6: Main Occupation 1 = Farming, 2 = Wage labour, 3 = Formal employment, 4 = Small scale business, 5 = Others (specify)
D7: Name of farm/date of establishment
D8: Farming Status 1= Full time; 2= part time
D9: Production capacity/kg/annum 1= < 100kg/yr., 2=. <500kg/yr., 3= <1000kg/yr., 4= < 1500kg/yr., 5= > 1500kg/yr
D10: Species cultured 1= catfish; 2= Tilapia; 3= both; 4 = others (specify)
D11: Culture facilities used 1= Earthen ponds; 2= concrete tanks; 3= Plastic tanks; 4= fibre tanks; 5= concrete/plastics
D12: Type of feed used 1= local feeds; 2= foreign feeds; 3=Both
D13: Source of feeds 1= On-farm; 2= Commercial, 3= others (specify).
D14: If on-farm, what are the ingredients used?
D15: What is the source of each ingredient?
D16: Reason for choice of feed
D17: Which source is more profitable?
D:18 Selling price of fish/kg
D19: Feeding frequency 1= once a day; 2= twice daily; 3= Thrice daily
D20: Where do you sell your fish? 1= farm; 2= Market; 3= Others (specify)
D:21: If answer is 2 above, what is the distance to the market from your farm?
D22: To Whom do you sell your fish? 1= wholesaler; 2= retailers 3= both
D23: Sources of power 1= public electricity, 2=generator plant; 3= solar
D24: Duration of Business 1= less than 5 years, 2= 5-10 years, 3= above 10 years
D25: Constraints encountered

Peer-review history:
The peer review history for this paper can be accessed here:
https://pr.sdiarticle5.com/review-history/146006