DEVELOPMENT OF AN IMPROVED FISH FEED PELLETIZING MACHINE

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ABSTRACT

This study focuses on various types of fish pelletizing machine that are in existence with particular interest on the areas of deficiencies like; choice of electric motor, size of hopper, size of pellet plate, diameter of Auger shaft and the diameter of pellet holes which eventually affected the overall performance of the machines. The identified problems in the existing pelletized machine informed the development of an improved one with better time management and portability. The machine consist of three major parts namely; the pelletized chamber that accommodates the auger; the electrical chamber that hosts the electric power of 2h.p with 1400rpm and its throughput capacity of 18kg/hour and the table made up of angle iron. The improvement in this work is its ability to accommodate different pellet plate hole of diameter 2mm, 4mm, 6mm, 8mm and 10mm. The developed machine was tested and the results show high machine efficiency of 93% and pelletizing efficiency of 96.3%. The production cost of the developed machine is ₦90,000 Nigerian naira (approximately $294). The machine is affordable and simple to maintain and therefore, it is recommended for small and medium scale fish farmers in both rural and urban areas.

Keywords: development; fish; pelletizing; machine

1.0 Introduction

Feed represents the major cost to animal production. Thus, the efficiency of its use, or quality control, can have a considerable impact on the performance of an enterprise (Halley *et al*, 1988). For many years, simple and common techniques have been used in processing livestock feeds, which are basically cereal grains and their by- products. They have been classified into hot or cold processes depending on the requirement of heat. Another classification is based on whether the process is wet or dry. The techniques that have been in use are grinding or particle size reduction, crushing, rolling, steam-flaking, micronization, roasting, chopping, cracking or crimping, popping, hot and cold pelleting (Harris, 1990).

According to (FDF, 1995) it is an established fact that protein from foods of animal origins is lacking in everyday diet of many Nigerians. This deficiency is responsible for a great deal of ill-health and many deaths in almost all the states of Nigeria. Even in the absence of ill health, protein deficiency leads to poor growth, muscular weakness and increase in susceptibility to many diseases. The support to meet the demand by various domestic animals and fish from natural water has so far failed to provide the populace with balanced diet needed. It is imperative therefore to increase protein production by all possible means. First is by the intensification of the existing means of production and second by the introduction and development of additional source of protein. Fish culture in artificial water is one of the best ways to increase the availability of food rich in protein. However, to get the best result from fish culture systems the role played by fish feed should also be defined (FDF, 1995).

Eugene (2002) designed a pelletizer that consist of a screw pump similar to a screw press or screw conveyor in which feed is compressed and worked to form a semi-solid mass. The feed is forced through a restricted opening of the die at the discharge end of the screw with low efficiency.

Ojomo et al (2010) carried out performance evaluation of a fish feed pelletizing machine. The machine consists of a hopper, barrel which houses the screw conveyor (auger), the cutting knife and the die orifice. Power supply to the machine is from 2 kW, 1420 rpm single phase electric motor. The performance evaluation of the machine was carried out. The machine showed higher throughput capacity of 19.7 kg/h with maximum pelletizing efficiency of 87.6%.

Davies R. M. and Davies O. A. (2011) developed and evaluate manually operated fish pelletizing machine. The operation of the machine does not require any highly technical expertise. The main features of the machine are: hopper, extrusion barrel, screw auger, bearing housing, crank arm, compression plate, flat die, pulley, sprout (gravity chute) knife cutter and the supporting frame. The performance of the machine was determined based on the following parameters namely: pelleting efficiency, percentage mechanical damage, percentage feed loss, throughput capacity. The limitation of this machine is that it can only be operated manually.

Olugboji et al (2015) worked on design, fabrication, development and testing of a cheap, electrically operated feed pellet machine with locally available materials. 2 h. p electric motor was used to drive the machine. The experimental work was carried out by testing the machine and the operation capacity was found to be 5kg/h*r*. The area of weakness of this machine is its ability to produce 2mm and 4mm diameter pelletized feed.

Ojediran et al (2017) developed and carried out performance evaluation on an indigenous fish feed pelletizing machine. The limitation of this machine is its ability to produce only 4mm diameter of pelletized fish feed.

Okolie et al (2019) designed and produced a fish feed pelletizing machine. It consists of hopper, screw conveyor, barrel, dies, drives system and heater. The design was carried out using engineering principles with due consideration to cost, ease of operation, serviceability, durability, and performance. It is designed to be driven by a 1.5 h.p, three-phase electric motor with a heating element of 1500 W attached to the barrel surface to ensure adequate heating of the feed as they travel through the barrel. The machine is limited to produce a pelletized feed of 2-8mm diameter.

All the deficiencies identified in the existing machines are improved upon in this work.

2.0 Materials and Methods

2.1 Design computation

The housing where the material (feed) to be densified (compacted) is stored and feed into the machine at a pre-determined rate inside the hopper. The capacity of the hopper and weight governs the choice of construction materials for this section hence mild materials sheet that is available in large quantity was selected. The metal sheet selected is thick and can be welded together easily by electric arc welding.

The hopper capacity dimensions are:

330mm x 330mm (at the top) and 110mm x 110mm (at the base)

The upper is a frustum of a square pyramid. The total height of the assumed pyramid is taken to be 390mm and the height of the pyramid section cut off is given as 90mm as shown below:

Now the capacity of the upper is given by

Volume of assumed pyramid – volume of cut off pyramid i.e. volume of

Hopper = ⅓ (base area) x h

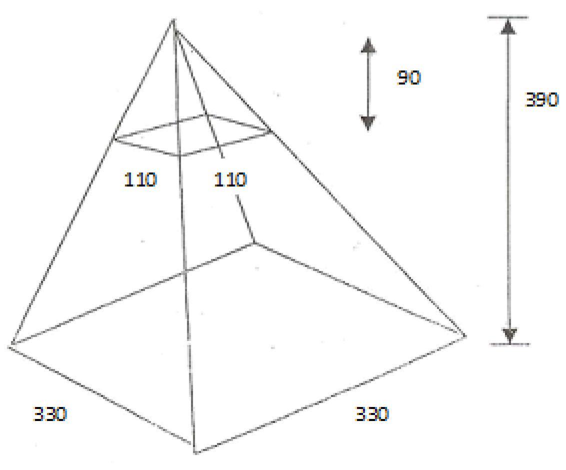

Figure 1: Frustum

From Figure 1, Volume of hopper = $\frac{1}{3} B \times H - \frac{1}{3} b \times h$ ------------------------- (1)

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Where B = base area at the upper side of hopper

b = base are of the lower side of the hopper

H = height of the whole assumed pyramid

h = height of the cut off pyramid

Hence

Volume of the hopper = ⅓ {(330 x 330) x 390} – ⅓ { (110 x 110) x 90}

$$\left\{ \frac{42471000}{3} - \frac{1089000}{3} \right\} mm^3$$

$$\frac{41382000}{3}$$

$$= 13794000mm^3$$

__2.2 Determination of the driver and driven pulley__

There are two pulleys used in the construction of the machine. The drive, which is on the electric motor and the driven pulley which is on the pellet mill shaft. These pulleys are of different sizes for the purpose of speed reduction and toque control. The operating speed of the electric motor is considered to be too high for save and efficient operation of the operation of the machine and toque generated by the motor may not be enough for efficient compaction by the machine. The speed of belt passing over both the driven and driven pulley is given as,

D_m = Diameter of driven pulley on motor,

D_s = Diameter of driven pulley on machine shaft,

N_m = Speed revolution of the motor,

N_s = Speed of revolution of the driven pulley,

T_m = Torque transferred to the machine

$$V_b = \pi D_m N_m = \pi D_s N_s$$

$$\pi D_m N_m = \pi D_s N_s$$

$$D_m N_m = D_s N_s$$

$\frac{D_m}{D_s}$ $\frac{N_s}{N_m}$ ---. (2)

The term $\frac{N_s}{N_m}$ is known as speed ratio,

Hence;

Speed ratio of the machine = $\frac{D_m}{D_s}$

Speed ratio = $\frac{70mm}{170m}$

= 0.4117

Therefore percentage speed reduction of the belt and pulley is 41.17%

But by considering the thickness of the belt speed ratio becomes

Speed ratio $\frac{D_m + t}{D_s + t}$ --- (3)

Where t = thickness of the belt

Speed ratio = $\frac{70+8}{170+8}$

= 0.43820

Taking the speed of the motor to be 1800 rev/min

Hence without consideration the belt thickness the machine will be moving at a speed given below

$\frac{N_s}{N_m}$ = 0.4117

$\frac{N_s}{1800}$= 0.4117

Ns = 0.4117 x 1800

= 741.1 rev/min

Considering the belt thickness, the speed of the machine shaft becomes

$\frac{N_s}{N_m}$ = 0.4382

$\frac{N_s}{1800}$= 0.4382

Ns = 1800 x 0.4382
= 885.6 rev/min

2.3 Determination of length of belt

The length of the belt to be used for the transmission depends on the following.

1. The radii of the two pulley
2. The distance between the centres of the two pulleys

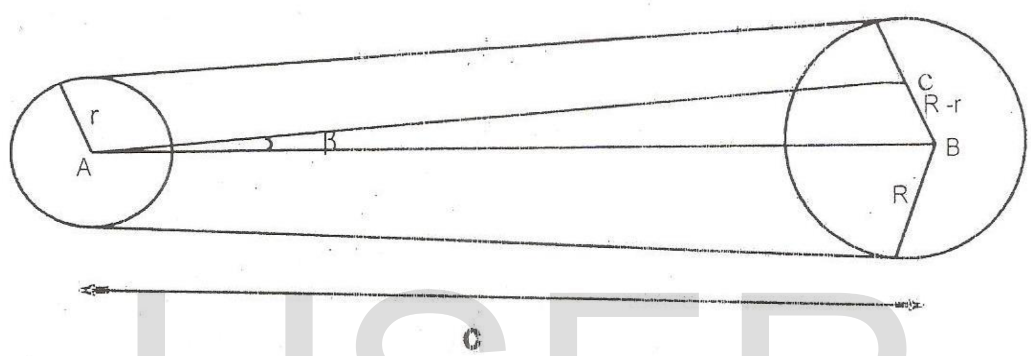

Figure 2: Diagramme for belt and pulley design

From Figure 2, considering triangle ABC we could see that

Sin β = $\frac{R-r}{C}$ -- (4)

Hence R = Sin $^{-1}$ $\left[\frac{R-r}{C}\right]$

Where R = radius of bigger pulley on the machine, r = radius of smaller pulley on the motor, C = centre distance

But D = 3D or 2(d + D)

But D = 170mm = large pulley diameter, d = 70mm = small pulley diameter

Hence

C = 2 (70 + 170) = 2 (240) = 480mm

Therefore

β = Sin^{-1} $\frac{85-35}{450}$

β = Sin^{-1} $\frac{50}{450}$

β = Sin-1 0.104166 = 5.97

For smaller or driver pulley, angle of lap $\alpha_1 = 180^0 - 2\beta$

α_1 = 170 – 2 (5.97) = 158.06

For driven pulley (bigger) angle of lap α_2 is given as α_2 = 180 + 2B

= 180 + 2(5.97) = 180 + 11.94= 191.94

The total length of the a V-belt is given by the relation below

$C^2 = \frac{1}{2}\left[L - \pi(R + r)\right]^2 - (R-r)^2$

Or

L= 2C Sin φ + 2 π R – 2 π (R –r) --- (5)

Where 4 φ = 90-R

= 90-5.97

φ= 84.03^0

Hence L = 2 x 480 sin 84.03 + 2π 85-2π (85-35)

= 960 sin 84.03 + 2π 65 - 2π x 50

= 960 sin 84.03 + 2π (85-50)

= 960 sin 84.03 + 2π x 35= 954.79 + 220= 1174.79mm

2.4 Determination of torque between the motor and the shaft

The ratios of torque transmitted to the machine through the input shaft from the motor are dependent on the ratio the speed of their pulley. Now neglecting energy lost through friction (slip). The equation below shows the torque speed relationship

Power = $\frac{2\pi\ NT}{60}$ --- (6)

Where N = Speed in rev/min (1800 rev/min), T = Toque, P = Power of the motor, which is 2 HP

Equivalent to 1.5 Kw

1500 = $\frac{2\pi\ 2800 \times T}{60}$m

Tm = $\frac{1500\ x\ 60}{2\pi\ 1800}$= 7.95-m

Provided there is no power loss, power at the motor pulley equals to the power at the input shaft

$P = \frac{2\pi N_m T_m}{60} = \frac{2\pi N_s T_s}{60}$ -- (7)

Where N_m & N_s = speed of revolution of the motor and input shaft pulleys.

T_m & T_s = Toque on the motor and input shaft pulleys

$N_m T_m = N_s T_s$

$\frac{N_m}{N_s} = \frac{T_s}{T_m}$

N_m = 1800 rev/min

T_m = 7.95 N-m, T_s = ?, N_s = 830.7 rev/min

$\frac{N_m}{N_s} = \frac{T_s}{T_m}$

$\frac{1800}{830.7} = \frac{T_s}{T_m}$

$T_s = \frac{1800 \, x \, 7.95}{830.7}$ = 17.2 N-m

But

$\frac{N_m}{N_s} = \frac{D_s}{D_m}$

Hence $\frac{N_m}{N_s} = \frac{T_s}{T_m} = \frac{D_s}{D_m}$ -------------------------------------- (8)

The toque ratio is

$= {}^{T}S/{}^{T}M$ --- (9)

${}^{17.2}/_{7.95}$ = 2.2

This shows that there is increase in torque by 2.2 x torque of the motor.

2.5 Determination of the tension on the belt

$P = (T_1 - T_2)V$……………………… (10)

V = Wr

Therefore $T_1 - T_2 = {}^{P}/\omega_r$ -------------------------- (11)

But $W = \frac{2\pi N}{60}$

Therefore $T_1 - T_2 = {}^{P}/\omega_r$

$= \frac{60 \, x \, p}{2 \, \pi \, N_r}$

$= \frac{1000\ x\ 60\ x\ p}{\pi\ DN}$

Where T_1 = Effective tension on tight side of belt (N)

T_2 = effective tension on stack side of belt

P = Power in kilowatts (Kw)

D = Diameter of pulley for the machine shaft (mm)

N = Speed of the machine shaft (rev/min)

$T_1 - T_2 = \frac{60\ x\ 1500\ x\ 1000}{3.142 \text{ x } 130 \text{ x } 830.7}$

$T_1 - T_2 = 265.3N$……………………… (12)

Also

$T_1 + T_2 = 3(T_1 - T_2)$

$T_1 + T_2 = 3(265.3)$

$T_1 + T_2 = 795.8N$

$T_1 = 795.8 - T_2$……………………………… (13)

Substituting equation (iii) into (ii)

$795.8 - T_2 - T_2 = 265.3$

$795.9 - 2T_2 = 265.3$

$- 2T_2 = 265.3 - 795.8$

$-2T_2 = 530.5$

$2T_2 = 530.5$

$T_2 = {}^{530.5}/_{2}$

$T_2 = 265.3N$

$T_1 - T_2 = 265.3$

$T_1 = 265.3 + T_2$

$T_1 = 265.3 + 265.3$

$T_1 = 530.5N$

2.6 Design of the shaft

The core diameter of the power screw is assumed to be a shaft transmitting the power from the pulley to the feed material

Let T_1 = Tension on belt tight side

T_2 = Tension on belt slack side

W = weight of the pulley

The total vertical load acting on the pulling W_T is given as

$W_T = T_1 + T_2 + W$ -- (14)

But T_1 = 530.5N

T_2 = 265.5N

W = 18N

W_T = 530 + 265 + 18 = 814N

Bending moment on the shaft M is given by

$M = W_T$ x L -- (15)

Where L = center distance between the motor and driven pulley = 450mm

M = 814 x 450 = 366300N – mm

Let d = diameter of the shaft

We know that equivalent twisting moment is given by

$T_2 = \sqrt{m^2 + T^2}$

$T_e = \sqrt{(Km\ x\ m)^2 + Kt + T)^2}$ --- (16)

Where km = combined shock and fatique factor for bending

K_t = combine shock and fatique factor for torsion

K_m = 1.5

K_t = 1.0

$T_e = \sqrt{366308 + 17208}$

T_e = 366703.6N-mm

$T_e = \frac{\pi}{16}$ x L x d^3 --- (17)

Where L is taken as 35 Mpa = 35Nmm^2

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$$d^3 = \frac{16T_e}{\pi\ x\ L} = \frac{16\ x\ 366703}{\pi\ x\ 35} = 53360.1742$$

$$d = \sqrt[3]{53360.1742} = 37.648mm$$

2.7 Construction Process

Fabrication was carried out at the central Engineering workshop of the School of Engineering and Engineering Technology, The Federal University of Technology, Akure, Nigeria. Figure 3 shows the exploded view of the machine (The hopper, the frame, the barrel, the die plate, the screw conveyor). The main frame and electric motor stand were fabricated from a standard length.

2.7.1 The Frame

The frame acted as a support to other components. It was a rigid structure and was designed to withstand dynamic stresses and welded to the base was a bearing support.

2.7.2 The Barrel

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.

2.7.3 The Hopper

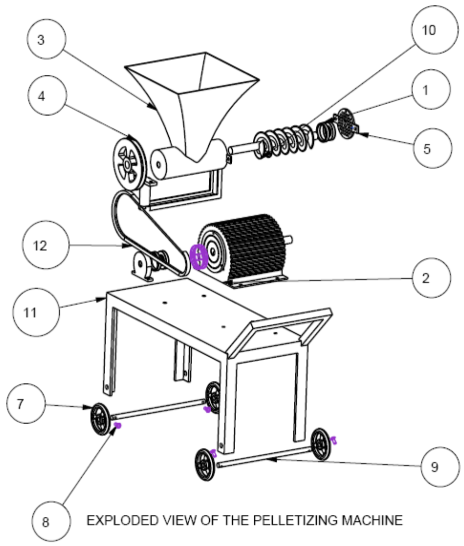
The hopper is a funnel shaped frustum cut out of a square pyramid. The height of the frustum is 300mm and it has a square top of length 330mm.

2.7.4 The Die

The extruder needed a die which could sustain the high pressure of material conveyed by the feed screw. The die was made using 5 mm thickness mild steel plate. It has a diameter of 80mm and is removable. Finally, thirty six (36) numbers of holes were drilled around the surface of the each die plate to make way for the resin pellets to pass through. The diameter of each drilled hole is 2 mm in the first die, 4mm hole each in the second die, 6mm hole each in the third die, 8mm hole each in the fourth die and the fifth die is of 10mm hole each. Thirty-six die inserts of 2,4,6,8 and 10 mm were drilled into five plates respectively.

2.7.5 The Screw Conveyor

The screw conveyor was a worm wound round a cylindrical shaft. The maximum outer diameter of the worm was 78 mm to give clearance between screw and barrel. The screw conveyor was carried on a solid shaft of 25 mm which is driven by a pulley.



S/N	PARTS	QTY
1	BALL_BAERING	1
2	ELECTRIC_MOTOR	1
3	HOPPER	1
4	MACHINE_PULLEY	1
5	PELLET_PLATE	1
6	PILLOW-BEARING	1
7	ROLLER	4
8	ROLLER_PIN	4
9	ROLLER_ROD	2
10	SHAFT	1
11	TABLE	1
12	V_BELT	1

Figure 3: Shows the exploded view of the Pelletizing machine.

The exploded design of an improved Pelletizing machine is as shown in Figure 3 and the Developed machine is as show case in Figure 4.

Figure 4: Shows the Pelletizing Machine Developed.

2.8 Performance Test

The developed machine after assembly was tested for machine efficiency, throughput capacity, pelletizing efficiency and feed dryness. The feed of the same qualities were weighed and put into the developed machine to obtain the dry pelletized feed. Time for complete pelletizing was recorded and the pelletized feed sample was weighed and taken for the test. The throughput capacity, machine efficiency and pelletizing efficiency was determined by Equation (18, 19 and 20)

The throughput capacity (TPC) is given as;

$$TPC = \frac{WR}{t} \tag{18}$$

Where WR is the recovered weight after pelletizing and t is the time taken for complete pelletizing.

The machine efficiency (ε) is given as:

$$\varepsilon = \frac{WR}{WF} \tag{19}$$

Where; WF is the weight of feed put into the developed machine.

Pelletizing efficiency (η) is given as;

$$\eta = \frac{WP}{WR} \tag{20}$$

Where; WP is the weight of the pelletized sample.

2.8.1. Throughput Capacity

The rate at which the feed sample fed into the machine is been recovered is known as the throughput capacity of a machine. So, in this research work 4kg of feed mixture was put into the developed machine and 3.1kg of the feed was recovered at a time interval of 10.5minutes. The result is 0.295kg/min, which is approximately 18kg/hr.

2.8.2. Machine Efficiency

The machine efficiency is the ratio of the weight of the feed sample fed into the developed machine to the weight of the sample recovered after the pelletizing process. This result is 93%. Hence; the percentage loss in the pelletizing process is 7%. This is a great improvement over the existing machine because the clearance between the tip of the screw and the barrel had been improved upon in this design.

2.8.3. Pelletizing Efficiency

The ratio of the weight of the pellets to the weight of the recovered feed gives the pelletizing efficiency. The separating efficiency was obtained to be 96.3%. However, the mechanical damage obtained was 3.7% which was far better than what was recorded in the existing machine due to improvement on kneading as the feed conveys along the barrel.

2.8.4. Feed Dryness Test

The result obtained when this test was carried out is as shown in Table 1 and Table 2.

Table 1: Dryness of feed at a varying temperature

S/N	1	2	3	4	5
TEMPERATURE (C)	120	170	195	245	290
DRYNESS (%)	53	58	65	76	85

Table 2: Dryness of feed at a varying time

S/N	1	2	3	4	5
TIME (seconds)	4	13	18	38	52
DRYNESS (%)	50	55	60	70	78

3.0 Results and Discussions

3.1 Results:

Adequate amount of feed was mixed with a proportionate amount as a binder. The weight of the feed to be pelleted was noted and the record was taken to be 4kg, the time taken to pelletized the feed was also recorded using the stop watch so as to determine the capacity of the machine and this time is 10.5minutes. The capacity of the machine per hour therefore is 18kg/hr.

3.2 Discussions:

The main features of the machine are the hopper, pulley supporting frame extrusion barrel, bearing housing. The experimental test was done by mixing various ingredients thoroughly into paste form using molten starch as binder and was then feed into the hopper. The machine was set to gyration. This extruded through the extruding holes of the die plates and was cut to desired size. The proportionate mixture of the water and the ingredient is to avoid watery compaction. It was also discovered that inconsistent mixture of the ingredients may lead to a sticky product and as such the pelletized feed break before getting to desired sizes.

4.0 Conclusion

In this research work, an improved fish feed pelletizing machine was developed, which has been able to solve 70% of deficiencies identified in the existing machines. The machine developed has a better throughput capacity of 18kg/min compared to the latest one. The machine efficiency is 93%. This is a great improvement over the existing machines because the clearance between the tip of the screw and the barrel had been improved upon in this design. Also, the developed machine has a pelletizing efficiency of 96.3% which was far better than what was recorded in the existing machines due to improvement on kneading as the feed conveys along the barrel. The cylindrical pellets size produced by the developed machine ranges from 2mm to 10mm depending on the type of die you use. The machine is simple to operate and easy to maintain. The cost of production is 90,000 Naira Nigeria currencies. The developed machine is affordable and recommended for all fish farmers both in rural and urban areas.

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