Development and performance evaluation of screw-like fish meal pelletizer

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Abstract: In aquaculture farming, good and balanced meals are essential for the fish to stay healthy. These meals are better produced through the usage of fish meal pelletizing machines. This study is to contribute to the existing fish meal pelletizing models in Nigeria through the designing, fabrication and performance evaluation of a new machine. The average discharge efficiency, percentage loss due to residue ingredients and production rate for the machine after four runs for 5 kg fish meal ingredients was processed for 2.5 minutes was 92.25%, 7.75% and 110.7 kg hr^{-1}, respectively. It was discovered that as the drying days increase, the percentage moisture content removal increased for the two categories of pelletized fish meal weight (4.6 and 4.65 kg) considered while the weight of the pelletized fish meal reduced after drying. Linear regression models were derived for the two pelletized fish meal categories for easy estimation of percentage moisture content removed and weight of pelletized fish meal after drying. Through this machine, medium and small-scale aquaculture farmers will be greatly assisted locally, thereby boosting the economy of the nation and reducing importation of foreign feeds.

Keywords: development, fish meal, mechanical engineering, modeling, pelletize, aquaculture, moisture content

Citation: P. P. Ikubanni, A. O. Oluwole, and O. B. Ogunsemi. 2019. Development and performance evaluation of screw-like fish meal pelletizer. Agricultural Engineering International: CIGR Journal, 21(4): 169–176.

1 Introduction

Fish serves as a good source of protein which will help to maintain good health. Good health is very important to the people living in a country. In Nigeria, for good health to be achieved, it is necessary for aquaculture farmers to acquire improved methods that will help in increasing fish production output for the increasing populace. According to Olukunle (2000), the first recorded fish farm was found in Lagos and is as old as the independence of Nigeria. Just as human beings need balanced diet to grow healthily, fishes also need balanced diet in their meals for proper growth. Fish meals are meals that are considered to be among the best source of proteins. This is because there is an essential amino acid profile that seems to meet the requirements most teleost species. Fish meals are also good sources of essential fatty acids, minerals and vitamins (Jobling et al., 2001). For the meal to be balanced such ingredients as soya beans, lipids which are fat, groundnuts and carbohydrates and cereal, especially maize in their respective proportions are used in Nigeria are important to be included. Furthermore, the source of vitamins and mineral salts for fish could be obtained from blood meal, fish cramps, palm kernel cake and so on. These ingredients are needed to be pelletized for a degree of homogenization which could be achieved when moisture, heat and pressure are combined; thereby making pellets highly desirable for fish feeding (Ikubanni, 2009; Odesola et al., 2016; Olugboji et al., 2015; Ojediran et al., 2017).

A screw-type fish meal pelletizer that required no usage of steam to gelatinize the ingredients was developed by Olusegun and Adekunle (2009). Heat generated by the screwing action of the machine together with the chemical binder added to the ingredients caused the binding of the ingredients. In order to produce different sizes of pellets, the machine had a die at the end of the screw chamber which was interchangeable. Fish feed pelletizing machine designed and fabricated by

Received date: 2018-08-06 **Accepted date:** 2019-05-08

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Ojomo et al. (2010) consists of a hopper, barrel which houses the screw conveyor (auger), the cutting knife and the die orifice. Moisture contents and the speed of operation effects on the machine performance were investigated. In the performance evaluation carried out, the increase in moisture and machine speed caused increase in performance parameters of the machine. Odesola et al. (2016) designed and fabricated a fish feed extruder with improved qualities and affordable cost using locally sourced materials to aid the production of extruded feeds by local small-scale farmers. It was reported that there was a drastic improvement in the quality of locally processed pellets. The dual purpose (electrically or manually operated) fish pellet making machine designed and fabricated by Nwaokocha and Akinyemi (2008) was a low- cost machine for making pellets for the purpose of research and for small scale production. The machine used a worm screw to propel the ingredients through the die. Olusegun et al. (2017) designed and fabricated a 113.1 kg h^{-1} fish meal pellet processing machine in which the efficiency of the machine was obtained to be approximately 94.2%. The percentage loss due to unprocessed ground particulate materials, moisture content of the pellets after 7 days of open-air drying, were 5.8% and 26.5% (wet basis), respectively. The floatation test carried out indicated that the pellets could stay afloat for 9 days, while the un-dried pellets only remained afloat for 2 days. A revolving die and roller fish feed pellet machine was developed by Kaankuka and Osu (2013). It was observed that due to the higher heat generated during the production process which resulted in gelatinization of the carbohydrates in the ingredients, higher pellet output was obtained from a die speed of 761 rpm.

Although several researchers (Ojo et al., 2014; Olugboji et al., 2015) have worked on designing and fabrication this machine, it is necessary to develop using another conceptualized design of a fish meal pelletizer for improved production of feed meals. Therefore, this study has highlighted the design, fabrication and the performance evaluation of fish meal pelletizer. More so, the discharge efficiency, percentage loss due to residue ingredients, and production rate were evaluated. Likewise, the percentage moisture content removal was investigated after drying for some days. It is hoped that through the production of this machine for the rural farmers, there will be increase in the quantity of fish meal pellets, increase in fish production and invariably increase in income for the aquaculture farmers.

2 Materials and method

In this work, the design analysis of the fish meal pelletizer was done, material selection for each component designed were determined, the design calculations of the machine parts were done, operating description of the system was discussed and the engineering drawings were shown. Electric motor serves as the primary source of driving the machine.

2.1 Machine description and working principle

The fish meal pelletizer consists of the feed-in unit (hopper); the pelletizing chamber, which consists of a shaft with a screw-like attachment which conveys the meal to the extrusion unit of the machine. The rotation of the shaft with its attachment is caused by the rotation of a driven pulley which is connected to a driving pulley of an electric motor by means of a V-belt. When the machine was switched on, the shaft rotates the shaft, the mixed fish feed was fed into the hopper to its full capacity. The feed is conveyed by the screw-like attachment on the shaft from the point of entrance to the extrusion plate. The cutter at the end of the worm shaft cut the feed into sizes as it extrudes. This process continues until there is no more feed to be fed into the machine and after this, the machine is switched off. The produced screw-like fish meals are collected for dying for moisture content reduction.

2.2 Design consideration and material selection for production

In order to have efficient design, various design considerations were put into place. The hopper, the pelletizing chamber, shaft with screw-like attachment on it and frame were from stainless steel and mild steel. The material selected for the design and construction of the machine was majorly the mild steel. Durability, strength, suitability for pelletizing operation, availability and low cost were the criteria for selecting these materials.

2.3 Design analysis

2.3.1 Design analysis of hopper

The hopper with four slanting sides, form a shape of the frustum of pyramid. Equation (1) gives the appropriate volume for the frustum of a pyramid and is calculated as follows:

$$V = \frac{h}{3}[A_1 + A_2 + \sqrt{A_1 A_2}] \quad (1)$$

where, V is the volume of the hopper (m^3); h is the height of the hopper (m); A_1 is area of the trapezium (m^2) and A_2 is area of rectangle (m^2).

However, the area of trapezium can be calculated using Equation (2)

$$A_1 = \frac{1}{2}(a+b)h \quad (2)$$

where, a and b are the short and long sides of the trapezium (m), respectively and h is the height (m).

Also area of rectangle is given in Equation (3),

$$A_2 = L \times B \quad (3)$$

where, L and B are the length and breadth of the rectangle (m).

By substituting all the derived answers obtained from Equations (2) and (3) into Equation (1), the value of the volume for the hopper was 0.009349 m^3.

2.3.2 Design analysis of cylinder (pelletizing chamber)

In designing the cylinder, it was very important to consider the volume of the outer cylinder, inner cylinder and the screw-like (worm) attachment on the shaft. Equations (4)-(6) relate the volume of outer cylinder, volume of the worm and volume of the inner cylinder, respectively.

$$Volume\ of\ outer\ cylinder\ (V_o) = \pi R^2 h \quad (4)$$

$$Volume\ of\ worm\ (V_w) = \pi a^2 h \quad (5)$$

$$Volume\ of\ inner\ cylinder\ (V_i) = \pi r^2 h \quad (6)$$

where, R is the radius of the outer cylinder (m); a is the radius of the worm (m) and r is the radius of the inner cylinder (m).

The volume of the outer cylinder (V_o), the volume of the worm and the volume of the inner cylinder were obtained to be 0.00458 m^3, 0.0012 m^3 and 0.0029 m^3, respectively.

The estimated volume of the cylinder (V_c) can be deduced using Equation (7)

$$V_c = V_o - V_i - V_w$$

$$= (0.00458 - 0.00209 - 0.0012) = 0.00317 \text{ m}^3 \quad (7)$$

2.3.3 Design analysis for length of belt

In the design of the belt, velocity of the belt, the tension under which the belt is placed on the pulleys, the arc of contacts between the belt and the smaller pulley and the condition under which the belt is being used, should be considered (Jones, 2002).

Velocity Ratio of the Belt Drive

This is the ratio between the velocities of the driver and the driven pulleys. The Equation (8) was obtained for velocity ratio of belt drive from Gupta and Khurmi (2006).

Mathematically,

$$\pi d_1 N_1 = \pi d_2 N_2 \quad (8)$$

Therefore, $$\frac{d_1}{d_2} = \frac{N_2}{N_1} \quad (9)$$

where, N_1 is speed of the driver (rpm); N_2 is speed of driven (rpm); d_1 is diameter of driver (m) and d_2 is diameter of driven (m).

When thickness of the belt is considered, the velocity ratio is given by Equation (10).

$$V.R = \frac{N_2}{N_1} = \frac{(d_1 + t)}{(d_2 + t)} \quad (10)$$

The range of speed for the worm drives for extrusion is between 70 rpm and 300 rpm depending on the material texture and if the pulley of 1:5 is selected to have compact belt drive.

The length of the belt can be determined using Equation (11a) or Equation (11b) (Gupta and Khurmi, 2006).

$$L = \pi(R + r) + 2x + \frac{(R - r)^2}{x} \text{ in terms of pulley radius} \quad (11a)$$

or

$$L = \frac{\pi(D + d)}{2} + 2x + \frac{(D - d)^2}{4x} \text{ in terms of pulley diameter} \quad (11b)$$

where, L is total length of the belt (m); D is diameter of the larger pulley (m); d is diameter of the smaller pulley (m); x is distance between the centre of two pulleys (m); R is radius of the larger pulley (m) and r is radius of the smaller pulley.

Therefore, by computation, the length of a belt is 1.1763 m. This is approximately 1.2 m.

Design Analysis of V-Belt Driver

Using the Equation (12), the tight and slack tension can be determined

$$2.3\log\left(\frac{T_1}{T_2}\right)=\mu\theta\cos\text{ec}\beta \qquad (12)$$

where, T_1 is tension on tight side of the belt (N); T_2 is tension on slack side of the belt (N); μ is coefficient of friction and β is half of the groove angle.

The tension determinant formula was obtained using Equation (13)

$$T_1=T-T_c \qquad (13)$$

where, T is maximum belt tension and T_c is centrifugal belt tension

But $T=\delta a$ and $T_c=Mv^2$ (14)

where, δ is allowable stress in belt material, 2.5 MPa; a is cross-sectional area of the belt material.

$$a=L\times B-2\left(\frac{1}{2}BH\right) \qquad (15)$$

where, L is length (m); B is breadth (m) and H is Height (m).

Also $T_c=Mv^2$

where, M is mass per unit length of the belt material (kg m^{-1}); v is belt velocity (m s^{-1}).

$$v=\omega r=2\pi N_pR_p \qquad (16)$$

where, N_p is number of revolutions per minute and R_p is radius of the pulley (m).

To determine T_2, Equation (12) can be transformed into Equation (17). Equations (18) and (19) are also used in determining some values in which the obtained values are substituted into Equation (17),

$$T_2=\frac{T_1}{e^{\mu\theta}\sin\beta} \qquad (17)$$

To obtain θ, $\theta=180-2\alpha$ (18)

By computation, the tension on the tight and slack sides of the belt, respectively are 178.8 and 12.93 N.

From this, it can be deduced that the ratio of tight to the slack tension is dependent on the value of the wrap angle, that is,

$$\frac{T_1}{T_2}=\frac{178.8N}{12.98N}=13.83=14$$

2.4 Design Analysis of Power Transmitted Belt

Power transmitted by the belt was obtained using Equation (19)

$$P=(T_1-T_2)V \qquad (19)$$

where, P is power transmitted (W) and V is velocity of the belt (m s^{-1}). This is given by Equation (20)

$$V_1=\frac{\pi DN_1}{60}\text{ and }V_2=\frac{\pi DN_2}{60} \qquad (20)$$

where there is no slip, $V_1=V_2=V$

where, D is diameter of the driver (m); d is diameter of the driven (m); N_1 is speed of the driver (Motor speed) (rpm); N_2 is speed of the driven (Worm speed) (rpm).

By computation, the power transmitted by the belt was obtained to be 2.5 kW

2.5 Design of shaft

The shaft was designed based on maximum shear theory of failure (Gupta and Khurmi, 2006).

$$\tau_{\max}=\frac{16}{\pi D^3}\sqrt{(K_bM)2+(K_tT)^2} \qquad (21)$$

The diameter of the shaft in Equation (21), can be obtained using Equation (22),

$$d^3=\frac{16}{\pi\tau_{\max}}\sqrt{(K_bM)2+(K_tT)^2} \qquad (22)$$

where, d is shaft diameter (m);; $\tau_{\max}$ is maximum shear stress (N m^{-2}); M is maximum bending moment (N m^{-1}); T is maximum torsional moment (N m^{-1}); K_b is combined shock and fatique factor applied to bending moment (K_b= 1.5); K_t is combined shock and fatique factor applied to torsional moment (K_t = 1.5).

2.6 Shaft design for torsional rigidity

Equation (23) was utilized to determine the torsional rigidity of the shaft (Gupta and Khurmi, 2006).

$$\frac{\tau}{J}=\frac{G\theta}{L} \qquad (23)$$

But $J=\frac{\pi d^4}{32}$ for solid shaft (24)

Therefore $\theta=\frac{32\tau L}{\pi Gd^4}$ (25)

where, θ is Angle of twist (rad); d is shaft diameter (m); L is shaft length (m); τ is Torsional moment (N m^{-1}); G is torsional modulus of rigidity (N m^{-2}); J is polar moment of inertia (m).

From Equation (22),

$$d^3=\frac{16}{\pi\tau_{\max}}\sqrt{(K_bM)2+(K_tT)^2}$$

Torque with the value 104.22 Nm was be derived using Equation (26)

$$P=T\times\omega \qquad (26)$$

where, P is power (W); T is torque (N m) and ω is angular velocity (rad s^{-1}).

Therefore, the maximum torsional moment was obtained to be 52.18 MN m^{-2}.

2.7 Machine drawing and fabrication processes

Figure 1 shows the orthographic views of the machine while Figure 2 shows the isometric view of the machine. The fabrication processes of the machine are as described from section 2.7.1 through section 2.7.5.

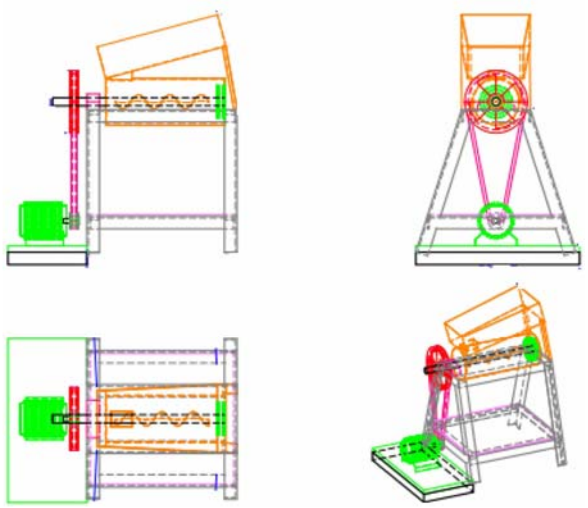

Figure 1 Orthographic view of the fish meal pelletizing machine

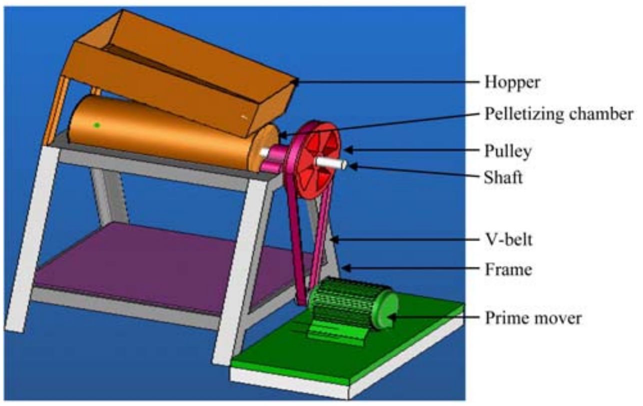

Figure 2 Isometric view of the fish meal pelletizing machine

2.7.1 Fabrication processes of the discharge plate

A 3 mm plate was cut and also an inner diameter was cut to diameters 220 mm and 97 mm and was turned to get a smooth surface. Also, a hole for the shaft head was created on the material using the Lathe machine. 6.5 mm diameter holes were drilled on the material for the extrusion of the feed and 5.5 mm diameter holes were drilled at four points to hold the thick material and the 3 mm plate using bolts and nut. The drilling machine was employed in carrying out this operation.

2.7.2 Fabrication processes of the hopper

Two metal plates 425 mm×120 mm were cut and a metal plate of 405 mm×120 mm was also marked and cut out of a metal sheet using the Guillotine shear. The three plates were joined together using the arc welding machine.

2.7.3 Fabrication processes of the shaft

A solid rod of 600 mm×28 mm was cut using the grinding machine with its cutting disc. For smooth surface and good finishing, facing operation was carried out on the rod and the desired diameter of 25 mm was obtained using the Lathe machine.

2.7.4 Fabrication processes of the cylinder and hopper

A metal pipe 650 mm×103 mm was marked and cut out using a Guillotine shear and the hopper was welded to the cylinder at one end of the cylinder.

2.7.5 Fabrication processes of the worm

Metal rods of 680 mm×10 mm were cut, heated and twisted to form the worm round the shaft. These worms are welded to the shaft. The depth of the worm to the shaft was 42 mm.

2.8 Machine testing and performance evaluation

For the machine to be tested, fish meal ingredients as stated by Olusegun et al. (2017) were properly mixed. The total weight of the mixed ingredients was 5 kg which was obtained using a weighing scale. Fish meal ingredients mixture was fed into the machine via the hopper. A container was placed to collect the fish meal pellets compacted through the discharging die. The testing process was repeated in quadruplets in which the averages of the needed terms were obtained.

The discharged pellets were weighed with a weighing balance so as to determine the discharge rate (efficiency of the machine) and the percentage loss due to non-pelletized ingredients. The percentage moisture content removed after drying between 1 and 7 days were also determined by measuring the weight of the pelletized fish meal before and after drying for 7 days. Equations (27)-(29) were used to obtain the discharge rate (efficiency), percentage loss due to non-pelletized ingredients and the percentage moisture content loss after drying.

$$Discharge\ Rate\ (Efficiency) = \frac{Pelletized\ meal\ weight}{Weight\ of\ Ingredient} \tag{27}$$

$$\%\ loss\ due\ to\ non-pelletized\ ingredients = \frac{Residue\ Ingredient\ weight}{Weight\ of\ Ingredient} \tag{28}$$

$$\%\ moisture\ content\ removal = \frac{Wt.\ of\ pellet\ fish\ meal - Wt.\ of\ pellets\ after\ drying}{Wt.\ of\ pellet\ fish\ meal} \quad (29)$$

3 Results and discussion

3.1 Performance evaluation of the pelletizing machine

The production rate, discharge efficiency and the non-pelletized percentage loss are as shown in Table 1. The average value was obtained for the weight of the ingredients, discharge time, weight of the pelletized meal, weight of the residue ingredients, production rate, efficiency and the percentage loss due to non-pelletized ingredients were 5 kg, 2.5 min, 4.61 kg, 0.39 kg, 110.7 kg hr^{-1}, 92.25% and 7.75%, respectively. This implied that when 5 kg of the prepared fish meal ingredients is processed for 2.5 minutes, the production rate is 110.7 kg hr^{-1}, the efficiency of the machine is 92.25% and the percentage residue loss is 7.75%. When the efficiency of this work was compared with that of Ojomo et al. (2010), it was discovered that the efficiency of this machine was 4.6% higher. However, the efficiency obtained for this work was 1.95% lower to that of Olusegun et al. (2017). This might be due to the number of minutes allowed for 5 kg prepared fish meal ingredients to be processed. If further time is allowed, the efficiency will increase slightly.

Table 1 Production rate, discharge rate (efficiency), percentage loss due to non-pelletized ingredients

No. of runs	Wi (kg)	Dt (min)	Wpf (kg)	Wri (kg)	Pr (kg h^{-1})	Dr (%)	Plp (%)
1	5	2.5	4.6	0.4	110.4	92	8
2	5	2.5	4.62	0.38	110.88	92.4	7.6
3	5	2.5	4.58	0.42	109.92	91.6	8.4
4	5	2.5	4.65	0.35	111.6	93	7
Average	5	2.5	4.61	0.39	110.7	92.25	7.75

Note: * Wi - Weight of Ingredients; Dt - Discharge Time; Wpf - Weight of Pelletized feed; Wri -Weight of residue ingredients; Pr-Production rate; Dr - Discharge rate (efficiency); Plp - loss due to non-pelletized ingredients (%).

3.2 Relationship between percentage moisture content removal (percentage dryness value) and drying days

Pellets are necessary to be stored. For easy storage, pelletized meals are required to be dried so as to have longer shelf life and to be able to float on water for longer time. The pelletized meal produced was dried for 7 days. The percentage moisture content removal can be termed the percentage dryness of the pelletized fish meal. Tables 2 and 3 show the percentage moisture removal at 4.6 and 4.65 kg pelletized meal weight. It was observed for Tables 2 and 3 that as the drying day increases, the weight of the pelletized meal decreases whereas the percentage moisture content removal increases with respect to the initial weight of the pelletized meal before drying. Invariably, this showed that the moisture content loss reduced as the day or time increased with respect to the previous day. This is in agreement with the studies of Siddique and Wright (2003) on the effects of different drying time and temperature on moisture percentage of Pea seeds and Modibbo et al. (2014) on the effect of moisture content on drying rate. This is further shown in Figures 3 and 4. On the sixth and last day of this experiment, it was observed that the percentage moisture removal remains constant. This might be due to an appreciable removal of the moist in the feed which implied that it is good and ready for packaging and storage. The percentage moisture content removal at 4.6 and 4.65 kg pelletized meal weights on the last day was 18.0% and 18.1%, respectively.

Table 2 Percentage moisture content removal at 4.6 kg pelletized meal weight

Drying day	WPM (kg)	WPMD (kg)	PMCR (%)
1	4.6	3.85	16.3
2	4.6	3.82	17.0
3	4.6	3.80	17.4
4	4.6	3.79	17.6
5	4.6	3.78	17.8
6	4.6	3.77	18.0
7	4.6	3.77	18.0

Note: * WPM - Weight of pelletized meal; WPMD - Weight of Pelletized meal after drying; PMCR - Percentage moisture content removal

Table 3 Percentage moisture content removal at 4.65 kg pelletized meal weight

Drying days	WPM (kg)	WPMD (kg)	PMCR (%)
1	4.65	3.90	16.1
2	4.65	3.87	16.8
3	4.65	3.85	17.2
4	4.65	3.83	17.6
5	4.65	3.82	17.8
6	4.65	3.81	18.1
7	4.65	3.81	18.1

Note: * WPM - Weight of pelletized meal; WPMD - Weight of Pelletized meal after drying; PMCR - Percentage moisture content removal.

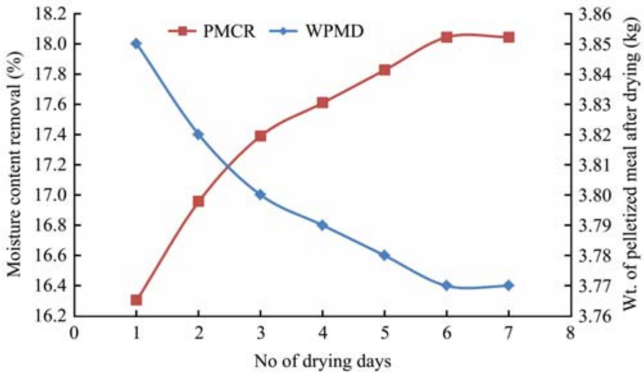

Figure 3 Weight of pelletized meal after drying and percentage moisture content removal against number of drying days at 4.6 kg

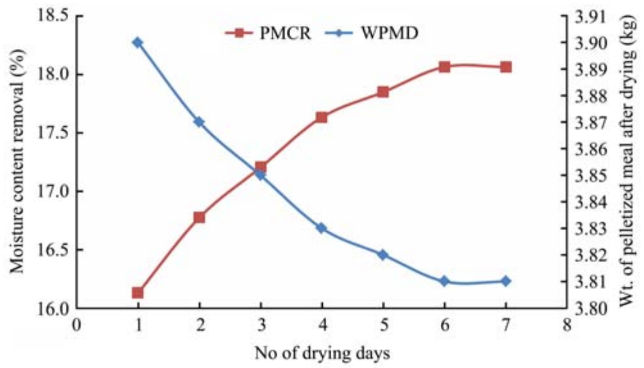

Figure 4 Weight of pelletized meal after drying and percentage moisture content removal against number of drying days at 4.65 kg

From Figures 3 and 4, as the number of drying days increased, the amount of moisture being removed from the pellets increased while the weight of the pelletized meal reduced per day. It could be deduced that percentage moisture removal was inversely proportional to the weight of the pellets after each drying day. This is better for the pellets because the presence of moisture could cause easy spoilage of the pellets and could hamper storage for a long time.

The linear regression models were developed in which R^2 of the linear regression models is 0.9. These could be used to determine the estimated weight of pelletized meal after drying and the percentage moisture content removal that is the percentage dryness value, respectively, at any particular day. The models are given in Equations (30) and (31), respectively.

$$W_{PMD}=-0.0129D_D+3.8486 \quad (30)$$

$$\%_{MCR}=0.2795D_D+16.335 \quad (31)$$

where, W_{PMD}, D_D and $\%_{MCR}$ are weight of pelletized meal after drying, drying days and percentage moisture content removal, respectively.

The linear regression models were developed in which the R^2 of the linear regression models is 0.9149 and could be used to determine the estimated weight of pelletized meal after drying and the percentage moisture content removal which is the percentage dryness value with respect the initial weight of the pelletized meal, respectively, at any particular day. The models are given in Equations (32) and (33), respectively.

$$W_{PMD}=-0.015D_D+3.9014 \quad (32)$$

$$\%_{MCR}=0.3226D_D+16.098 \quad (33)$$

where, W_{PMD}, D_D and $\%_{MCR}$ are weight of pelletized meal after drying, drying days and percentage moisture content removal, respectively.

Figure 5 showed the comparison of the percentage moisture content removed at 4.6 and 4.65 kg pelletized meal weight as the number of drying days increased. As earlier stated, the moisture content reduction increased as the drying days increased with respect to the initial weight of the pelletized meal. The percentage moisture content removal at after certain days converged for the two weights (4.6 and 4.65 kg) under consideration. This could mean that the presence of the moisture introduced during the mixing of the ingredients has been reduced to the lowest. Therefore, it can be established that as number of drying days increase in drying pelletized fish meal, the percentage moisture content removed increases until a certain stage when there will no longer be significant removal of moisture from the pellets. At this stage, it therefore means that the produced and dried pellets ready for storage for future usage.

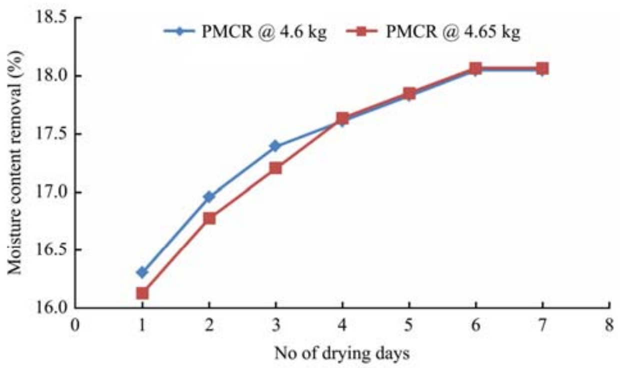

Figure 5 Comparison of the percentage moisture content removed at 4.6 and 4.65 kg pelletized meal weight

The comparison of the weight of pelletized meal after drying at 4.6 and 4.65 kg pelletized meal weight alongside with the drying days showed the same pattern as indicated in Figure 6. Both revealed that as the drying days increased, there was a reduction in the weight of the pelletized meal. The reduction in weight was an indication that the pellets when stored will be more preserved than when it is not dried.

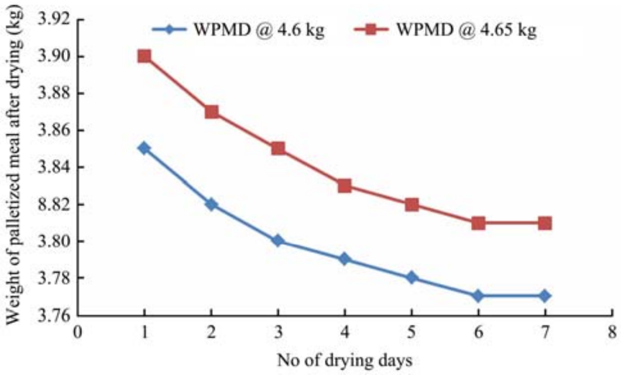

Figure 6 Comparison of the weight of pelletized meal after drying at 4.6 kg and 4.65 kg pelletized meal weight

4 Conclusion

The screw-like fish meal pelletizer was designed, fabricated and appraised. The average production rate of the machine was 110.7 kg hr^{-1} at an average discharge efficiency of 92.25%. The increase of the discharge time led to an increase in the discharge efficiency of the machine thereby reducing weight of residue ingredients. Moisture content reduction percentage increases as the drying days increase whereas the weight of the pellets reduces as the drying days increase. The linear regression models developed in the study could be used to estimate the moisture content reduction percentage and the weight of pellets at any particular day. The machine is easy to operate, efficient and affordable. Therefore, the developed machine would go a long way in helping small and medium scale fish farmers to process their own feeds. This will alleviate the challenges associated with importing fish meals.

References

Gupta, J. K., and R. S. Khurmi. 2006. *Machine Design*. 14th ed. India: Rajendra Ravindra Printers (Pvt) Ltd.

Ikubanni, P. P. 2009. Modification, construction and testing of a worm-type pelletizer. B. Eng. Project. Department of Mechanical Engineering, University of Ilorin.

Jobling, M., E. Gomes, and J. Dias. 2001. *Food Intake in Fish: Feed Types, Manufacture and Ingredients*. Oxford: Blackwell Science Ltd.

Jones, M. G. 2002. *Mechanics of Materials*. 2th ed., pp.1–43 Nelson Thornes, Cheltenham, United Kingdom.

Kaankuka, T. K., and D. T. Osu. 2013. Development of a revolving die and roller fish feed pelletizer. *International Journal of Engineering Innovations and Research*, 2(1): 105–110.

Modibbo, U. U., S. A. Osemeahon, M. H. Shagal, and M. Halilu. 2014. Effect of moisture content on the drying rate using traditional open sun and shade drying of fish from Njuwa Lake in North-Eastern Nigeria. *IOSR Journal of Applied Chemistry*, 7(1): 41–45.

Nwaokocha, C. N., and O. O. Akinyemi. 2008. Development of a dual-mode laboratory sized pelletizing machine. *Leonardo Journal of Sciences*, 7(13): 22–29.

Odesola, I. F., R. A. Kazeem, and N. C. Ehumad. 2016. Design and construction of a feed extruder. *International Journal of Scientific & Engineering Research*, 7(8): 1378–1386.

Ojediran, J. O., J. T. Fasinmirin, and O. P. Owa. 2017. Development and performance evaluation of an indigenous fish feed palletizing machine. *Journal of Engineering and Engineering Technology*, 11(2): 139–148.

Ojo, S. T., O. J. Olukunle, T. O. Aduewa, and A. G. Ukwenya. 2014. Performance evaluation of floating fish feed extruder. *IOSR Journal of Agriculture and Veterinary Science*, 7(12): 103–113.

Ojomo, A. O., L. A. S. Agbetoye, and F. O. Ologunagba. 2010. Performance evaluation of a fish feed pelletizing machine. *ARPN Journal of Engineering and Applied Sciences*, 5(9): 88–97.

Olugboji, O. A., M. S. Abolarin, M. O. Owolewa, and K. C. Ajani. 2015. Design, construction and testing of a poultry feed pellet machine. *International Journal of Engineering Trends and Technology*, 22(4): 168–172.

Olukunle, O. 2000. Homestead fish ponds management. Ibadan: Archers Publishers.

Olusegun, H. D., and A. S. Adekunle. 2009. Design, construction and testing of a wormlike pellet fish meal processing machine. *International Journal of Engineering*, 3(1): 31–44.

Olusegun, H. D., A. S. Adekunle, I. O. Ohijeagbon, K. A. Akande, and B. G. Mohammad. 2017. Design, fabrication and evaluation of fish meal pelletizing machine. *Journal of Science and Technology*, 37(1): 51–63.

Siddique, A. B., and D. Wright. 2003. Effect of different drying time and temperature on moisture percentage and seed quality (viability and vigour) of pea seeds (*Pisum sativum L.*). *Asian Journal of Plant Sciences*, 2(13): 978–982.