EFFECT OF SOME MACHINE PARAMETERS ON FLOATABILITY AND WATER STABILITY OF FISH FEED PELLETS

Olaniran, J. A.[1], Adebayo, A. O.[2] and Afonja, A. B.[3]

1 & 2. Department of Agricultural Engineering, Ladoke Akintola University of Technology, Ogbomoso, Nigeria (1. jaolaniran@lautech.edu.ng ; 2. aoadebayo57@lautech.edu.ng)
3. Works and Physical Planning Department, Babcock University Ilisan Remo, Nigeria; benjaminafonja@gmail.com
Corresponding Author Email: jaolaniran@lautech.edu.ng

ABSTRACT
Fish feeds are mostly pelletized to enable solidification of the feeds. High percentage of the floating and good water stability have become great issues of fish feed produced from a locally developed fish-feed pelletizer. The current study focuses on the effect of barrel length (140, 280, and 420 mm) and die sizes (4, 5, and 6 mm) on the floatability and water stability of pellets produced from a locally developed pelletizer. Data were collected and analyzed by using a $3^2 \times 3$ factorial experiment in design expert (10.01 version) at $P \leq 0.5$. Results show that pellet floatability at the 140 mm barrel length and die size of 4, 5, and 6 mm ranged from 98.0% to 98.5%, while the corresponding values obtained at 280 mm barrel length ranged from 98.0% to 98.3%, and at the 420 mm barrel length with the same die size, the pellet floatability ranged from 98.0% to 98.5%. Also, water stability at 140 mm barrel length and die size of 4, 5, and 6 mm ranged from 85.0% to 85.3%, while the corresponding values obtained at 280 mm barrel length ranged from 84.9% to 85.2%, and at the 420 mm barrel length with the same die size, the pellet floatability ranged from 85.0% to 85.1%. There was a significant effect of barrel length and die size on the water stability of the pellets produced at $p \leq 0.05$. The developed fish-feed pelletizer gave a good pellet in terms of its floatability and water stability at the barrel length of 280mm and die size of 5mm, and can be used for local production of fish pellets.

KEYWORDS: Barrel Length, Die Size, Fish feed, Floatability, Pelletizer, and Water Stability.

1. INTRODUCTION

Pellets are solid feed, among numerous fish feeds available, with a wide range (3 – 9 mm) in diameter. It is produced from the combination of available feed stuffs such as fish meals, shrimps, wheat bran, corn, rice, bone meal, and oyster shell among others, to meet the nutrients need of the animals such as fishes, rabbits, turkey, ducks and other animals. As a result of this, the production and processing of pellet is being encouraged, so that the demand of the user will be met. In Nigeria, medium to large scale fish feed mill equipment fabricators are still few (Philips *et al*, 2009), and traditional processes are still being widely employed. There was a need for improved fish feed mill production technology to meet acceptable standard. According to Adedipe (2004) and Olomola (2007), in Nigerian economy, agriculture employs an estimate of 70% of the active labor force in which fish farming takes an important position, because fish is the cheapest source of animal protein consumed by the average Nigerian. Fish as a protein source contribute up to 50% of the total animal protein intake (Federal Department of Fishery, 2007).

The cost of fish feed is a major challenge militating against expanding fish farming in Nigeria, as it accounts for about 60-80% of input costs (Olomola, 2008). Large percentage of the floating fish feeds with good water stability marketed in Nigeria is mainly imported and the cost of imported feed is very high, making it unaffordable to the local farmers. Adesina (2012) affirmed that Nigeria spent N117.7 billion annually on the importation of fish feeds. Meanwhile, the local farmers tend to use the sinking pellets because of its affordability. But, the limitations of sinking pellets include pond pollution and selective consumption by the fish. The sinking pellets dissolve easily in water and this leads to pond water pollution and wastage of feed. According to Vijayagopal (2004), the factors that mostly influence the nature of the pelletized product are basically classified into two, which are the operating conditions of the machine (temperature, applied pressure, die aperture diameter) and the rheological properties (moisture content, and the physical state) of the food amongst others. Also, the materials and their chemical composition particularly the amount and type of starches, protein and fats, and others. Therefore there is a need to produce floating pellets for local farmers at affordable cost. To achieve this goal, the design and fabrication of a low cost pelletizing machine was applied and the performance evaluation based on barrel length and die size were conducted. Although there are fish feed pelleting machine which are developed in Nigeria, but a low cost pelletizer suitable for this study was developed to determine some appropriate machine parameters (barrel length and die pitch), as they influence the floatability and water stability of the pellet. The designed machine capacity was at least ½ ton (500 kg/day) of pellets.

2. MATERIALS AND METHODS

2.1 Description of the Developed Pelletizing Machine

The main frame supports the subsystems of the developed pelletizing machine. It was constructed from 1¼ angle bars and cut to specification. The upper part of the main frame was joined by welding and its legs were bolted type, plank was placed on the upper part of the frame to hold the pelletizing machine and the electric motor. The pelletizing machine was constructed and mounted in position through the slots on the main frame. The Isometric view and the exploded view of the machine with the component parts are shown in Figure 1 and 2 respectively. The hopper was cut from a 2 mm thick mild steel plate after marking out had been done with scribe and rule, using shear cutter and it was designed to be bolted to its main body. The body was cut from a 100 mm diameter and 6 mm thick mild steel pipe. Drive shaft was turned to dimension between centers on a lathe, pulley was made from a steel blank turned, drilled, bored and grooved mounted between centers on the lathe. Die discs were made from 7 mm thick plate and hole was made on it relatively to the diameter of the pellet to be produced. The pictorial view of the developed pelletizer is shown in Figure 3.

2.2 Feed Composition

The feed materials that was pelletized were purchased from Glory Vet feed mill company No 1 Olope Marun Care-taker area Ogbomoso. The proximate composition of feed and metabolized energy of the feed is given in the Table 1. The choice of feed is based on recommendation from local livestock farmers.

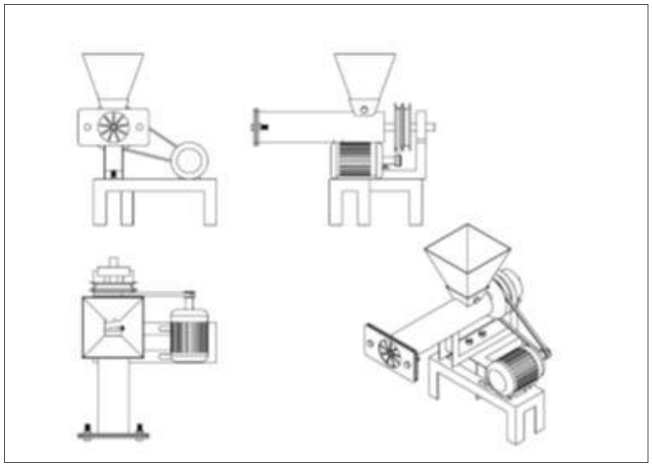
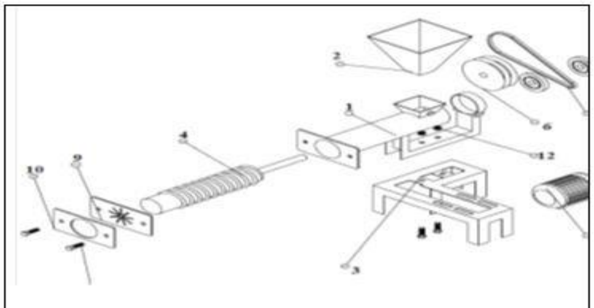


Figure 1: The Isometric view of the Pelleting Machine



ITEM NO.	PART NUMBER	DESCRIPTION	QTY
12	NUT	14 mm	8
11	BOLT	14 mm	4
10	FLANGE	WELDED	1
9	GASKET	WELDED	1
8	BELT	PURCHASED	1
7	MOTOR	PURCHASED	1
6	PULLEY	MACHINED	1
5	BEARING	PURCHASED	2
4	SHAFT	MACHINED	1
3	FRAME	WELDED	1
2	BODY	WELDED	1
1	BODY	WELDED	1

Figure 2: The Exploded view of the Pelleting Machine

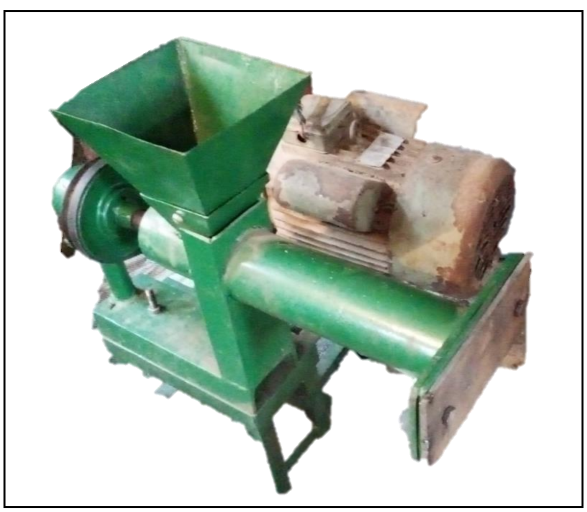


Figure 3: Pictorial view of the Fabricated Pelletizing Machine

Table 1: Fish Feed Composition

Ingredients	Mass Constituent (kg)
Soya meal	4.25
Fish meal	3.125
Carbohydrate (cassava)	4.15
Salt	0.0375
Lysine	0.0125
Methionine	0.00625
Vitamin C	0.00625

Source: (Oyewole, 2015)

2.3 Floatation Test

The floatability of the pellet was carried out by selecting 10 pellets randomly from the three barrel used to produce the pellets. These selected pellets were dropped in a 250 cm^3 glass beaker filled with water of about 150 cm^3. The total observation time was 30 min at an interval of 5 min. At the end of each observation time the number of pellets that were floating was recorded accordingly. The processes were replicated five times for each treatment and the mean number of the floating pellets was recorded and the percentage floating pellets was calculated with Equation 1 (Solomon *et al.*, 2011).

The percentage of the floating pellets is expressed as:

$$\text{Percentage floating pellets} = \frac{X_1}{X} \times 100 \qquad 1$$

where;

X_1 is the number of floating pellet

X is the initial number of pellet

2.4 Water Stability Test of Pellet

The water stability test was determined over a period of 50 min as described by Keri *et al.* (2013). Five (5) grams of pellet from each treatment were weighed in three places. The weighed 5 g of each sample were dropped into a nylon sieve size of 0.1 mm. This nylon sieve with the pellets was then immersed into the glass beaker of 250 cm^3 filled with water to a level of 150 cm^3. Three nylon sieves were used, and the immersion time ranged from 10 - 50 min with removal of each sample after every 10 min (Keri *et al*., 2013)

At the end of every test time, the nylon sieve was slowly removed from the beaker and allowed to drain for 3 min. The wet pellets were oven dried at 105 ^oC for 30 min. and further dried to a constant weight, and then cooled in a desiccator (Keri *et al*., 2013). The water stability was calculated using the Equation 2:

Percentage water stability = $\frac{Y_1}{Y}$ x 100 2

Where;

Y_1 is the weight of retained whole pellets

Y is the initial weight of sampled pellets

2.5 Experimental Design

A historical data of a standard surface response methodology was applied to study the effects of variance in the length of barrel (140, 280 and 420 mm), and die size (4, 5, 6 mm) on the floatability and water stability of the pellets produced from the developed pelletizing machine. The experiment was designed to be a 3^2 factorial thereby making it 9 runs of experiments as given in the experimental matrix (Table.2). Statistical analysis was carried out to determine the level of significance of the experiment at ($P \leq 0.05$) using design expert 10.0.1 software version.

3. RESULTS AND DISCUSSION

The results obtained in this study for the performance evaluation of the pelletizing machine, with respect to the effects of barrel length (140, 280 and 420 mm) and die size (4, 5 and 6 mm) respectively on floatability and water stability of fish pellets produced from the developed machine are as discussed.

3.1 Effect of Barrel Length and Die Size on Floatability of the Pellet

The results obtained are presented in Table 2. The results show that the difference in the floatability of the pellets varying both the barrel length and die size are not significant, they fall within the range of 98 to 98.5%. This implies that within 60 minutes of suspension, all pellets produced from the developed pelletizing machine float almost equally. Table 3 provides the statistical analysis of the floatability test of the pellets produced from the pelletizing machine developed. The ANOVA (Analysis of Variance) (Table 3) shows that there was not any significant difference along the factors considered and across the factors as well. The values of Prob>F less than 0.0500 indicated that model terms are significant. In this test there are no significant model terms. Values greater than 0.1000 indicated the model terms are not significant. The "Lack of Fit F-value" of 1.00 implies the Lack of Fit is not significant relative to the pure error. There is a 46.58% chance of Lack of Fit F-value.

Floatation of pellet from this research work was observed not to be influenced by the length of the barrel and die size. However, there was a marginal difference such that, as the die size increases the floatability reduces slightly. This is partly similar to the findings of Sunmonu *et al*, (2018) who reported that the statistical analysis of the performance indices with respect to the 3 mm and 5 mm dies sizes of designed fish feed pelletizer using a non-conventional feed sources showed that performance indices had significant differences on formulated feed having fermented citrus peel while not statistically significant for feed formulated with fermented plantain peel at $p < 0.05$. Floatability of pellets has been attributed to carbohydrate constituent element in the composition of the feed.

Table 2: Results of Floatability Test

Runs	Length of barrel (mm)	Die size (mm)	Floatability
1	140	4	0.982
2	280	4	0.982
3	420	4	0.983
4	140	5	0.982
5	280	5	0.981
6	420	5	0.982
7	140	6	0.981
8	280	6	0.981
9	420	6	0.982

The results obtained were in line with Adekunle et al. (2012) findings who reported that the development of farm-made floating feed for aquaculture species highly depend on the composition of the feed constituent. The authors deduced that no floatation of feed could be attributed to the molecular weight of the feed ingredient. High molecular weight with high relative density caused the feed to exhibit no or low buoyancy. Saalah et al., (2010) gave similar results on the effect of formula variation in the properties of fish feed pellets. They reported that as temperature increases, corn component give a significant effect on swelling, whereas swelling increases as corn component increases.

Table 3: Analysis of variance of Floatability Test

Source	Sum of Squares	Df	Mean Square	F Value	p-value Prob> F	
Model	0	0				
Residual	0.751463	26	0.028902			
Lack of Fit	0.231991	8	0.028999	1.004824	0.46583	not significant
Pure Error	0.519473	18	0.02886			
Cor Total	0.751463	26				

Std. Dev. = 0.17, Mean = 0.95, R-Squared = 0.0000, Adj R-Squared = 0.0000, C.V. % = 17.92, Pred R-Squared = -0.0784, PRESS = 0.81, Adeq Precision = Nil

However, swelling decreases as composition of tapioca flour and steering increases in the formulation. This clearly indicated the importance of pellet feed constituent on the floatability of pellets as stated by Nehu *et al*, (2005) that there are several factors which contribute to the production of high quality feeds in the extrusion process, and these include various feed parameters, aquaculture and extrusion processing parameters. However the barrel length and the die size of 140 mm against 5 mm will be suitable, for it give the best floatation despite not been significant. Figure 3 shows the effect of barrel length and die size on the floatability test carried out on the pellet produced from the developed pelletizing machine and it indicates that the relationship between the variables are parallel, which is a clear sign of insignificance of the variable factors on the floatability of the pellets.

3.2 Effect of Barrel Length and Die Size on Water Stability of the Pellet

The results obtained are presented in Table 4. The results show that the differences in the water stability of the pellets varying both the barrel length and die size are very closely related as they fall within the range of 84.9 to 85.3%. This implies that within 60 minutes of suspension, all pellets produced from the developed pelletizing machine were stable with little variance. Table 5 provides the statistical analysis of the water stability test of the pellets produced from the developed pelletizing machine. The water stability was found to be influenced by barrel length and die size, the most observed phenomenon was that of the thickness of the pellet in accordance to the size of the die, the die size has a significant effect on the stability of the pellet. This result agree with the conclusion of Okewole and Igbeka, (2016) who reported that the effect of operating parameters (moisture content of the compounded feed, die speed of the pelleting press, and the feed rate) was significant for pellet efficiency, pellet durability, throughput capacity and pellet bulk density on the performance of a pelleting press. Also, Kaddour *et al*, (2006) concluded that both the geometrical dimensions of die and rations' components are the most important parameters influencing the efficiency of extrusion machine and the quality of pellets. Islam *et al*, (2022) in the study of effect of some engineering parameters on the performance of a locally made fish feed extruder also observed that highest rate of the machine productivity occurred at the highest values of screw speed, feeding rate and die hole diameter.

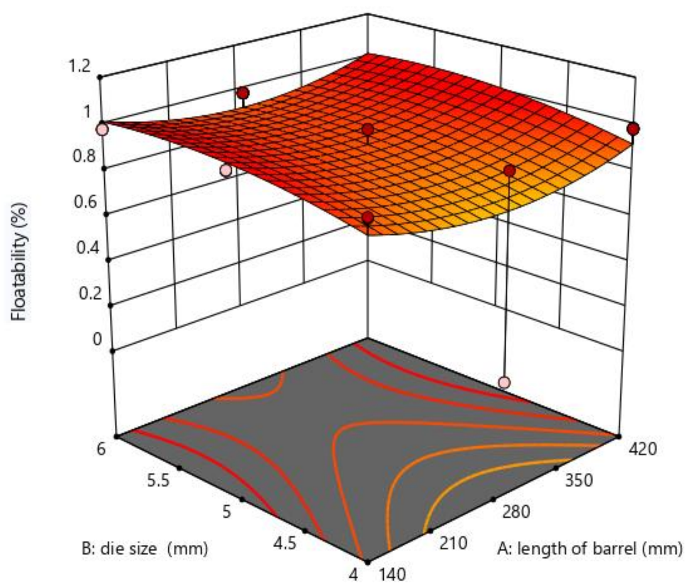


Figure 3: Effect of length of barrel and die size on the floatability

Increase in the die size brings about increase in the thickness of the pellet. Thereby increasing the stability of the pellets produced. According to Oyewole, (2015) who worked on effects of drying temperature and time on floating ability and water stability of fish pellets produced from different carbohydrate sources, reported that pellets water stability is also dependent on the constituent element of the feed. Hence, this study also shows that other factor that can influence the water stability of fish pellet is the thickness. Effiong *et al.*, (2009) worked on the comparative studies on the binding potential and water stability of duckweed meal, corn starch and cassava starch and reported a water stability as high as 82.81 % for fish feed formulated using cassava starch as binder. Table 5 is the analysis of variance which shows that there was significant different along the factors considered and across the factors as well. The model f-value of 4.27 implies the model is significant; there is only a 0.78% chance that an f-value this large could occur due to noise. Values of "prob> f" less than 0.0500 indicated model terms are significant. Therefore in this case A, B, AB and B^2 are significant model terms. Values greater than 0.1000 indicated the model terms are not significant, the "lack of fit f-value" of 14.39 implies the lack of fit is significant.

Table 4: Water Stability Test Results

Runs	**Length of barrel (mm)**	**Die size (inches)**	**Water stability (%)**
1	140	4	85.1
2	280	4	84.9
3	420	4	85
4	140	5	85.3
5	280	5	85.1
6	420	5	85.1
7	140	6	85
8	280	6	85.2
9	420	6	85.1

Table 5: Analysis of Variance for Water Stability Tests of the Fish Pellets

Source	**Sum of Squares**	**Df**	**Mean Square**	**F Value**	**p-value Prob> F**	
Model	0.138148	5	0.02763	4.268665	0.007785	Significant
A-length of barrel	0.027222	1	0.027222	4.205722	0.004297	
B-die size	0.027222	1	0.027222	4.205722	0.042974	
AB	0.03	1	0.03	4.634877	0.043107	
A^2	0.022407	1	0.022407	3.461853	0.076862	

Std. Dev. = 0.080, Mean = 85.09, C.V. % = 0.095, PRESS = 0.22, R-Squared =0.9041, Adj. R-Squared = 0.8060, Pred. R-Squared = 0.8097

Figure 4 shows the effect of barrel length and die size on the water stability of the produced fish pellets, the figure implies that the two independent parameters considered for this experiment have effect on the water stability of the pellets produced. At initial barrel length of 140 mm the water stability was declining, while it became stable at barrel length of 280 mm and die size of 5 mm. This indicates that, to have a water stable pellets it is appropriate to make the barrel size 280 mm and die size 5 mm. Table 6 shows the prediction of the best combination of the machine parameters considered to produce a water stable pellet with good floating ability and this combination was 280 mm of barrel length and 5 mm die size.

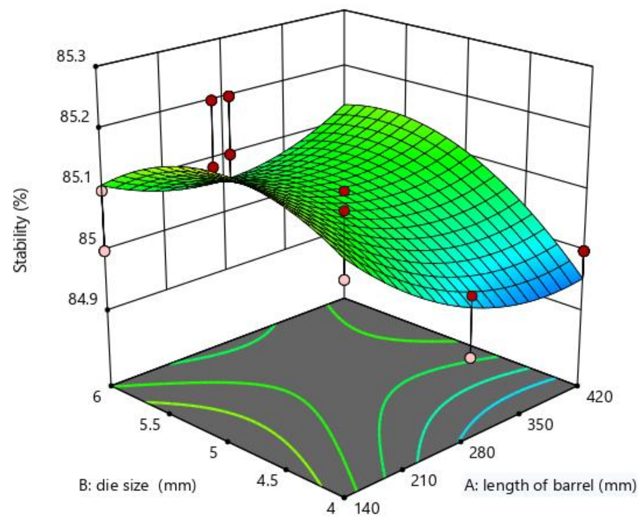


Figure 2: Effect of length of barrel and die size on the water stability

Table 6: Predicted value and Actual Value

Factor	Name	Level	Low Level	High Level	Std. Dev.	Coding	
A	Barrel length	140	140	420	0	Actual	
B	Die size	5	4	6	0	Actual	
Response	Prediction	SE Mean	95% CI low	95% CI high	SE Pred	95% PI low	95% PI high
Floatability	0.948	0.033	0.882	1.016	0.173	0.593	1.305
Water Stability	85.092	0.035	85.021	85.165	0.0876	84.910	85.274

4. CONCLUSION

From the performance evaluation of the low cost pelleting machine developed to study the influence of selected machine parameters, it was discovered that the barrel length and die size had no significant effect on the floatability of the pellets. However, barrel length of 140 mm and die size of 5 mm gave the best pellets floatability. Furthermore, two independent parameters tested (barrel length and die size) had significant effect on the water stability of pellets, with R-square value of 0.9041, and the barrel length and die size of 280 mm and 5 mm respectively gave a good water stability pellets. In overall, the developed low cost pelletizing machine was found suitable for the use of medium-size fish farmers. Also, for the production of good floatability and water-stable pellets, barrel length of 280 mm and 5 mm die size were found appropriate combination.

REFERENCES

Adekunle, H. L., Sadiku, S.O.E. and Orire, A. M. (2012). Development of farm made floating feeds for aquaculture Species. *International Journal of advanced biological reserach.2 (4), 579-583*

Adedipe, B. (2004). The impacts of oil on Nigeria's economic policy formulation. Paper Presented at the Conference on Nigeria: Maximizing Pro-poor Growth; Regenerating the Socio-economic Database. Organized by Overseas development Institute in Collaboration with the Nigerian Economic Summit Group, 16th-17th June, 2004.

Adesina, A. (2012). Federal ministry of agriculture and rural development Nigeria. Retrieved March 3, 2012, from http://wikipedia .org

Effiong, B. N., Sanni, A. and Sogbesan, O. A. (2009). Comparative Studies on the Binding Potential and Water Stability of Duckweed meal, Corn Starch and Cassava Starch. *New York Science Journal, 2(4), ISSN 1554-0200. http://www.sciencepub.net/newyork, sciencepub@gmail.com*

Federal Department of Fishery (FDF), (2007). Fisheries Statistics of Nigeria, Fourth Edition (1995-2007). Publication of the Federal Department of Fisheries.

Islam, F. E., Adel, H. B., Samir, A. A., and El-Sayed, G. K. (2022). Effect of Some Engineering Parameters on the Performance of a Locally Made Fish Feed Extruder. *MISR Journal of Agricultural Engineering 39(4):537–554. DOI: 10.21608/mjae.2022.165330.1085. https://mjae.journals.ekb.eg/.*

ISSN-Print: 1687-384x, ISSN-Online: 2636 - 3062

Kaddour, U. A. K., Awes, T. R., and Afify (2006). Influence of geometric dimension of extrusion die holes on machine efficiency and pellets quality. Conference of Mansoura University, *Journal of Agricultural Science. 31(7): 337 - 359*

Keri, A. I., Aziz, B. A. and Abol-Munafi, A. B. (2013). Water stability and nutrient leaching of different levels of maltose formulated fish pellets. Publication of the Faculty of Fisheries and Aqua-Industry, University of Malaysia Terengganu. 10(6): 638-642.

Nehu, C., Kurt, A. R. and Muthukmarappan, k. (2005). Utilization of distillers dried grains for fish feed by extrusion technology. A review ASAE Annual International Meeting Sponsored by ASAE. Tampa Convention Center, Tampa, Florida. 17 -20 July

Okewole, O. T. and Igbeka, J. C. (2016). Effect of some operating parameters on the performance of a pelleting press. *Agric. Eng. International: CIGR Journal 18(1): 326 - 338*

Olomola, A. (2008). Captured fisheries and aquaculture in Nigeria. A comparative economic analysis. In: *Africa rural Social Science Series* Report No13.

Olomola, A. S. (2007). Strategies for managing the opportunities and challenges of the current Agricultural commodity boom in SSCA. Seminar paper on Managing Commodity Boom in Sub-Saharan Africa. A publication of the AERC Policy Seminar IX. African Economic Research Consortium (AERC), Nairobi, Kenya.

Oyewole, O. A. (2015). Effects of drying temperature-time on floating ability and water

Stability of Fish pellets produced from different carbohydrate sources. Unpublished M.Tech Thesis at the Department of Agricultural Engineering Ladoke Akintola University of Technology Ogbomoso.

Phillip, D., Nkonya, E., Pender, J. and Omobowale. A. O. (2009). Constraints to increasing Agricultural Productivity in Nigeria: A Review. Nigeria Strategy Support Program (NSSP), Paper No. NSSP 006, September 2009. International Food Policy Research Institute (IFPRI). Email: ifpri-nigeria@cgiar.org , www.ifpri.org. Accessed May, 2022

Saalah, S., Shapawi, R. Othman, N. A. and Bono, A. (2010). Effect of Formula Variation in the Properties of Fish Feed Pellet. *Journal of Applied Sciences 10(21): 2537-2543*.

Solomon,S. G., Ataguba,G. A and Abeje, A. (2011).Water stability and floatation test of fish pellets using local starch sources and yeast. Department of Fisheries and Aquaculture, University of Agriculture, Makurdi, Benue State Nigeria.Vol1:1-5

Sunmonu, M. O., Odewole, M. and Falua, K. J. (2018). Design of a Varying Die-plate Fish Feed Pelletizer and Performance Evaluation using a Non-conventional Feed Sources. *KMUNTB International Journal of Applied Science and Technology 11(4). DOI: 10.14416/j.ijast.2018.10.001*

Vijayagopal, P. (2004). Aquatic Feed Extrusion Technology: An Update. *Fishing Chimes, 23(1): 10 – 11*.