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PERFORMANCE EVALUATION OF AN INNOVATIVE FISH FEED MILL MACHINE

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Abstract
The innovative fish feed pelleting machine used for the analysis consists of three distinct units; grinding, pelleting and drying. Three feed samples of the fish feed materials- X1, X2 and X3 weighing 250g each were prepared at different moisture contents of 7, 11, 13 and 15%. The samples were dried at a temperature of 102°C for 24hrs and weighed after cooling. Also, the samples were subjected under three machine speeds: 75, 95, 138 and 200 rpm and die diameter of 3, 4, 5 and 6 mm. The results showed that pelleting efficiencies of 94.0%, 93.2%, and 92.1% for the feed samples X1, X2 and X3 respectively were obtained at moisture contents of 7%, die hole of 3mm and speed of 75rpm. The result also revealed that the feed mixtures of X1, X2 and X3 processed at die hole diameter of 4mm, die speed of 95rpm and moisture content of 11% gave the lowest values of throughput of 36, 38, and 34 kg/h respectively for the machine. The feed mixture (X1) at die hole diameter of 4mm, die speed of 95rpm and moisture content of 11% gave the highest value of pelleting durability of 85.7% among the feed mixtures evaluated. Therefore, the performance of the innovative fish feed pelleting machine show that the machine would help in selecting the best machine variables for different feed mixtures

Keywords: Innovative, feed ration, die sizes, pellets, and drying

Introduction

Pelleting of feeds involves the extruding of individual ingredients or mixtures by compacting, forcing the materials through die holes by mechanical process. This process of feed production increases the efficiency of the utilization of the feed nutrients. The processing of finely ground and blended ingredients for animal feed into pellets enhances animal growth, handling, homogeneity, free flowing agglomerates and transportation (Steven, 1985; Arora, 2007; Koh 2007). Pellets are produced by grinding, conditioning and forcing the mixture through dies holes of ranges 2 to 10mm or more (Oduntan and Koya 2015). Pelleting in fine form influences the quality of feed processing operations, thus resulting to high production efficiency (Lahaye *et al.,* 2014: Greenwood and Beyer 2003). Information obtained from several research findings show that 35% of total input cost was spent on fish feed (Nwaokocha and Akinyemi 2008). Fish feeds are mostly produced by the utilization of agricultural wastes such as fermented shrimp head waste meal, maggot meal, poultry offal in the formulation of the least cost fish feed (Fasakin 2008; Nwanna 2003; Sogbesan 2014; Sotolu 2008). Cylindrical pellets from combined agricultural wastes was formed from pelleting machine using maize, groundnuts and millets yielding palatable pellets for animal feeds (Amadi 2007). In Nigeria, for agricultural mechanization to succeed, indigenous designs, relatively affordable, simple in operation and less energy free flowing agglomerates consuming must be encouraged (Lope *et al.,* 2010: Jekayinfa, 1995: Jekayinfa *et al.,* 2003: Odigboh 1999; Odigboh, 1997). In order to produce fish feed pellets that are durable, a holistic review of literature is vital. This is as a result of the limited number of industries involved in the manufacture of fish feed equipment. The durability of feed pellets can be described as the ability of the pellets to withstand destructive loads and frictional forces during handling and transportation. Hill and Pulkinen (1988) reported 20 to 50% of the product being damaged in the process of handling, transportation and distribution. Suni *et al.,* 2017 designed a pelleting machine which provided the advantage of producing different sizes of pellets using different die sizes. The demerits of the machine are the unstablity of voltage in the multi lever inverter. This suggests a modified switching scheme for balancing the capacitor voltage and improved performance of the machine (Ojomo *et al.,* 2010). Van Quyen and Nagy, 2016 designed a model for the pelletizing behavior of different raw materials based on piston press single pelletizer unit. The result of the machine testing showed that the amount of the raw material is less in the process and the parameters could be changed easily (Olusegun *et al.,* 2017). Burmamu *et al.,* 2015 designed a manually operated fish meal feed pelleting machine. The major components of the machine were hopper, bearing and the pelleting chamber. Olugboji *et al.,* 2015 designed, constructed, and tested poultry feed pelleting machine. The result showed that moisture content constituted a greater portion of variability in efficiency than the speed. For pellets within the range 3 mm to 6 mm, a periphery speed on the die of 10.16 mm/s is most appropriate. These variables mentioned in literature formed the basis for the performance evaluation of the developed fish feed mill machine in this study.

Materials and Methods

The materials used for the development of the integrated fish feed machine include; stainless steel angle iron, stainless steel plate, stainless steel flat bar, mild steel shaft, bolts and nuts, bearings, V-belts, speed reducer, electric motor, stainless steel pulleys, speed reducer, heater, fan, electric wire, vernier caliper, metal cutter, arc welding sets, grinder, sprockets, conveyor cloth, grinder plates, and oil paint. The innovative fish feed mill machine used for the evaluation is described in Figure 1.

Innovative Fish Feed Mill Machine

The integrated fish feed machine consists of three distinct units; the- grinding, pelleting drying units. It is powered by one electric motor of 3HP rating. The Grinding unit consists of the hopper which receives the raw materials, conveyor shaft, grinding teeth (which grinds the ingredients to the size and texture of choice), delivery pan, belts, pulleys and bearings (which assist the flow process in this unit). The pelleting unit consists of a big press screw and its housing, die plates, knife, pulleys and bearings (which assist the flow process in this unit). The drying unit consist of the conveyors clothes (which slowly carries the pellets throughout the heating period until exit), heater, fan, rolling shafts and idle support shafts, sprockets and bearings (which assist the flow process in this unit through to the final exit point of the dry fish feed pellet). The machined components were made of stainless steel (Figure 1).

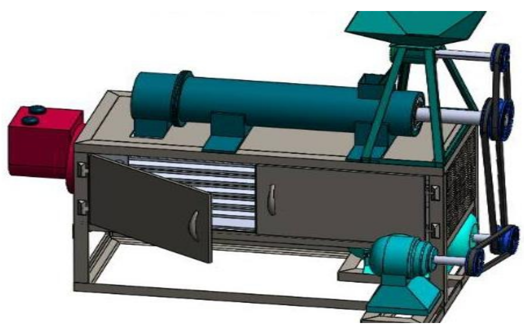


Figure1: Innovative fish feed pelleting machine

The frame acts as a support to other components. It is a rigid structure and designed to withstand dynamic stress. The bearing support was welded to the base of the frame. The barrel was also welded to the vertical part of the frame. The barrel is a cylinder with internal diameter of 80 mm and thickness of 5 mm. It has a length of 300 mm. A flange was welded to the end of the barrel to support the die plate. The hopper is a funnel shaped frustum cut out of a square pyramid. The height of the frustum is 150 mm and has a square top of length 200 mm. The pelleting die is required to restrict the flow of feed material and provide the cylindrical shape of the pellet. The die plate has a thickness of 5 mm. The effective diameter of the die plate is 80 mm. Thirty-six die inserts of 8 mm were drilled into the plate. The screw conveyor is a worm wound round a cylindrical shaft. The maximum outer diameter of the worm is 78 mm to give clearance between screw and barrel. The screw conveyor is carried on a solid shaft of 25 mm which is driven by a pulley.

Development of Models for the Performance Evaluation

Three samples of the feed weighing 250g each was prepared at a moisture content of 5, 7, 11, 13 and 15%. An electric oven was used to determine the moisture content of the feed mixture. The samples were placed in the drying oven at a temperature of 102°C for 24 hours and weighed after cooling. Equation 1 was used to determine the moisture content of the samples used in the evaluation.

$$M_C(W_b\%) = \frac{\text{weight of wet sample} - \text{weight of dry sample}}{\text{weight of wet sample}} \times \frac{100}{1} \ldots\ldots 1$$

The samples were tested at three machine speeds of 400rpm, 600rpm and 900rpm. The speed of the machine was varying the voltage source of the electric motor to give three different speed values for each replicate. The processes were repeated for additional five moisture contents of 7%, 9%, 11%, 13% and 15% and die diameters of 3, 4 and 6mm were used as presented in Table 1.

Table 1: Parameters used for the evaluation of the fish feed pelletizer

S/N	Variables	Levels
1	Feed moisture content (%)	7,11,13, 15
2	Machine speed (RPM)	75, 95, 138, 200
3	Die diameters (mm)	3, 4, 5, 6

The performance of the fish feed pelletizing machine was evaluated in terms of the following: (i) percentage of pelleted feed recovered at the die orifice (%)
(ii) Percentage of feed unpelleted (%)
(iii) Pelleting efficiency (%)
(iv)Throughput capacity (kg/h)

Percentage of Pelleted Feed Recovered at the Die Orifice

The fraction of the pelleted feed recovered at the die orifice was determined using equation 2 (Ojomo *et al.*, 2010).

$$P_R = \frac{W_P}{W_O} \times \frac{100\%}{1} \quad ....2$$

Percentage of Feed Unpelleted

The percentage of unpelleted feed was determined using equation 3 (Ojomo *et al.*, 2010).

$$\text{percentage unpelleted } (\%UP) = \frac{W_P - W_A}{W_O} \times \frac{100\%}{1} \quad ....3$$

Pelleting Efficiency of the Machine

The pelleting efficiency of the machine was calculated using equations 4 and 5 (Ojomo *et al.*, 2010).

$$\text{Total feed input } (T_F) = Q \times K.........4$$

$$\text{Pelleting efficiency}(\eta p) = \frac{W_A}{T_F} \times \frac{100\%}{1}......5$$

Pelleting Throughput of the Fish Feed Machine

The pelleting throughput of the machine was determined using equation 6.

$$P_T = \frac{\text{Quantity pelleted}}{\text{Total time for pelletization}} \left(\mathrm{kg}/\mathrm{h}\right) \quad ......6$$

Pelleting Durability of the Fish Feed

The pellet durability was determined using a durability tester (tumbling box) as specified by the American Society of Association Executives (ASAE standard, 1996). Equation 7 was used to determine the pelleting durability.

$$\text{Pelleting durability}(P_D\%) = \frac{W_{AT}}{W_{BT}} \times \frac{100}{1} \quad ......7$$

Where:

$M_c(W_B\%)$ is the moisture content of sample on wet basis, W_A is the actual weight of pelleted fish feed in kg, W_o is the original weight of feed in kg, W_P is the weight of pelleted fish feed in kg, T_F is the total feed input on(kg/h), Q_R is the feed rate (kg/h), P_T is the pelleting throughput in kg/h, P_R is the percentage of the pelleted feed recovered at the die orifice, K is the co-efficient of friction between barrel wall and feed material, W_{AT} is the weight of pellets mass after tumbling in kg, and W_{BT} is the weight of pellets mass before tumbling in kg.

Experimental Fish Feed Rations used in the Pelleting Machine

The fish feed ingredients were mixed and grounded. The mixtures were fed into the compression chamber through the hopper. The chamber comprises the power screw and compression plate. The power shaft is rotated through the crank arm. The continuous movement of the crank lever rotates the screw conveyor. This moves the compressed feed ingredients through the die and the discharge port.

Table 2: Experimental fish feed rations used in the pelleting machine

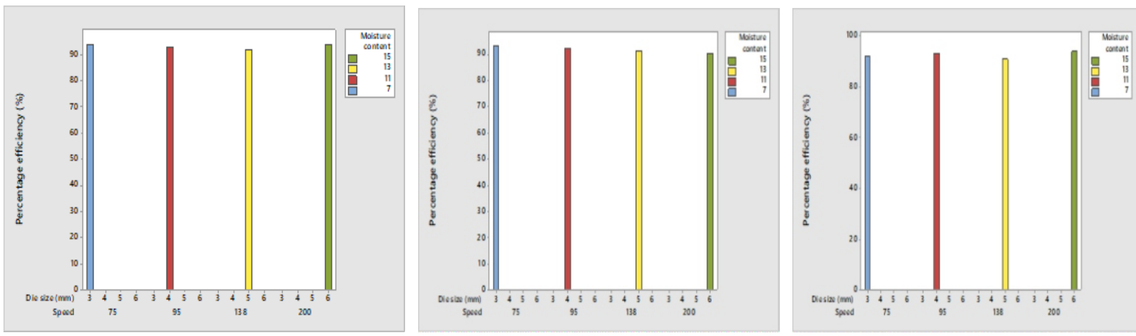
S/N	FEED INGREDIENTS	WEIGHT (g) (X1)	PERCENTAGE COMPOSITION BY WEIGHT (X1)	WEIGHT (g) (X2)	PERCENTAGE COMPOSITION BY WEIGHT (X2)	WEIGHT (G) (X3)	PERCENTAGE COMPOSITION BY WEIGHT (X3)
1	WHITE MAIZE	100	10.0	100	10.0	100	10.0
2	BLOOD MEAL	75	7.5	75	7.5	75	7.5
3	BONE MEAL	20	2.0	20	2.0	20	2.0
4	GROUNDNUT CAKE	110	11.0	90	9.0	120	12.0
5	FISH MEAL	115	11.5	115	11.5	180	18.0
6	PLANTAIN PEEL	160	16.0	200	20;0	120	12.0
7	SALT	60	6.0	60	6.0	60	6.0
8	SOYBEAN MEAL	90	9.0	90	9.0	70	7.0
9	POTATO STARCH	85	8.5	85	8.5	80	8.0
10	FAT AND OIL	95	9.5	95	9.5	90	9.0
11	VITAMIN PREMIX	90	9.0	70	7.0	85	8.5
	TOTAL	1000	100	1000	100	1000	100

Results and Discussion

The performance of the fish feed milling machine developed produced satisfactory pellets. The machine reduced drudgery in fish molding usually done manually.

Effects of die holes diameter, die speed and moisture content on the machine efficiency

The results in Figure 2 showed the effect of die holes on the pelleting machine efficiency at different moisture contents of feed mixture (X1, X2 and X3). The results showed that pelleting efficiency of 94.0%, 93.2% and 92.1% for fish feed mixtures X1, X2 and X3 respectively were obtained at moisture content of 7%, die hole of 3mm and speed of 75rpm. The results also, showed that pelleting efficiency of 93.0%, 92.4% and 93.2% for fish feed mixtures X1, X2 and X3 respectively were obtained at moisture content of 11%, die hole of 4mm and speed of 95rpm. The results further, showed that pelleting efficiency of 92.0%, 92.4% and 90.9% for fish feed mixtures X1, X2 and X3 respectively were obtained at moisture content of 13%, die hole of 5mm and speed of 138rpm. Finally, the result showed that pelleting efficiency of 94.1%, 90.5% and 94.3% for fish feed mixtures X1, X2 and X3 respectively were obtained at moisture content of 15%, die hole of 6mm and speed of 200rpm. The results showed that the appropriated variables mix should be used to obtain the best pelleting efficiency as illustrated in Figure 2.



(X1) (X2) (X3)

Figure 2: Effects of different moisture contents, die holes and speeds, on pelleting efficiency using different feed mixture (X1, X2 and X3)

Effects of die holes diameter, die speed and moisture content on the percentage recovery

The results in Figure 3 showed the effect of the different die holes diameter, die speed and moisture content on the percentage recovery of the different feed mixtures. The result showed that the product recovery at die hole diameter of 4mm, die speed of 95rpm was best at moisture content of

11%.

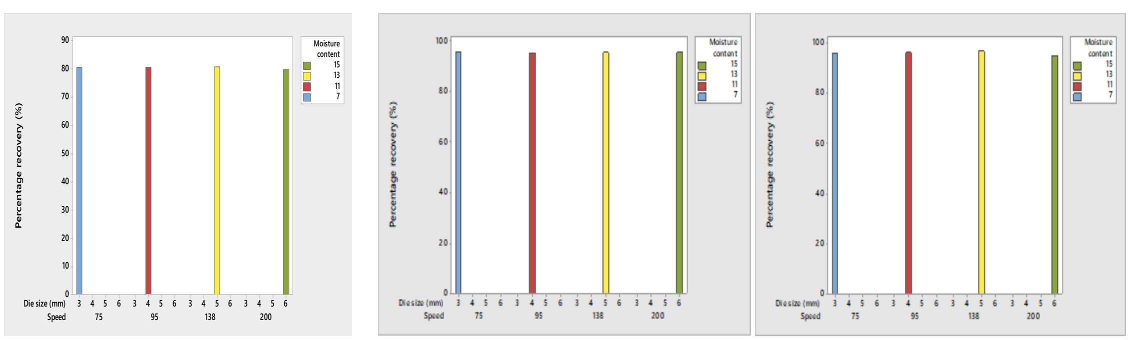
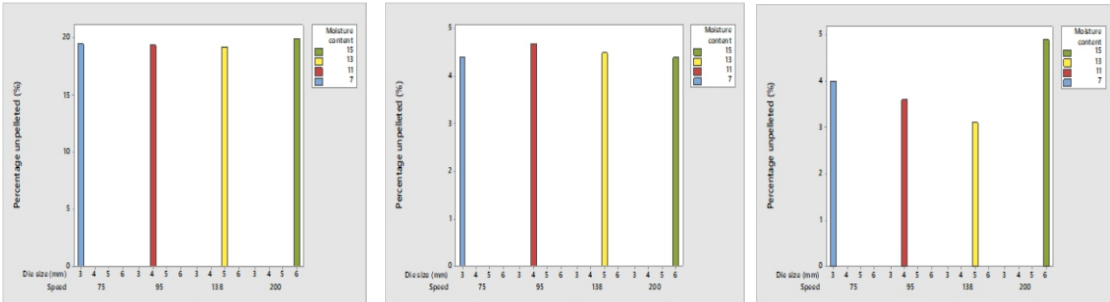


Figure 3: Effects of different moisture contents, die holes and speeds, on percentage recovery of pellets using different feed mixture (X1, X2 and X3)

Effects of die holes diameter, die speed and moisture content on the percentage unpelleted

The results in Figure 4 show the effect of die holes diameter, die speed and moisture content on the percentage unpelleted of the different feed mixtures. The result revealed that at a die hole size of 6mm, die speed (200rpm) and moisture content (15%) gave the highest value of the percentage unpelleted of 20% for feed mixture X1, while die hole diameter of 6mm, die speed of 200rpm and moisture content of 15% gave the lowest value of 4.4% for feed mixture X2. Similarly in X3 feed mixture, die hole diameter of 6mm, die speed of 200rpm and moisture content of 15% gave the highest value of 4.9%.

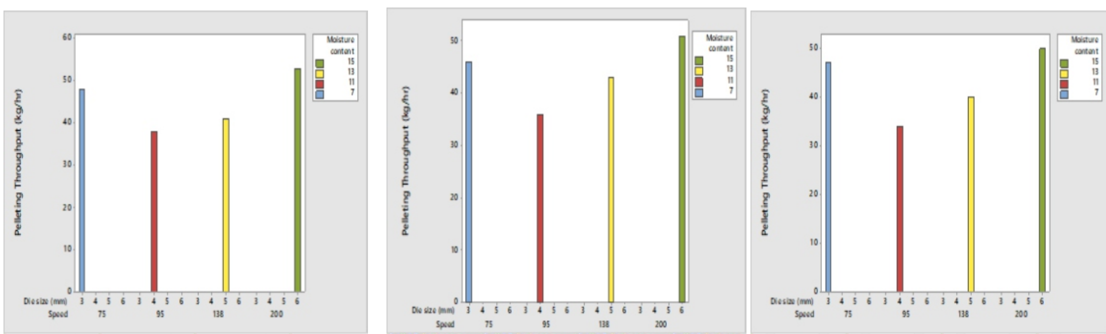


(X1) (X2) (X3)

Figure 4: Effects of different moisture contents, die holes and speeds, on the percentage unpelleted using different feed mixture (X1, X2 and X3)

Effects of die holes diameter, die speed and moisture content on the pelleting throughput

In Figure 5, the results showed that the feed mixtures of X1, X2 and X3 processed at die hole of diameter of 4mm, die speed of 95rpm and moisture content of 11% gave the lowest values of throughput of 36, 38 and 34kg/h respectively. The die hole diameter of 6mm, die speed of 200rpm and moisture content of 15% gave the best values of throughput for the three feed mixtures.

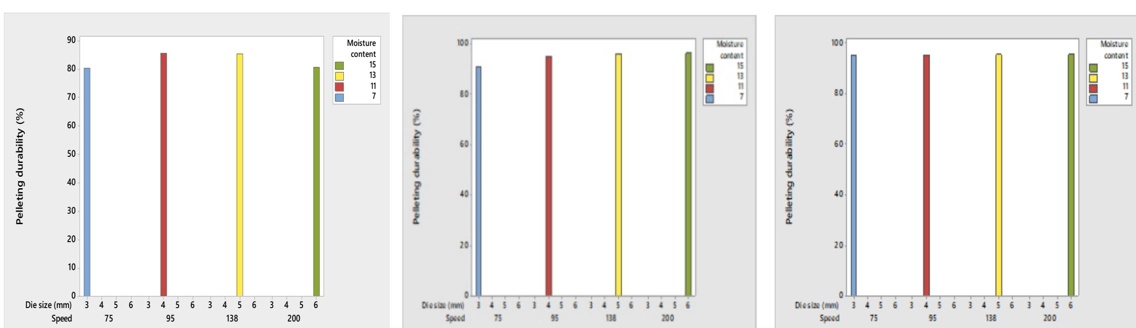


(X1) (X2) (X3)

Figure 5: Effects of die holes diameter, die speed and moisture content on the pelleting throughput

Effects of die holes diameter, die speed and moisture content on the pelleting durability

Results shown if Figure 6 revealed that, the feed mixture of X1 at die hole of diameter of 4mm, die speed of 95rpm and moisture content of 11% gave the highest value of pelleting durability of 85.7% among the variables used. Similarly, the die hole diameter of 6mm, die speed of 200rpm and moisture content of 15% gave the highest values of pelleting durability for X2 and X3 feed mixtures.



(X1) (X2) (X3)

Figure 6: Effects of die holes diameter, die speed and moisture content on the pelleting durability

Conclusion

The Innovative integrated fish feed pelleting machine was tested using three different fish feed rations. The feed rations were formulated with fish constituents such as white maize, blood meal, bone meal, groundnut cake, fish meal, plantain peel, salt, soybean meal, potato starch, fat and oil and vitamin premix. The concept of the fabrication of the innovative fish feed pelleting machine allows for ease of maintenance and usability with detachable dies for the production of different sizes of fish feed. The results obtained from the machine testing recorded high pelleting efficiency of 94.0%, 93.2% and 92.1% for feed samples of X1, X2 and X3 respectively on moisture content of 7%, die hole of 3mm and speed of 75rpm. Moreover, the machine had the highest percentage unpelleted feed of 20% for feed mixture X1. Also, die hole diameter of 6mm, die speed of 200rpm and moisture content of 15% gave the lowest value of 4.4% for feed mixture X2. The performance of the innovative fish feed pelleting machine showed that the machine would help in selecting the best machine variables for different feed mixtures.

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