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Development and Performance Evaluation of a Fish Feed Processing Machine

*[1]Dauda, S. M., [1]Balami, A. A., [1]Aliyu, M., [1]Mohammed, I. S., [1]Francis A. A., [1]Kadiri M., [1]Egbunu G. O. & [2]Ahmad D.
[1]Agricultural and Bioresources Engineering Department, Federal University of Technology, PMB 65 Minna Niger State, Nigeria
[2]Department of Biological and Agricultural Engineering, Universiti Putra Malaysia 43400 Serdang, Selangor Darul Ehsan, Malaysia
*Corresponding author email: smdauda@futminna.edu.ng, +2348038964659

ABSTRACT
Pelleting machine is used for converting materials and food items such as maize, groundnuts and millets with other additives in good ratios to fish feed. In this research, pelleting machine for fish feed was developed by incorporating milling, mixing and pelletizing operations together in order to reduce drudgery and improve timeliness in fish feed production. Design considerations, Power requirement and component parts design were done according to available relevant literatures. The pelleting efficiency of the machine, throughput capacity, percentage of mechanical losses and the specific energy consumption obtained were 85.4 %, 11.25 kg/hr, 14.6 % and 0.39 kWhkg^{-1} respectively.

Keywords: *Development, Fish Feed, Machine, Pelleting, Performance Evaluation.*

1 INTRODUCTION

Pelleting machine is one of the outstanding developments in fish farming. It is one of the most important techniques in processing pellets for production of healthy wholesome animal feed. Production of animal feed through processing of raw food items depend upon proper use of existing traditional methods and modern development derived from the spectrum of research. Pelleting machine is one that is used to create cylindrical pellets from a mixture of dry powdered stocks, such as molasses or as a machine used for converting materials and food items such as maize, groundnuts and millets with other additives in good ratios to fish feed. (Burmamu et al., 2015).

Pellets are produced through the process called extrusion. Pelletizing machine comprises of some basic component like the hopper through which the feed meal is feed into the machine, to the pelleting chamber which consists of the worm, auger or screw (shaft) which propel the feeds. The shaft is controlled manually by the handle which could also be motorized. The output pellet is formed by compacting and forcing through a die opening (with suitable diameter die hole) by a mechanical process (Nwaokocha and Akinyemi, 2008).

To minimize cost of production and enhance profitability of fish farming, it is imperative to domestically formulate and process the feed in an acceptable, economically cheap and valuable form (in pellets) from some Agricultural by- products which are readily available and cheaper than buying already processed feed from the market. Pelleted feed are shaped or compressed masses of homogenously mixed feeding substances made to withstand rigorous handling and transportation. They can be small hard ball, tablets or strings formed by compaction and moulding of mixed diets through an open die as a mechanical compressor. Pelleted fish feed can be wet or semi dried at production. Semi dried feed pellets are the newness form of fish feed Technology that requires special technical approach in feed production to obtain a targeted product of 20%-25% moisture content. Local production of fish feed in Nigeria has been an issue of concern to farmers as most feed millers prefer producing poultry feed in large quantities rather than both at equal ratio, though fish feed preparation method/ technique is not wide apart from that of poultry feed but machines required in these processes exist as separate entities hence, making fish feed production tedious and time consuming (Okadinya et al., 2013). Therefore, there is need to improve on fish feed processing technique through construction of an on farm machine that will incorporate unit operations in one viable machine which will encourage fish feed production domestically. However, there is a limitation to the use of the livestock feed pelleting machine due to the high cost of the equipment for pellets processing (Orisaleye et al., 2009). Hence, the local livestock farmer, particularly in Nigeria cannot afford to utilize the sophisticated livestock feed pelleting machine.

Therefore, the aim of this research is to develop an adaptive low-cost machine that can produce semi-dried feed pellets for small scale fish industries by incorporating grinding, mixing and pelleting units into a single pass process and to evaluate the performance of the machine.

2 MATERIALS AND METHOD

2.1 MATERIALS

The materials used for the design of the machine include mild steel sheets, angled iron, pulleys, v-belt, screw conveyor, die plate, electric motor, bearings, bolts and nuts.

2.2 DESIGN CONSIDERATIONS

Operational condition factors (such as Temperature and pressure) influencing the pelleting process and the rheological properties of the feed ingredient were also considered to ensure efficiency of the machine. The materials used for the construction of the machine were selected based on their availability, cost, suitability and viability in service among other considerations. These materials were sourced locally.

2.3 DESIGN CALCULATIONS

2.3.1 Volume of the hopper

The volume of the hopper was calculated using the standard formula in equation 1.

$$V = \frac{1}{3}\pi r^2 h \quad (1)$$

Where,

r = radius of the hopper (m)
h = height of the hopper (m)
π = Constant (3.142)

2.3.2 Determination of the Torque Transmitted By the Electric Motor

The torque transmitted was calculated using equation 2.

$$T_t = \frac{P}{\omega} \quad (2)$$

Where,
P = power transmitted (Watts)
ω = Angular speed of the motor (rads/sec)
But,

$$\omega = \frac{2\pi N}{60}$$

Where,
N = speed of the motor (rpm)
π = constant

2.3.3 Determination of the Belt Tension

The tension on the belt was calculated using equation 3 below (Khurmi and Gupta, 2006).

$$T_t = (T_1 - T_2)R \quad (3)$$

$$\frac{T_1}{T_2} = e^{u\ coseeβ}$$

Where,
T_t = Torque transmitted (Nm)
R = Radius of the driven pulley
T_1 = Tight side tension of the belt (N)
T_2 = slack side tension of the belt (N)
μ = Co-efficient of friction
Θ = Angle of wrap or contact
2β = Groove angle of the pulley

$$\Theta = \frac{(180-2\alpha)}{180}\pi$$

$$\text{Sin } \alpha = \frac{r_1 r_2}{180}$$

r_1 = radius of the driven pulley (m)
r_2 = radius of the driving pulley (m)

2.3.4 Determination of the Length of the Belt

The length of the belt was determined using equation 4

$$L = \frac{\pi}{2}(D_1 - D_2) + 2x + \frac{(D_1 D_2)^2}{4x} \quad (4)$$

D_1 = Diameter of driving pulley (m)
D_2 = Diameter of driving pulley (m)
x = distance between the pulleys (m)

2.3.5 Determination of the Shaft Diameter

The shaft diameter was determined using equation 5 (Khurmi and Gupta, 2006)

$$d = \left(\frac{16}{\pi S_a}\sqrt{(K_b M_b)^2 + (K_t M_t)^2}\right)^{1/3} \quad (5)$$

Where,
d = diameter of shaft (m)
M_b = bending moment (N m)
M_b = tortional moment (N m)
K_b = combined shock and fatique factor applied to bending moment
K_t = combined shock and fatique factor applied to tortional moment
S_a = allowable stress (N/m^2)

2.3.5 Operational Speed of the Conveyor

The operational speed of the conveyor was determined as reported by Agada (2010).

$$N_1 D_1 = N_2 D_2 \quad (6)$$

Where,
N_1 = Speed of the divining pulley (rpm)
N_2 = Speed of the driven pulley (rpm)
D_1 = Diameter of the driving pulley (mm)
D_2 = Diameter of the driven pulley (mm)

2.3.6 Determination of Torsional Moment in the Shaft

The force acting on the shaft is Torsional force as a result of the rotation of the shaft and this was determined using equation 7 (Khurmi and Gupta, 2006).

$$M_t = \frac{16T}{\pi D^3} \quad (7)$$

Where,
M_t = Torsional Moment (MNm)
T = Torque (Nm)
D = Diameter of the shaft (mm)
π = Constant

2.3.7 Power Required by the Machine

The power required by the machine was calculated using equation 8 below.

$$P = \frac{T x 2\pi N}{60} \quad (8)$$

2.3.8 Area of the Mixer

The area of the mixer was determined as reported by Agada (2010) in equation 9.

$$A_m = 2\pi r_m h_m + 2\pi r_m^2 \quad (9)$$

Where, A_m = Area of the mixer (m^2)
r_m = radius of the mixer = $\frac{D}{2}$ (m)
h_m = height of the mixer (m)

2.3.9 Volume of the Mixer

The volume of the mixer was determined as reported by Agada (2010) and is given as

$$V_m = \pi r_m^2 h_m \quad (10)$$

Where, V_m = volume of the mixing unit (m^3)
r_m = radius of the mixing unit (m)
h_m = height of the mixing unit (m)
π = constant

2.3.10 Capacity of the Conveyor

The capacity of the conveyor was determined using equation 11 as reported by Khurmi and Gupta (2006) and is given as

$$Q = 60n\emptyset P\rho\,(D^2 - d^2)\frac{\pi}{4} \quad (11)$$

Where Q = Capacity of a conveyor (t/h)
n = number of screw rotations
Ø = factor introduced for inclined conveyor
P = conveyor pitch (m)
ρ = bulk density (kg/m^3)
D = pitch diameter of conveyor (m)
d = diameter of shaft (m)
π = constant

2.3.11 Power Required by the Conveyor

The power required by the conveyor was determined as reported by Orisaleye *et al.* (2009) in equation 12.

$$P = \frac{QL(W_o + \sin\beta)}{100\gamma} \quad (12)$$

Where,
P = Power required by the conveyor (kW)
L = Length of the screw conveyor (mm)
W_o = Material factor
β = Angle of inclination of screw to the horizontal
Q = Capacity of the conveyor (t/h)
γ = Assumed efficiency of the screw conveyor (%)

2.3.10 Determination of Extrusion Pressure

The extruding pressure of the die was determined using equation 13 as reported by Nwaokocha and Akinyemi (2008).

$$P_e = \frac{F_e}{An} \quad (13)$$

Where n = Number of perforated holes
P_e = Extruding pressure (N/mm^2)
F_e = Design Extrusion Force (N)
A= Area of Die (mm^2)

2.4 MACHINE DESCRIPTION

The machine consists of hopper, milling chamber, mixing and pelleting chamber. The unit operations include grinding, mixing and pelleting of the feed ingredient. The milling operation ensure an effective size reduction of the feeding material into desired particle size, the mixing operation stir the ingredients into homogenized mixture, the pelleting operation produces sufficient heat which is generated under rotary working principle under an air tight condition and under this moderate temperature condition, the starch and fibre content of the feed material is cooked and formed into semi dried pellets by shape moulding action of the die. The pelleting machine is shown in Figure 1 and Plate I below.

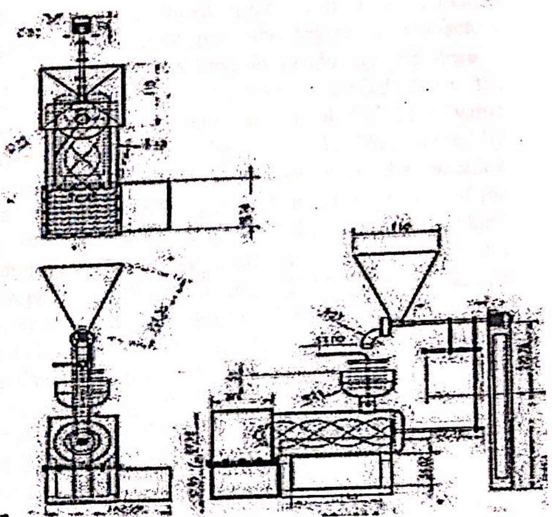

Figure 1: Projection of the pelleting machine

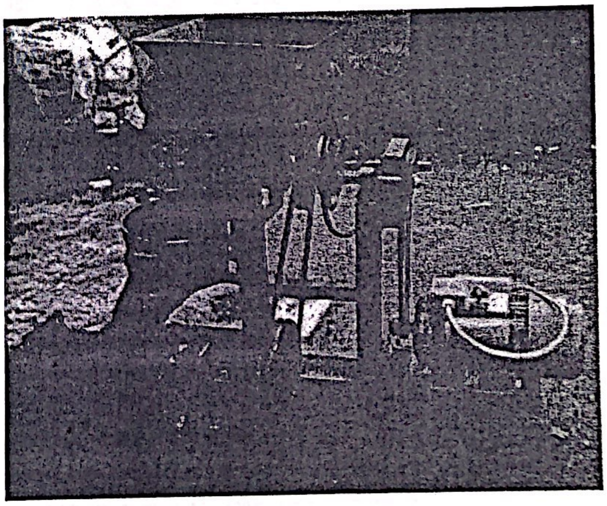

Plate I: The constructed pelleting machine

2.5 FEED FORMULATION AND BINDER

The Feed Samples used in this study were formulated using Pearson Square method and was prepared at 30 % crude protein in 3 Kg per sample rap. Cassava starch binder was prepared and mixed with the fish feed as reported by Orire *et al.* (2001).

2.6 MODE OF OPERATION AND PERFORMANCE EVALUATION OF THE MACHINE

A 5 horse power electric motor was used to operate the machine. The feed ingredients were separately fed into the machine; the mixing chamber was locked until all sample ingredients were milled. Six hundred grams (600 g) of hot water was introduced into the feed in the mixing chamber for homogenous mixing of the feed. It was then, unlocked and loaded into the pelletizing chamber. The pellets were collected at the collection beam and were sun dried. Equations 14 - 16 were used as the performance indices (Pelleting Efficiency, Throughput Capacity and Mechanical Dammage) for the evaluation of the machine as reported by Burmamu *et al.* (2015).

2.6.1 Pelleting Efficiency of the Machine

The pelleting efficiency is the ratio weight of pellet obtained to the weight of material feed into the machine (Burmamu *et al.* 2015).

$$Em = \frac{X_p}{Q_i} \times 100\ \% \quad (14)$$

Where Em = Efficiency of the machine (%)

X_p = Average weight of pellets obtained (g)

Q_i = Quantity of feed introduced into the machine (g)

2.6.2 Throughput capacity of the machine

The throughput capacity of the machine was determined as reported by Burmamu *et al.* (2015) and is given in equation 15

$$T_c = \frac{Q_i}{T} \quad (15)$$

Where, Q_i = Quantity of feed introduced into the machine (kg)

T = Average time taken (hr)

T_c = Throughput capacity = kg/hr

2.6.3 Mechanical Damage

$$M_d = \frac{W_r}{Q_i} \times 100\ \% \quad (16)$$

Where, M_d = Percentage of mechanical Damage

W_r = Average Weight Retained (Kg)

Q_i = Quantity of feed introduced into the machine (kg)

2.6.4 Specific Energy Consumption

The specific energy consumption of the machine was determined using equation 17 as reported by Orisaleye *et al.* (2009).

$$S_E = \frac{P_E \times T}{X_p} \quad (17)$$

Where, S_E = Specific Energy Consumption (kWhkg^{-1})

P_E = Power of the Electric Motor (Kw)

T = Time taken (hr)

X_p = Mass of pellets produced (kg)

2.6.5 Determination of the dimensions of the Produced Pellets

The dimensions of pellets (diameter and length of each 10 pellets sample) were measured by digital Vernier Caliper (Model TESA 1p65- Range 0-150 mm ± 0.01 mm, Swiss) as reported by Khater *et al.* (2014).

3 RESULTS AND DISCUSSION

The performance evaluation of the machine and the pellets produced are shown in table 1and Plate II below. The pelleting efficiency gives the degree of satisfactory performance of the machine in producing the desired pellets. The pelleting efficiency recorded from the evaluation of the machine was 85.4 %. This value determined is in line with the result (83.4 %) obtained by Burmamu et al. (2015). The capacity of the machine shows the quantity of the pellets that can be produced for every one (1) hour. The capacity of the machine determined was 11.25 kg/hr which was higher than 9.0 kg/hr reported by Burmamu et al. (2015). The mechanical losses determined was 14.6 % which is higher than that reported by Burmamu et al. (2015), this indicate that some of the fish feed fed into the machine were not pelletized. Also, the average specific energy consumption determined was 0.38 kWhkg-1, this value is lower than 0.69 kWhkg-1 obtained by Orisaleye et al. (2009). This low value obtained will make the machine more economical to maintain by local processors. Orisaleye et al. (2009) also reported that an acceptable standard by Food and Agricultural Organization (FAO) requires that good pellets which are properly formed should have their lengths to be about two and a half times (2 ½) of their diameters, this is evident in plate II which shows that the pellets were of standard quality.

TABLE 1: PERFORMANCE EVALUATION OF THE PELLETING MACHINE

Performance Indices	Values Obtained
Pelleting efficiency (%)	85.4
Throughput capacity(kg/hr)	11.25
Mechanical losses (%)	14.6
Specific energy consumption (kwhkg^{-1})	0.39

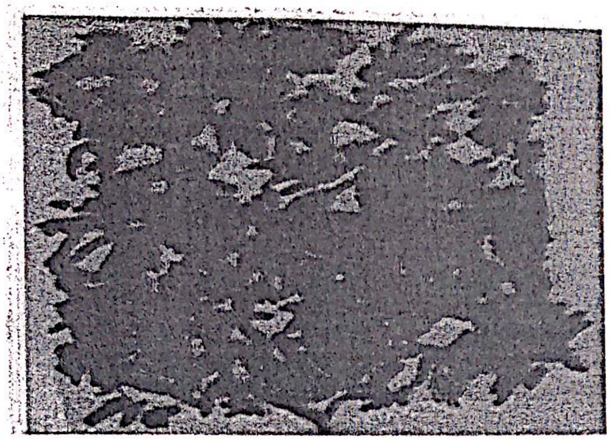

Plate II: Produced pellets

4 CONCLUSION

A fish feed pelleting machine that combines milling, mixing and pelleting operations was designed and constructed using available local resources. Performance evaluation of the machine gave satisfactory results with pelleting efficiency, throughput capacity, Mechanical losses and specific energy consumption of 85.4 %, 11.25 kg/hr, 14.6 % and 0.39 kWhkg-1 respectively. The produced pellets were of good standard quality..

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