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Development and Performance Evaluation of an Indigenous Fish Feed Palletizing Machine

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Key words:
Pelletizer;
Fish Feed;
Moisture Content;
Throughput Capacity

A B S T R A C T

Fish feed pelleting machine was designed and fabricated using locally sourced materials. Design calculations were carried out to determine the specifications of essential parameters for the development of the machine and the performance of the machine was evaluated. Some of the parameters evaluated include pelletizer efficiency, throughput capacity and percentage float of the pellets. Results showed that the mean pelletizer efficiency was highest (72.35±6.46) in feed materials at 18% moisture content and lowest (18.45±1.70) in feed materials with 10% moisture content. Percentage pellet float was highest (78.67±3.06) in feed materials with 18% moisture content, while the lowest percentage float was recorded in feed materials with 10% moisture content. However, the throughput capacity was highest (4.13±0.31) in feed with 25% moisture content followed by feeds with 18% moisture with a value of 3.80(±0.36). the lowest throughput capacity of value 2.43(±0.15) was recorded in feed materials with 10% moisture content. Findings from the research are useful in the design of pelletizer with optimum capacity to produce pellets, through the use of appropriate moisture condition for feed materials.

1. Introduction

Aquaculture development in Africa compared to the rest of the world is insignificant (Changadeya et al., 2003). According to Hetcht (2000), the entire continent contributed only 0.4% to the total world aquaculture production for the period 1994 to 1995. In the year 2000, it contributed a mere 0.97% of the total global aquaculture (FAO, 2003). The demand for animal protein from fish is on the increase worldwide. However, with the current supply trends combined with ever increasing population, the per capita consumption of fish in Africa is stagnating and in Sub-Saharan Africa has fallen drastically (Muir et al., 2005). To arrest this deplorable condition and boost production of fish, aquaculture remains the only feasible option that can sustain adequate fish supply in Africa.

Despite the increasing interest of individuals in domestic and commercial fish farming, the escalating cost of fish feed is putting many off the business. Fish feed technology is one of the least developed sectors of aquaculture particularly in Africa and other developing countries of the world (FAO, 2003). Fish feed development in Sub-Saharan Africa has not made a significant progress in aquaculture as expected. According to Hecht (2000), the research on inexpensive feed ingredients has not contributed greatly to aquaculture development in Africa and suggested that more research on how best plant protein can be used as fish feed is required. Development and management of fish feed, play very vital role in aquaculture growth and expansion. In fact, it is a major factor that determines the profitability of aquaculture venture. Jamiu and Ayinla (2003) reported that feed accounts for at least 60% of the total cost of fish production in Africa, which to a large extent determines the viability and profitability of fish farming enterprise.

The challenge of quality feed production most times is associated with the fish feed source, the materials and the processing options, which eventually determines the structure of the finished product. The structure of the ingredients, whether it is coarse or fine have a significant effect both on the physical properties and nutritive value of the finished product (Igbinosun, 1991). Frame (1994) stated that the main mechanical means of producing pellets are through extrusion in special palletizing mills, or using a screw extruder to convey the material for extrusion. It was also stated that in both cases, the moist plastic mixture is forced

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to pass through the holes of a die. The friction of the material pushed through the holes provided the mechanical resistance that is needed for obtaining compaction; adjustable blades can shear the rod like extruded material into segment of the desired length. Significant efforts have been made to improve the physical quality of pellet (Fine reduction) and increase through put to make pelleting process more economical.

Fish feed palletization tends to increase homogeneity of the feed constituent and increase in the energy constituent of each pellets. It facilitates easy transportation and handling of the feed. Also pelletized feed requires less storage space, palletization of fish feed reduces wastage, because a loose particle fish feed can easily be eroded away or dissolved in the water. Also pelletized feed increase energy in fish, thereby increasing productivity and growth rate, which decreases their vulnerability to predation. Despite the importance of this palletization process and volumes of work that have been done on, little information is available in literatures on the combined processes of palletization and drying of fish feed. The objective of this research is to develop and evaluate the performance of indigenous fish feed palletizer and dryer machine.

2. Methodology

2.1 *Design of Machine Components*

The machine components such as hopper, drive mechanism, pulley and belt, transmission mechanism and power requirement were designed for as follows:

2.1.1 *Hopper*

The volume of the hopper determines the volume of feed it can accommodate at once. It is assumed that the hopper is in the shape of frustum of a pyramid and the formula was estimated as follows

$V =$ Volume of frustum (m^3)

$h =$ Height of frustum (m)

$A_1 =$ Area of upper base (m^2)

$A_2 =$ Area of lower base (m^2)

Top (A_1) and bottom (A_2) areas of the hopper are calculated as follows:-

$$A_1 = 355\ mm \times 240\ mm = 85200\ mm^2.$$

$$A_2 = 80\ mm \times 60\ mm = 4800\ mm^2.$$

Hence, volume is calculated as:-

$$V = \left(\frac{250}{3}\right)\left(85200 + 4800 + \sqrt{(85200 \times 4800)}\right).$$

$$= 9185229.954\ mm^3.$$

$$= 0.00918\ m^3$$

Density of the dry fish feed was estimated using the relationship given by Ovevainen (1983) with the assumptions that Dry fish feed (14 g) occupies 21.650 mm^3

$$\text{Dry density} = \frac{Mass}{Volume} \qquad 2$$

$$= \frac{14 \times 10^{-3}}{21.650 \times 10^{-6}}$$

$$= 646.651\ kg/m^3$$

Choosing a moisture content of 15% wet basis (Ovevainen 1983)

$$M = (15\%\ of\ M_i) + M_i.$$

$$= (15\%\ of\ 14) + 14.$$

$$= 2.1 + 14.$$

$$= 16.2\ g.$$

$$\text{Wet Density} = \frac{16.2\ g}{21.650\ mm^3}.$$

$$= \frac{0.0162\ kg}{21.650 \times 10^{-6} m^3}.$$

$$= 748.268\ kg/m^3.$$

Recall

$$\text{Volume of the hopper} = 9.18\ m^3$$

Mass of feed that the hopper can accommodate will be:

Mass of feed = wet density x volume of hopper

$$M = \rho \times V$$

$$= 748.27 \times 0.00918$$

$$= 6.869\ kg$$

2.1.2 *Design of Drive Mechanism*

Table 1 presents values selected for use as basic parameters needed for the design of the machine's V-Belt drive.

Table 3.2: Basic V-belt parameters

S/N	Parameters	Value
1	Electric motor speed	1410 rpm
2	Center to center distance	317.5 mm
3	Coefficient of friction	0.11
4	Angle of Groove	45^0
5	Diameter of the driver pulley	75 mm

$$N1D1 = N2D2 \qquad (3)$$

where:

N1 = speed of the driven pulley (rpm)

N2 = speed of the driving pulley (rpm)

D1 = diameter size of the driven pulley (mm)

D2 = diameter size of the driving pulley (mm).

The minimum pitch diameter for A – type V-belting transmitting power at a speed of 1410 rpm is 2.2 inch (or 55.9 mm). For this reason, a driving pulley diameter of 75 mm was chosen.

2.1.3 Pulley and Belt Design

Belt speed $V_b = R_1\omega_2 = R_2\omega_2$

$$R = \frac{D}{2}$$

$$\omega = \frac{2\pi N}{60} \qquad 4$$

Therefore,

$$\frac{N_1}{N_2} = \frac{D_1}{D_2}$$

N_1 = Speed in revolution per minute of motor

N_2 = Speed of the shaft in revolution per minute

D_1 = Diameter of the motor pulley

D_2 = Diameter of the shaft pulley

ω = Angular speed

Belts are major type of flexible power transmission equipment. It requires relatively close spacing and precise centre distance. It transmits power from motor to shaft, and the center distance between motor and shaft is adjustable.

Various types of belts include;

Type V1, 21, A1, B1, and C1

For the design, type A was chosen.

Therefore, the speed of the belt is calculated below. Choosing electric motor speed of

$N_1 = 1410$ rpm

$D_1 = 75$ mm Also choosing type A pulley with

$D_2 = 385$ mm

From equation 3

$$N_2 = \frac{N_1 D_1}{D_2}$$

$$= \frac{1410 \times 75}{385}$$

$$= 274.67 \text{ rpm}$$

Velocity of belt

$$V_b = \frac{\pi N_1 D_1}{60}$$

$$= \frac{\pi \times 1410 \text{ rpm} \times 75 \text{ mm}}{60}$$

$$= 5537.77 \text{ mm/s}$$

$$= 5.5 \text{ m/s}$$

2.1.4 *Belt Length*

The length of the belt was determined using the equation below, as reported by (Gupta, 2006)

$$L = 2C + \frac{\pi}{2}(D_1 + D_2) - \frac{(D_2 - D_1)^2}{4C} \qquad 6$$

Where:

L = total length of the belt (m)

D_1 and D_2 = diameter of the driven and driving pulleys (mm)

C = distance between the centers of the two pulleys (mm)

Condition to choose C is given as

$$C \geq D_1 + \frac{D_2}{2} + 50 \text{ mm}$$

$$C \geq 75 \text{ mm} + \frac{385 \text{ mm}}{2} + 50 \text{ mm}$$

$$C \geq 317.5 \text{ mm}$$

Choosing

$$C = 317.5 \text{ mm}$$

Therefore, length of belt used becomes;

$$L = 2(317.5) + \frac{\pi}{2}(75 + 385) - \frac{(385 - 75)^2}{4(317.5)}$$

$$L = 635 + 722.66 - 75.67$$

$$L = 1281.99 \text{ mm}$$

$$L = 1.28 \text{ m}$$

From tables, preferred length 1250 mm

2.1.5 *Angle of Wrap*

The angle of wrap was determined using the expression given by (Gupta, 2006)

$$\theta_S = \pi - 2\text{Sin}^{-1}\left(\frac{D-d}{3C}\right) \qquad 7$$

where:

θ_S = Angle of wrap (rad).

D = Diameter of bigger pulley

d = Diameter of smaller pulley

C = Centre to distance between both pulleys.

Substituting these values of D, d and C into equation (7)

Using the data presented in Table 1 the resulting value of angle of wrap is 2.92 radians.

$$\theta_S = \pi - 2\text{Sin}^{-1}\left(\frac{385 - 75}{3(317.5)}\right)$$

$$= \pi - 2\sin^{-1} 0.3255$$

$$= \pi - 2 \times 18.99$$

$$= 180 - 37.99$$

$$= 142.01^0$$

2.1.6 Maximum Tensile Strength and Mass per unit length of Belt

Adopting the values of maximum tensile strength for frictional rubber belting and mass per unit length of belt of 5.5 N/m^2 and 0.38 kg/m, respectively The belt cross-sectional area was estimated for the type V – belt using a belt with B and H values of 14.17 mm and 7.88 mm, respectively.

2.1.7 Belt Cross Sectional Area

For A – type V – belts with B and H values of 14.17 mm and 7.88 mm, respectively, the cross sectional area was estimated as:

$$A = B \times H \quad (8)$$
$$= 14.17\ mm \times 7.88\ mm$$
$$= 111.66\ mm^2$$
$$= 1.117 \times 10^{-4} m^2$$

2.1.8 Transmission Calculations

The relationships that exist between tensions in belts in V-belt design is given as follows:

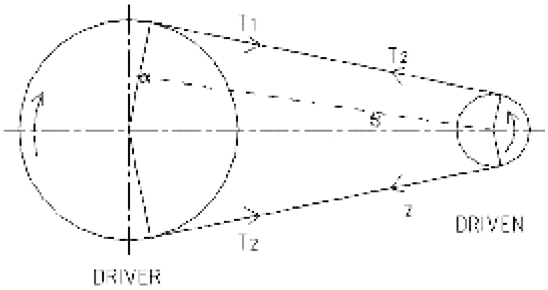

Fig. 1: Belt section showing the tensions

$$T_1 = \sigma a \quad (9)$$

$$T_2 = mv^2 \quad (10)$$

$$\frac{T_1 - T_C}{T_2 - T_C} = e^{\mu\theta \operatorname{cosec}\beta} \quad (11)$$

Where:

β = semi-angle of the grove

T_1 = Tight side tension (N)

T_2 = Slack side tension (N)

T_c = Centrifugal tension (N)

m = mass per unit length of the belt (kg/m)

From equation (9), $T_1 = \sigma a$,

Where:

a = belt cross sectional area = 8.x 10^{-4} m^2

σ = 5.5 N/m^2

Therefore, the resulting value of T_1 is = 473 N

From equation (10), $T_2 = mv^2$

Recall that m = 0.38 kg/m, and V= 5.5 m/s from

Previous values obtained

Therefore,

Centrifugal tension T_2, from equation (13) becomes

$$T_2 = 0.38 \times 5.5^2 = 2.09\ N.$$

In calculating for the value of T_2, using equation (11), recall that

$\mu = 0.12$, $\theta = 2.48$ radians, $\frac{\beta}{2} = \frac{45^0}{2} = 22.5^0$

By substitution,

$$e^{\mu\theta \operatorname{cosec}\beta} = e^{0.12 \times 2.48 \times \operatorname{cosec} 22.5^0}$$

$$= 2.498$$

Recall from equation (13)

$$\frac{T_1 - T_C}{T_2 - T_C} = e^{\mu\theta \operatorname{cosec}\beta}$$

$$\frac{T_1 - T_c}{T_2 - T_c} = 2.498$$

$$\frac{473 - 2.09}{T_2 - 2.09} = 2.498$$

T_2 = 190.6 N

2.1.9 **Design of Auger Conveyor**

The Auger conveys the feed along the shaft pressure plate (die). The die facilitates the pellet formation. A shaft diameter of 80 mm, clearance 1 mm and screw container (Cylinder) of 90 mm were chosen Arowolo (2003). According to Henderson and Perry (1980) pitch of auger must approximately be equal to the screw diameter; therefore screw length of 225 mm was selected.

The design formula for auger according to Ogunleye (2001) is:

$$P_x = \frac{4VDL}{\frac{\pi}{4}(D^2 - d^2)N} \quad (12)$$

Where,

P_x = pitch screw

V = inlet velocity

L =Length of shaft

The inlet velocity will be

$$V = \frac{P\pi(D^2 - d^2)N}{16DL}.$$

$= 0.6 m^3$/ Sec.

2.1.10 Design of Shaft

The shaft is the main component of the machine and is acted upon by weights of material being processed, pulley, conveyor belt and the fruits. In operation, the shaft transmits the power being generated by the gear reduction motor to the conveyor belt. Therefore, in order to safeguard against bending and torsional stresses, the diameter of the shaft was determined from the equation given by Shigley (2001)) as:

$$d^3 = \frac{16\,T}{0.27\pi\delta_0} \qquad 13$$

Here, d = diameter of the shaft in mm,
T = Torque transmitted by the shaft in Nm,
δ_0 = yield stress for mild steel in N/m² and
π = constant = 3.142.

Given that
T = 60 Nm and
δ_0 = 200 N/mm².
π = 3.142.

Hence, d = 17.82 mm.
Therefore, a mild steel rod of diameter 250 mm and length 400 mm was used for the shaft.
The weight of shaft and the weight of screw will have effect on the critical speed of the critical shaft.
Critical Speed of Shaft (Ws)

$$W_s = \sqrt{\frac{48EI}{ML^2}} \qquad 14$$

Where,
E = Modulus of elasticity of steel = 2 x 10⁵N/mm²
I = Moment of initial = $\frac{\pi d^4}{64}$
L = Shaft length = 400 mm
To calculate mass (M) of shaft, a piece of steel 1m² area, by 1m long has a mass of 0.785kg.

Area of the shaft $= \frac{\pi d^2}{4} = \frac{\pi \times 25^2}{4}$

$= 490.94\ cm^2$.

Length of shaft = 0.4 m
Since $1\ dm^3$ of steel has a mass of $0.785\ kg/dm^3$
Mass of the shaft = $4\ dm \times 4.9\ dm^2 \times 0.785\ kg/dm^3$

$= 15.4\ kg$.

I = Moment of inertia = $\frac{\pi d^4}{64}$ 15

$= \frac{\pi \times 0.25^4}{64}$.

$= 1.92 \times 10^{-4} m^4$.

Therefore, critical speed of shaft from equation (16) is,

$$W_s = \sqrt{\frac{48 \times \left(2 \times 10 \frac{kg}{m}\right) \times (1.92 \times 10^{-4} m^4)}{15.4\ kg \times 0.4^2\ m}}.$$

$$W_s = 0.27\ m/s$$

Determine the screw weight
Using 1.5 mm thick plate (n)
Volume of screw per pitch is given by (Ogunleye 2001) as
Volume of screw per pitch = $\pi D^2 h - \pi d^2$

$= \pi h(D^2 - d^2)$.

$= \pi \times 0.015(0.03^2 - 0.025^2)$

$= 1.296 \times 10^{-5} m^3$

Since it has 3 pitches
Volume of the whole screw is

$= 1.296 \times 10^{-5} m^3 \times 3$

$= 3.888 \times 10^{-5} m^3$

$1\ m^3$ of steel weights = $0.785 \times 10^3 kg/m^3$
$3.888 \times 10^{-5} m^3$ will weigh
$3.888 \times 10^{-5} m^3 \times 0.785 \times 10^3 kg/m^3$

$= 0.0305\ kg$.

$= 30.5g$.

Moment of inertia I

$$= \frac{\pi\,(D4 - d4)}{64} \qquad 17$$

$= \frac{\pi\,(80^4 - 25^4)}{64}$.

$= 1991702\ mm^4$.

Calculating the overall critical speed from Dunkerleys formular

$$\frac{1}{\omega^2} = \frac{1}{\omega_s^2} + \frac{1}{\omega_{sc}^2}$$

$$\frac{1}{\omega^2} = \frac{1}{40.774^2} + \frac{1}{1617.7^2}$$

$$\frac{1}{\omega^2} = 00060187$$

$$\omega^2 = 1661.46$$

$$\omega = 40.76$$

Since,

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

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

$$N = \frac{60 \times 40.76}{2\pi}$$

$= 389.18$ rpm

The speed of the shaft is 320.41 rpm and the critical speed is 389 rp. Since the critical speed is greater than the design speed, the machine will work effectively and efficiently.

2.1.11 Torsional Deflection

Torsional deflection is due to the torsion load on the shaft. This is based on the permissible angle of twist. This twist depends on various applications and varies about 0.3^0/m for machine tool shaft to about 3^0/m for him shafting (Ogunleye 2001)

$$\theta = \frac{584TL}{Gd^4} \quad 18$$

Where:

$G =$ Modulus of rigidity

$= 84 \times 10^9 N/m^2$

$$\theta = \frac{584 \times 56.65 \times 0.45TL}{84 \times 10^9 N/m^2 \times 0.025^4}$$

$= 0.454^0$ twist.

2.1.12 Machine Capacity

The capacity of screw conveyor is given as:

$$C_s = (D^2 - d^2) \times P \times N \quad 19$$

$$C_s = (0.08^2 - 0.025^2) \times 0.075 \times 253$$

$$C_s = 0.1095 m^2/min$$

$$C_s = 1.83 \times 10^{-3} m^2/sec$$

The above expression gives the volumetric flow rate per second to determine the mass flow rate.

Since $\text{mass} = \text{Volume} \times \text{density} \quad 20$

$$\text{Mass flow rate} = 1.83 \times 10^{-3} \frac{m^3}{sec} \times 744 \frac{kg}{sec}$$

$$= 1.36\ kg/sec$$

The actual capacity will be much less than the theoretical because of screw housing clearance, characteristic of the material, screw length, type of material (Henderson and Perry 1980).

2.1.13 Power Requirement

The power requirement of the machine was estimated from the relationship in equation 20.

$$\text{Power Requirement} = \frac{WX}{F} \quad 21$$

where:

W = Mass flow rate

X = Effective length of the auger

F = power factor

It is assumed that the power factor (Pf) of com meal will be applicable for feed pelleting (Henderson and Perry, 1980).

Pf = 0.4

The factor chosen above will give the power required in horse power. It was calculated previously that mass flow rate is 1.3 kg/s

X=0.5

$$X = 0.45$$

$$\text{Power requirement} = \frac{1.36kg/sec \times 0.45}{0.4}$$

$= 1.53$ Hp

Converting the required power to kilowatt

$1\ kW = 0.75\ hp$

$1\ 53\ hp = 1.530 \times 0.75$

$= 1.15\ kW$

2.1.14 Design Calculation for Drying Chamber

The main components are:-

i. Drying Chamber with length of 3.25m and diameter of 0.35m
ii. Heater
iii. Blower (fan)
iv. Fasteners (bolts and nuts)
v. Electrical/electronic components (wire, thermostat, and temperature regulator)

2.1.15 Heater Design

The design of the heating unit was carried out using the followings as baseline:

Feed rate = 8 kg/hr = M_w

Intended drying time = 0.16 hr =10mins

Initial moisture content of the pellet = 18%

Desired final moisture content = 5%

Therefore, weight loss from wet to dried chips is calculated using

$$m_d = m_w\left(\frac{100 - m_o}{100 - m_f}\right)$$

$$m_d = 8\left(\frac{100 - 18}{100 - 5}\right)$$

$= 6.91$ kg

where,

m_w = mass of wet feed pellet (kg)

m_o = initial moisture content (%)

m_d = the mass of dried feed pellet (kg)

m_f = final moisture content (%)

Therefore,

Quantity of heat required to remove the water = quantity of heat on the pellet + latent heat of evaporation of water inside the feed pellet. And quantity of heat on pellet, MCT is calculated using the values.

Specific heat of feed pellet = 83.3J/^{o}CKg. (Hahn and Keyer, 1985)

Latent heat = 22.6×10^5

Temperature change =2^{0}C

where,

Q = mass of feed X sp. heat of the pellet X temperature difference + Mass of water X L

= (1332.8+24.634) kJ x 10^5

= 1357.434 kJ

Power of heater to be used = Quantity of heat /Time 24

= 1357.434/ (10 x 60)

= 2.275kW. From the calculation, a heater of about 3kW was used. 23

2.1.16 Fan Design

Length of the drying chamber (previously stated) = 3.25 m

Breadth of the drying chamber (previously stated) = 0.35 m

Height at which pellet fill chamber = 1.2 m

Total depth of pellets = 1 x 1.2 =1.2 m

Volume of the material in the chamber (m^3) = 2.0 x 2.5 x 1.2 = 6.0 m^3

Minimum required range of air velocity necessary for drying food products as recommended is 0.5 m/s (Bulent *et al* 2007; Ndukwu, 2009).

$$\text{Fan horse power (P)} = \frac{\text{volume air flow rates x total static pressure}}{6320 \times \text{fan efficiency}}$$

Most industrial fan have efficiency between 70- 85% (Adzimah and Seckley, 2009), Hence,

$$P = \frac{1156.607 \times 10.638}{6320 \times 0.85}$$

= 2.29 Hp

A centrifugal fan with 2.5 Hp was selected for use.

2.2 Method of Production and Assembly

Sheet metal of 1.5 mm thickness was cut to dimension and this was welded to form the hopper, a pipe of required diameter was slice into equal half and joined together using bolt and nuts to serve as the auger housing, two pieces of pressure plates were also bolted at the beginning of auger housing and the end with six holes to allow passage of compressed pellets, the mm pitch worm is welded into auger housing, and it is supported by two bearing on both sides of the stand, the pulley is forced to the shaft near the two bearings. A cylindrical metal was cut into the designed dimension and was used for the drying chamber, a fan was mounted to the cylindrical metal using bolts and nuts, a copper wire was used tighten the heating element to a perforated metal sheet and the perforated metal having been tighten to the element was welded to the cylindrical metal, and three angle iron rods were welded to the cylindrical metal to form the standing frame for the drying chamber. The sectional and pictorial views of the pelleting /drying machine is presented in Figures 1 and 2.

2.3 Manufacturing Process

The fundamental criteria for determining the economic product of various parts of machines are as follows: functional design of the part or assembly with maximum simplicity consistent with appropriate authentic quality, choice of material from a compromise of physical properties appearance, cost and ease of processing, choice of the correct processes for production at the lowest cost (Redford, 1981).

2.4 Feed Mixture

The fish feed mixture comprise of the followings:

i. Groundnut cake (GNC)
ii. Soya milk
iii. Maize.

When these materials were milled and mixed, binders were added in proportion of 1:4. Materials used as binder include:

iv. Fat
v. Starch
vi. Molasses.

2.5 Performance Evaluation

The machine was tested using feed samples obtained from Landmark University Farm. In order to determine the reliability of the machine, the test procedures carried out were based on variation of moisture content of the feed and the die size. The machine was tested on zero load and normal speed of rotation was found to be 275 r.p.m. Three samples of the feed weighing 8kg each were prepared at moisture contents of 10%, 18%, 25% and machine speeds of 275 rpm. Three replicates results were noted at each moisture content level. The fish feed pelletizing machine was evaluated in terms of percentage of materials retained, percentage unpelleted, pelleting efficiency, and throughput capacity (kg/h) following the method described by Akinyemi (2002); Ojomo *et al.,* (2010); Ojo *et al.,* (2014); and Burmamu *et al.,* (2015).

3 Results and Discussion

3.1 Effect of Moisture on Pellet Formation

Results obtained using 0.8 mm die showed no significant difference (p = 0.05) in pellets formed at the same speed and moisture content as shown in Table 1. It was observed that the machine performed satisfactorily with pellets formed at 18% moisture content. Pallet formation was significantly low at 10% moisture content comparatively with pallet formation at 18% and 25% moisture contents. Samples at 10% moisture content may not readily form

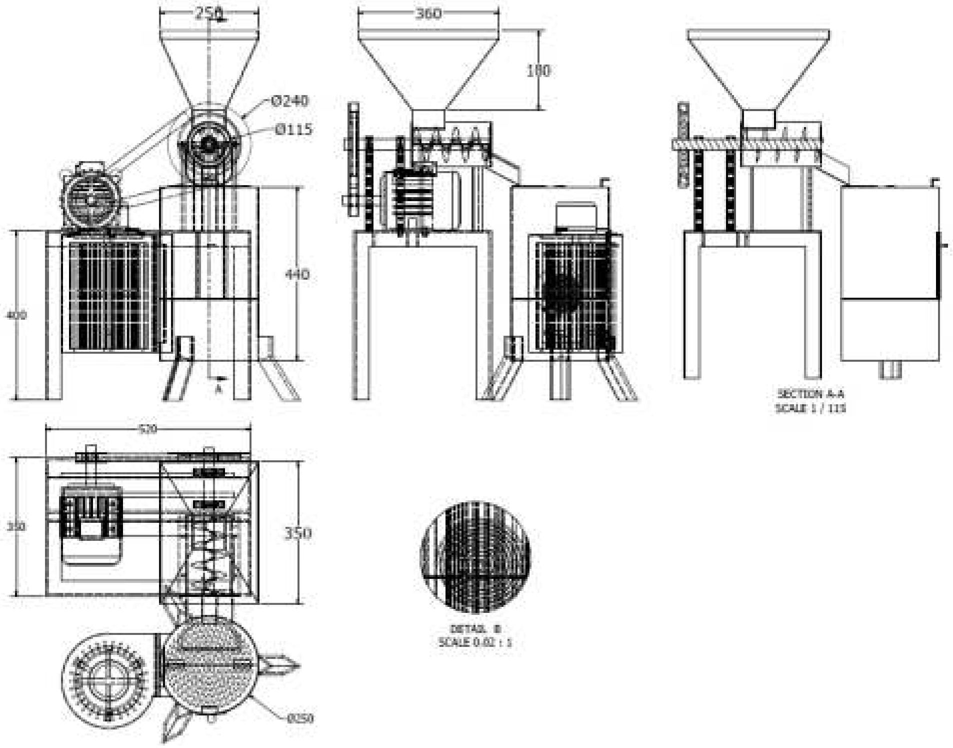

Figure 1: Sectional view of the fish feed pelletizing cum drying machine with dimensions.

molds due to the very low moisture condition and the components of the fish feed, which may not readily absorb moisture. The observation conforms to the findings of Shultz, 1990 and Ojomo *et al.,* (2010), who stated that the presence of water promotes gelatinization of starch components and stretching of expandable components.

3.2 Dry Weights of Pellets on function of Moisture Content Experiment

Drying experiments were carried out three times to ascertain the actual drying rate and safe temperature to dry the sample. Drying proceeded entirely in the falling rate phase. This is expected as the fish feed was not a high moisture content product. Results are presented in Table 2. Percent moisture contents of pellets affected the dry weights (Table 2). The mean wet weight and the corresponding mean dry weight of pellets at 10% MC are 5.26(±0.25) g and 3.93(±0.22) g, respectively. Increased moisture content from 10% to 25% led to increase in mean dry weight to a value of 5.83(±0.28)g

3.3 Pelleting Efficiency of Machine

The pelleting efficiency of machine was highest at 18% moisture content with a value of 79.75%, while the lowest pelleting efficiency (16.75%) was recorded at 10% moisture content (Table 3). Though pellets were formed at the 25% moisture content, the efficiency of pelleting was significantly low when compared with machine efficiency at 18% moisture content. However, the mean highest and lowest pelleting efficiencies were 72.35(±6.46) and 18.45(±1.70), respectively.

3.4 Percentage Pellet Floating Time

The percentage pellets float time was highest (82%) in samples at 18% moisture content followed by samples at 25% moisture content. The enhanced floating time of these samples might have been caused by the seemingly plastic/viscous nature of the products. The plastic/viscous properties resulted from temperature rise of materials under pressure before being extruded from the die. Similar finding was reported by Ojo *et al.,* (2014).

The mean percentage float of samples with 10% moisture content at 3 minutes of observation in water was 46(±5.29)%. This scenario of quick sink of pellets of 10% moisture content was due to poor viscous formation of fish aggregates despite rise in temperature within the pelletizer chamber. Moderate increased moisture of fish feed samples resulted to paste formation and consequently the formation of cake, which eventually was extruded through the die.

3.5. The Percentage Recovery of Pellets

The percentage pellets recovery from die was highest in sample with 10% moisture content followed by samples with 25% moisture content and least in sample with 10% moisture content. Moisture rise and temperature rise within the pelleting chamber induced enough pressure under which samples with 18% and 25% moisture content was forced out through the die, while the samples with 10% moisture content, though had considerably high recovery rate was lowest comparatively with samples at 18% and 25% moisture content.

3.6 Throughput Capacity of Pelletizer

The throughput capacity of pelletizer was highest when material moisture content was 25% with a value of 4.40 kg/min and

Table 1. Pellet formation with respect to moisture content of feed materials

	Moisture Content (wet basis)		
Pellet formation	10%	18%	25%
Replicate 1	0.70	7.40	7.00
Replicate 2	0.50	7.25	3.40
Replicate 3	0.25	7.20	3.50
Mean	0.48(±0.23)	7.28(±0.10)	4.63(±2.05)

Table 2: Dry weights of pellets at 45^{0}C for 10 minutes with respect to different moisture content

Trial	Dry weights of Pellets					
	10% MC		18% MC		25% MC	
	Weight before drying (g)	Weight after drying (g)	Weight before drying (g)	Weight after drying (g)	Weight before drying (g)	Weight after drying (g)
Replicate 1	5.45	4.09	7.42	5.23	7.96	5.86
Replicate 2	5.34	4.02	6.98	4.89	7.05	5.53
Replicate 3	4.98	3.68	7.28	4.96	7.42	6.09
Mean	5.26	3.93	7.23	5.03	7.48	5.83
Standard deviation	±0.25	±0.22	±0.22	±0.18	±0.46	±0.28

Table 3. Pelleting Efficiency of Machine (%) on function of moisture content of feed materials

	Moisture Content (wet basis)		
Trial (Palleting Efficiency)	10%	18%	25%
Replicate 1	16.75	79.75	50.43
Replicate 2	20.15	69.43	48.32
Replicate 3	18.46	67.86	51.42
Mean	18.45(±1.70)	72.35(±6.46)	50.06(±1.58)

Table 4: Percentage Pellet Float at 3 minutes in Water

	Moisture Content (wet basis)		
Trial (% Palleting Float)	10%	18%	25%
Replicate 1	40	76	72
Replicate 2	48	78	68
Replicate 3	50	82	74
Mean	46.00(±5.29)	78.67(±3.06)	71.33(±3.06)

Table 6: Throughput Capacity of Pelletizer

Throughput capacity (kg/min)	Moisture Content (wet basis)		
	10%	18%	25%
T1	2.30	3.50	3.80
T2	2.60	3.70	4.20
T3	2.40	4.20	4.40
Mean	2.43(±0.15)	3.80(±0.36)	4.13(±0.31)

lowest (2.30 kg/min) at 10% material moisture content. The high throughput value at 25% moisture content must have been caused by increase in bulk density of material as a result of increase in moisture, which eventually may have led to better mix during pelleting process and consequent increase in output per min.

4. Conclusion

The development and performance evaluation of a fish feed pelletizer was carried out in this research. Findings from the research showed that moisture content affected most of the parameters considered; such as pellet formation, pelleting efficiency of machine, floating characteristics of pellets and percent recovery of pellets from die outlet. The development of fish feed pelletizer using locally sourced materials is feasible; however, restraints must be exercised in order not to over-wet the fish feed material to be pelleted.

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