IJREAT International Journal of Research in Engineering & Advanced Technology, Volume 2, Issue 6, Dec-Jan, 2015
ISSN: 2320 – 8791 (Impact Factor: 1.479)
www.ijreat.org

Development Of A Manually Operated Fish Feed Pelleting Machine

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Abstract

Studies on the development of manually operated fish feed pelleting machine for small scale industries was carried out in order to discourage importation of similar machines into the country. To achieve this aim, materials were after design selected based on strength, durability, physical properties, availability of the materials, and their costs. The selected materials were appropriately cut into parts in line with engineering specifications. The parts were constructed in line with the design by welding, bolting and nuts connections. The machine was then tested with 3kg of mixture of fish feed where 2.65kg of the feed was recovered which gave the efficiency of 88.3%. Pelleting machine was recommended for both rural and urban fish producers since it is portable and can be operated manually.

Key words: *Fish feed, design, construction, pellets, strength, efficiency*

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 animals feed. Production of animal feed through processing of raw food items depends upon proper use of existing traditional methods and modern development derived from the spectrum of research. Amadi (2007) reported that a pelleting machine is one that is used to create cylindrical pellet from a mixture of dry powdered stocks, such as molasses, steam or as a machine used for converting materials and food items such as maize, groundnuts, and millets with other additives in good ratio. Pellets are produced through a process known as extrusion. Mc Donald et al., (1995) observed that in the past years, fish, poultry and other animals were fed in a primitive way which involved milling of grains and cereals as meals on stones and mortar. This could not meet the safe and healthy food requirements of animals let alone their growth and development in order to meet both aesthetic and market requirements of these animals. It was discovered that animals preferred feeding on solid and soft nutritious meals, and one of the devices that can provide this mixture of nutrients in powdered form is the pelleting machine. Similarly, Kumar

(1992) asserted that pelleting machines are built to perform the following functions: mould animals feed meals in form of soft capsules which can easily be consumed by fish and poultry animals, to produce saw dust as fuel used in a pellet stove, production of iron ore pellets in varying diameters for blast pig iron production, and production of chemical pellet (www.fao.org., 2003). More so, the design and construction of a manually operated pelleting machine is of paramount importance by way of improving food security and technology to ease the suffering of animals such as fish, chicken, turkey, birds, etc. Pelleting machine consists of some basic components such as the hopper through which the feed meal is fed into the machine, the pelleting chamber in form of worm auger or screw shaft propels the feed. 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 by a mechanical process. Samuel (2008) designed and constructed a pelleting machine for fish production, but there was less pressure in the screen because the number of holes on the screen was too many and also the clearance between the screw/auger and the cylinder wall was too large which reduced the efficiency of the machine.

The traditional method of processing fish and poultry feeds which includes grinding of grains and cereals on stones and mortar is very primitive and unhealthy though still predominant. This technique is extremely arduous and causes great discomfort to the operators. It also becomes difficult to predict the time of grinding and proper mixing ratio causing damages during processing and resulting into low quality feeds. That is why it is necessary to undertake this study in order to reduce the burden and drudgery encountered during fish feed formulation. The objectives of the work were to: (i) formulate the feeds and test the manually operated fish feed pelleting machine, (ii) modify the screen and the screw/auger in order to increase pressure for the feed pelleting, (iii) develop an adaptive low-cost machine that can produce pellets for small scale fish industries.

Materials and Methods

Design Requirements: - Mott (1985) asserted that the general requirements of a good pelleting machine are:

(i) To receive the mixture of feed into the machine steadily
(ii) To introduce the mixture of feeds into the cutting unit uniformly
(iii) To cut the mixture of feeds uniformly
(iv) To discharge the pellets out of the machine steadily

Other requirements considered were its simplicity in terms of structure; being constructed with locally sourced materials. The cost of construction was low and the materials used were readily available in order to ease maintenance.

Selection of Construction Materials

The general consideration for the selection of materials to produce an adaptable machine in which the hopper allows materials pass through effectively with minimum wastage was made. The pelleting chamber was made of metal to increase durability; the hopper being sloppy was to allow pellets slide downward and discharge by gravity. Generally, several factors were taken into consideration before the choice of materials due to variations in condition of service and specifications of materials available such as;

i) Type of machine to be designed
ii) Size of design
iii) Weight of materials
iv) Strength of materials
v) Physical properties like corrosion, conductivity, etc
vi) Cost and availability of materials
vii) Durability of materials

Method of Machine Development

Design and Description of Machine Parts: - In the design of each component, some mathematical relationships were used to come up with each part.

Design Analysis:

i). Design of screw/auger – this forms part of a rotating shaft at the base of the hopper which conveys the materials to be pellet. Screw/auger was made up of a rod wound round a bar in a worm-like form of mild steel. The screw had a pitch diameter Dp = 27mm, thread pitch Pt = 10mm and the thread wear diameter Dp was = 19.9mm less than the specified diameter of 27mm.

ii). Design of Pellet pressure chamber – the inner diameter d_1 = 70mm and the outer diameter d_2 = 75mm giving the thickness t, to inner diameter ratio as t/d = 0.07. A cylinder with t/d < 0.05 is generally regarded as a thin wall cylinder (Balogun, 1999). Thus, this pelletizing cylinder is a thick walled cylinder. Radial stress,δr hoop stress, δh and axial stress, δ_z in the body of cylinder were calculated. For open ends of cylinder when internal pressure Pi was applied, the minimum stresses occurred at the cylinder bore, i.e. d = d_1. The internal pressure, also equal to the extrusion pressure was: Pi = design extrusion force/bore area = $441.18/\pi x70^2/4$ = 0.115N/mm^2 also = $\delta r.$ δh = 0 while δz was = 1.67N/mm^2.

iii). Design of winding handle – the turning moment of the operating handle is the product of the force and the perpendicular distance from the axis of rotation to the line of action of force.

Thus, torque = product of length of pivot arm and a force acting perpendicular (length of arm x perpendicular force in Nm). Since human power is one tenth of a horse power, i.e. equivalent to 75 watts as 75N/m (Mott, 1985) the shaft is expected to make 1.5 rpm and the length of the winding was 170mm. Therefore, Force = torque/distance = 75/0.170 = 441.18N

iv). Design of bearing load: - axial load = 14.14KN, radial load = 166N. Single row sealed ball bearing met the above operational conditions.

Other dimensions considered in the design were as follows:

(a). The hopper: – in form of rectangular based pyramid frustum was made of mild steel sheet. The development of hopper was such that dimensions were marked and cut out from a mild steel sheet, and then welded together (Fig. 1). The selected dimensions were:

(b). Upper part of hopper: - $260mmx260mm$

- Lower part of hopper - $70mmx70mm$
- Height of hopper - $280mm$
- Capacity of hopper - $84480mm^3$

(c). The screw/auger: – is the part of the rotating shaft at the base of the hopper which conveys the pellets. The screw/auger is made of a rod wound round a round bar in a worm which is made of mild steel.

(d). Worm screw: – worm screw specified has a pitch diameter, $Dp = 70mm$ and thread pitch $Pt = 60mm$. In designing the thread wear, Doboronolsky et al., (1977) equation was used.

(e). Winding handles design: – the turning moment of the operating handle is the product of the force and the line perpendicular distance from the axis of rotation to the line of action of force. Thus, torque = product of length of pivot arm and a force acting perpendicular watts and 75N/m, the shaft is expected to make 1.5 rpm (Ryder, 1977) and the length of the winding handle was 170mm.

(f). Pelleting Pressure Chamber: – with inner diameter d_1 = 70mm and outer diameter d_2 = 75mm, while the thickness t, to inner diameter ratio was $t/d_1 = 0.07$. A cylinder with $t/d_1 < 0.05$ is generally regarded as a thin walled cylinder (Ryder, 1977). Thus, the pelleting cylinder was a thick walled cylinder. This pelletizing chamber was reduced to increase the pressure in the chamber as against the one constructed by Samuel (2008) with $t/d_1 = 0.07$.

(g). Screen: – this was to ensure the flow of mixture of feed from the pressure chamber to the outlet

(h). Cutting blade: – a metallic component designed I frustum shape through which the content (mixture) was passed out.

(i). Frame: – base of the machine, it provided support for the machine in use and after use. It was made from an angle of bar iron of 50mm x 50mm and its length was 240mm

(j). Bearing: – this was used for various rotating parts of the machine. It was fitted into the bearing housing which enabled them to be removed and cleaned during maintenance. They have the internal and external diameters of 15mm and 30mm respectively.

(k). Bolts and nuts: – a total number of 19 bolts and nuts were used. Some components of the machine were joined permanently by welding while other parts were temporary with bolts and nuts in case there was need for changing of parts.

Table 1: Bill of Engineering Measurements and Evaluation (BEME)

SN	Description of Parts	Materials	Length (mm)	Diameter (mm)	Quantity (mm)
1	Back plate	Mild steel	3	70	1
2	Base stand	Mild steel	300 x 240	-	2
3	Bearing	Cast steel	47	15	2
4	Bolts and nuts	Mild steel	200	8	2
5	Screw/auger	Mild steel	390	20	1
6	Hopper	Mild steel	260 x 240	-	1
7	Winding handle	Mild steel	170	20	1
8	Housing	Mild steel	190	75	1
9	Stand	Mild steel	240 x 120	-	1
10	Perforated plate	Mild steel	126	8	1
11	Cutting blade	Mild steel	40 x 30	-	1

Method of Fabrication

The various methods used in developing the machine were:

• Marking out and bending the length of materials used in the construction to the required measurements with the aid of hack-saw and shearing machine.

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• Cutting – various parts were cut according to specifications of the design. The parts were then joined together by welding, riveting, bolts and nuts (bolting).

• Drilling – the outlet was drilled with 2mm, 3mm, 4mm, and 6mm drill bits which were then fixed to the machine with the aid of bolts. The length of the mild steel was measured into 190mm and 130mm folded with the aid of a rolling machine to make the housing. A shaft 390mm in length and 20mm in diameter was machined with lathe so as to house the bearings which was 20mm each in diameter. Drilling machine was used to drill some holes on the stand to create access for bolts and nuts.

• Coupling – the housing was welded at both sides of the cylinder with the aid of mild steel of 70mm diameter and again welded; while the other end was bolted to provide room for maintenance and for removal of the shaft conveyor. Similarly, the hopper was welded on the housing while the housing itself was welded on the base stand which was bolted with the aid of bolts and nuts (Fig. 1).

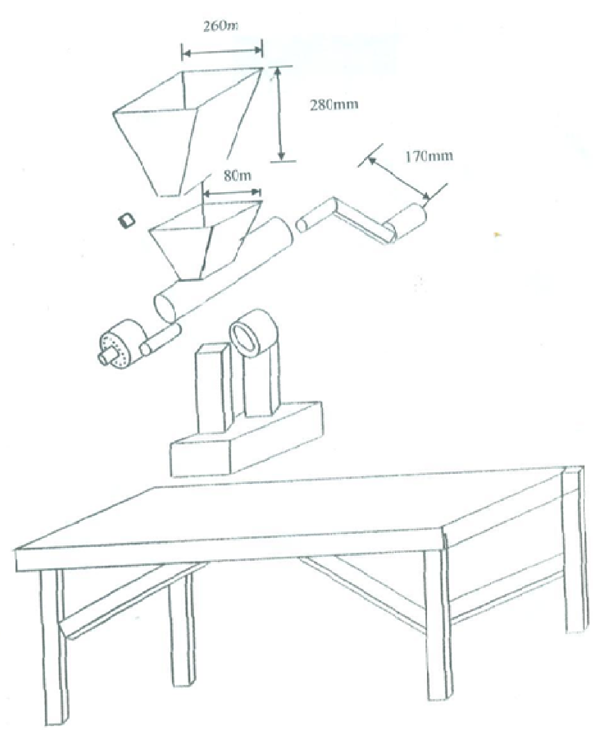
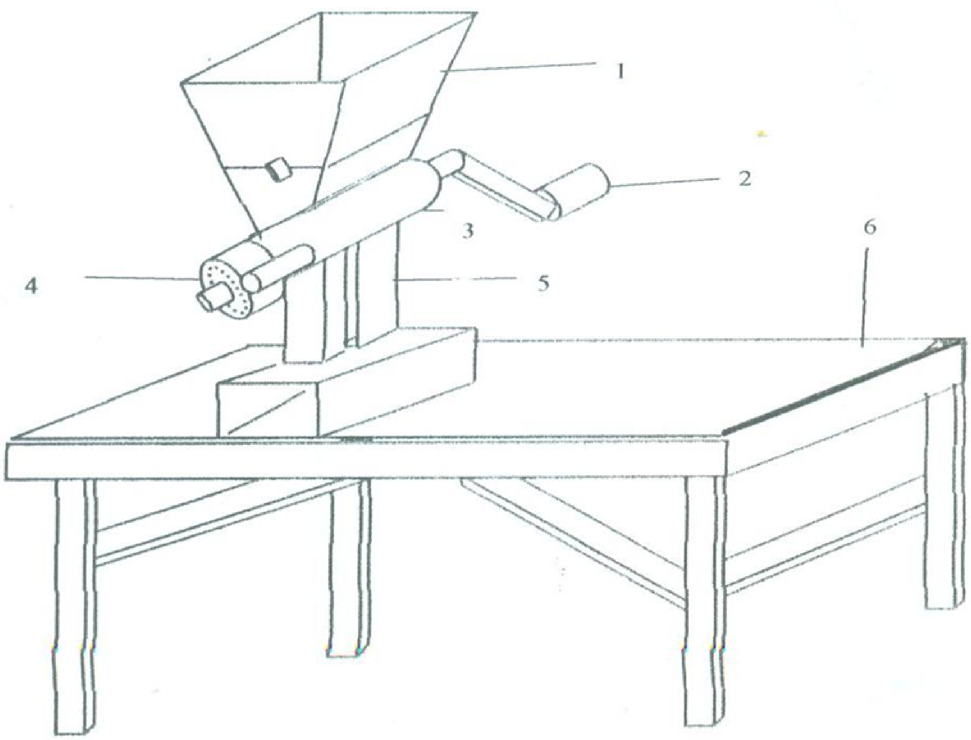


Figure 1: Design Parts of the Machine

Principles of Operation of the Machine

The feed to be pelleted was poured into the hopper, and due to gravitational action the feed passed into the pelleting chamber. The handle, connected to the motor rotated the screw/auger in the cylinder where the feed experienced circular orbit in a horizontal plane about the axis. With the help of the shaft and cylinder, the force on the cylinder impacts the feed into solid which was pushed to the die to produce pellets of uniform size, shape, and density and discharge out through the holes on the die (Fig. 2).



Legend

1. Hopper
2. Winder
3. Housing
4. Screen
5. Base Stand
6. Stand

Figure 2: Assembled Machine

Results and discussion

Performance Test

After the construction of the machine, it was necessary to know whether it was functioning according to the purpose for which it was designed. Therefore, a test was carried out. Feed formulation was prepared and the ingredients included: maize, ground nut cake, cotton seed cake, wheat meal, soya bean cake and palm kernel cake, yeast, rice meal, sorghum meal locally sourced were loaded into the machine through the hopper and gradually conveyed the mixture of the feed ingredients and additives to the perforated plate via conveyor shaft, which then was forced and cut out by the rotation of the winding handle of the machine. Table 2 below illustrates feeds formulation for fingerlings, juveniles, and adults.

Table 2: Feed formulation for fingerlings, juveniles and adults

SN	Feed Ingredients	Fingerlings (Kg)	Juveniles (Kg)	Adults (Kg)
1.	Maize	10.00	20.00	30.00
2.	Fish meal	10.00	10.00	09.00
3.	Ground nut cake	34.65	29.50	20.00
4.	Soya bean meal	34.65	29.35	24.65
5.	Wheat barn	10.00	10.00	15.00
6.	Salt	00.25	00.25	00.25
7.	Vitamins	00.25	00.25	00.25
8.	Palm oil	00.20	00.40	00.60
9.	Bone meal	-	00.25	00.25
		100	100	100

Performance Test Calculation

The result of the performance test in terms of the efficiency of the machine was calculated thus:

One measure of mixture of ingredients and additives used for the performance test = 3 Kg, total weight fed in (W_T).

Therefore, according to Akinyemi (2002), pelleting efficiency is derived from:

$$(\eta_p) = \frac{total weight recovered (W_R)}{total weight fed in (W_T)}$$

Total weight recovered (W_R) = 2.65 Kg, and total weight fed in (W_T) = 3.00 Kg

Therefore, pelleting efficiency (η_p) $= \frac{W_R}{W_T} x100 = \frac{2.65}{3.00} x100 = 88.3\%$, which shows that the efficiency of the machine is 88.3% higher than Samuel (2008) who obtained an efficiency of 72% in his studies.

Mechanical damage = total weight retained / total weight fed in = 0.35 / 3.00 x 100 = 11.6% because of the high pressure developed between the shaft and cylinder which damaged and retained some feeds in the pelleting chamber.

Through put capacity = measure of the amount of materials passing through the machine per unit time. Since 3Kg of the mixture of feed was pelleted in 20 minutes, i.e. 0.33 hours. Then, the through put capacity was = $\frac{3.00}{0.33} = 9Kg/hr$

It was discovered that the faster the speed of winding handle, the longer the pellets produced and the slower the speed of the winding handle, the shorter the pellets produced because when the speed of winding handle is faster, the pressure exerted by the screw/auger would be higher thereby making the pellets to be longer and when the speed of the winding handle is slow, the pressure exerted by the screw/auger is very low making the pellets to be very small.

Conclusion

Locally sourced materials such as mild steel, cast iron, bearing, bolts and nuts were used in developing a manually operated machine that pelleted 100 kg of fish feed formulated from food items such as maize meal, groundnut cake, soya beans cake, salt, borne meal, etc for feeding fingerlings, juveniles and adult fish. The developed machine was found to be effective and efficient, powered manually having efficiency of 88.3% and through put capacity of 9kg/hr while recording a minimum mechanical damage of 11.6% all in 20 minutes only. It takes care of power failure problems and can be used by both rural and urban dwellers. It is also affordable since the cost of production was low. Therefore, effort should be made to adopt and popularize this design, especially for the benefits of rural people who make up greater percentage of the nation's population. Interested companies and manufacturers can modify this machine by increasing its capacity and to be electrically operated or even electronically operated with the aid of computer.

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