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DESIGN AND CONSTRUCTION OF AN AUTOMATIC FISH FEEDER MACHINE

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ABSTRACT

Fish cultivation has become a worthwhile business activity, as it promotes food security and poverty eradication in developing countries; however, the feeding processes are done manually in Nigeria. Therefore, to solve the problem associated with manual feeding in aquaculture, an automated fish feeder was designed, fabricated and tested that automatically feed the feeder at a predetermined time. This eliminates the drudgery associated with manual feeding. The machine was electrically powered and had the capacity to dispense 420g of feed pellets at 90sec. The maximum shaft speed was 250rpm.

Keyword head: Automatic, feeder, Feed, Fish and Aquaculture.

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1. INTRODUCTION

Fish cultivation has become a worthwhile business activity, as it promotes food security and poverty eradication in developing countries. For there to be a bountiful harvest of fishes in this business, it is absolutely imperative to ensure that these fishes are being fed regularly to achieve proper growth and development [1]. With enhanced innovation such as automatic fish feeder, aqua cultural practice is improved by making it less laborious to the farmer. The inclusion of this

gadget in the cost of fish production has reduced to adequate broadcasting of feed at proper scheduled time as well as decreasing labour requirement [2].

Fish feeder framework is structured as a mechanical and electrical gadget that administers appropriate measure of nourishment to the fishes at an accurate time interval as planned by the farmer [3]. A programmed fish feeder is essentially a component that delivers an endorsed measure of feed to the fishes at wanted time interims. The main importance of programmed fish feeders is that it lessens the labour force required in manually feeding the fishes. One key element of programmed feeders is a form of programmable gadget that enables the administrator to vary the recurrence and measure of feeding [4]. This could be a mix of electrical and mechanical parts that release feed into the fish pond. Some concepts utilize electrical clocks to sequence the release of feed. Most often, smaller fishes are fed several times within each hour, and bigger fishes are fed on hourly basis. Programmable feeders utilize some sort of mechanical or pneumatic conveyor to spread the feed to the fishes [5].

Several automatic fish feeders have been built in the past few years to ease the work requirements in fish production. Sakshi Nirwan et al., [6] used Arduino Uno in the design of an automatic fish feeder system. The device is able to dispense fish food at different time intervals with precise amount of food. Also the device can be programmed to guarantee that the feeding plan is followed accordingly. While these programmable fish feeders are easily available for fish farmers in developed countries, they are scarce in developing countries like Nigeria, and this is as a result of the cost of importation [7].

This research paper is about the design and construction of an “Automatic Fish Feeder Machine”. This device broadcasts a particular quantity of fish food at different time interims. To ensure consistent feeding plan, the timing of the device is programmed. Also an Arduino Uno microcontroller board is used in controlling the feeding mechanism of this device.

2. MATERIALS AND METHOD

2.1. Electrical Components

The electrical components used include;

- I. Arduino Uno: - This is the brain of this whole project as it is the most important component needed for the automation required for the feeding operations. It is a programmable hardware which automatically turns on the motor at a given time interval base on the program given to it.
- II. Electric motor: - It is used to transmit power required to drive the Auger.
- III. Transistor: - A transistor acts as a switch or gate for electronic signals. It is a device that regulates current or voltage flow in an electric circuit.
- IV. Capacitor: - A device used to store an electric charge, consisting of one or more pairs of conductors separated by an insulator.
- V. Resistor: - Resistors reduce voltage levels within circuits. They can also be used to reduce current flow within circuits.
- VI. Relay: - Relays are used where several circuits must be controlled by one signal.
- VII. Transformer: - A transformer is an electrical device that transfers electrical energy between two or more circuits through electromagnetic induction.

2.2. Machine Component Description and its Assembling Pattern

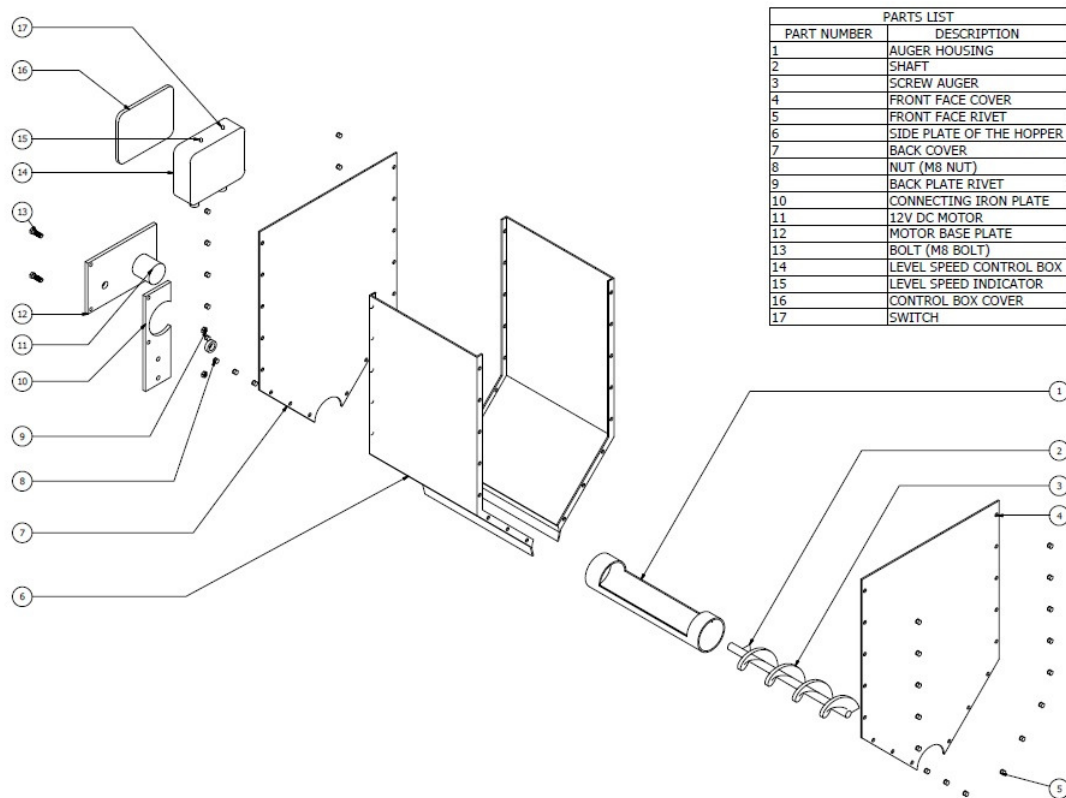


Figure 1 Exploded view of the fish feeder machine

The machine was designed with the aim of automating the feed metering rate and time spent on spreading of fish feeds on the pond. Components of the machine include; the feed hopper, feeding compartment, screw auger and process control panel. A rectangular surface plate and a prime mover (a 12V DC motor which drives the screw auger) were used in supporting the machine. Figure 1 above illustrates the automatic fish feeder machine.

The 12V DC motor shared the same platform with the gear box. Inside the drum was a four pitched screw auger. The drum was welded at both ends of the feed hopper.

2.3. Design Considerations

The design of the components of the machine was based on mechanical theories (properties), biological properties and physical properties of the fish feed. Some assumptions were made in the determination of various dimension selected. The following designs considerations were also made:

- I. The design and construction should be simple.
- II. The machine will be operated automatically by incorporating speed control lever.
- III. The machine power requirement should be relatively minimal (12V DC motor).
- IV. The construction of the automatic fish feeder should be at minimal cost compatible with its efficiency.
- V. The component of the machine should be easily replaceable in case any damage or wear.

2.4. Design of Machine Elements

2.4.1. Capacity of the fish feeder hopper

For the design of the hopper, the following were considered;

- I. The angle of the wall friction
- II. The material flow function
- III. The effective angle of internal friction

The average bulk density of the various sizes of feed pellets was also considered while building the hopper. The minimum outlet dimension and the semi-included angle were derived using Jenike Shear. The structure of the hopper had a combination of a cuboids and a triangular based prism.

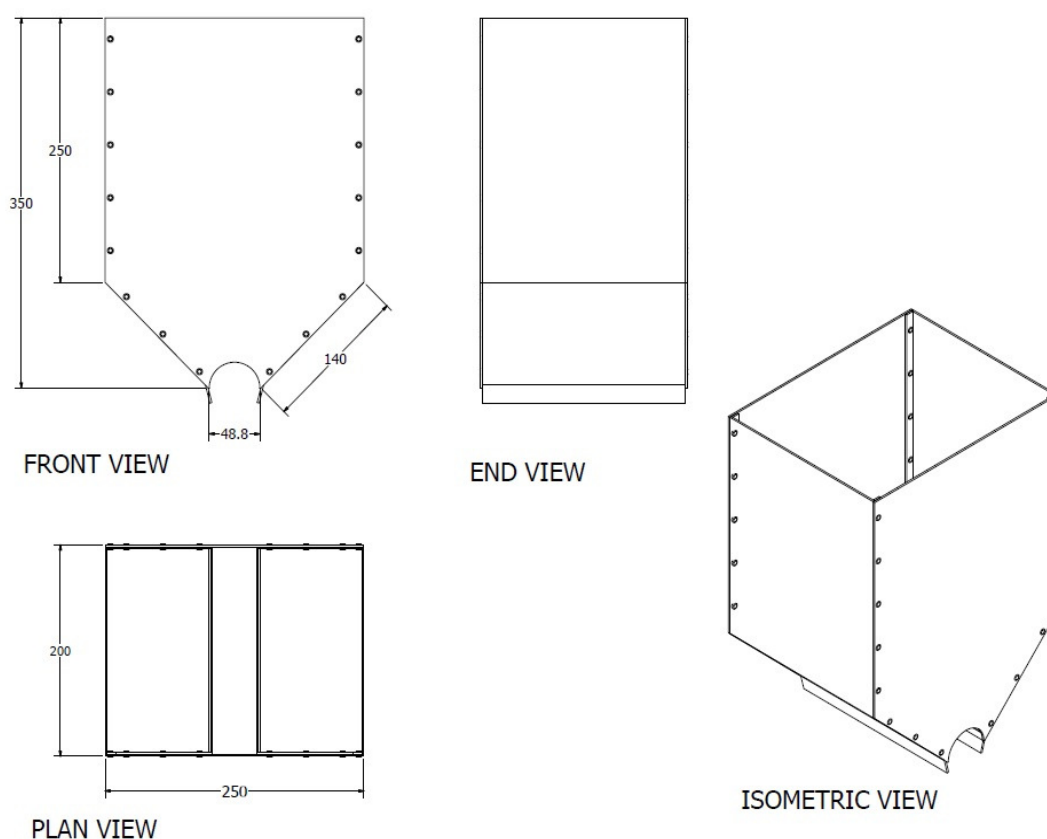


Figure 2 Orthographic view of the fish feeder hopper

$$\begin{aligned}
 \text{Volume of the hopper} &= \text{Volume of the cuboid} + \text{Volume of the triangular based prism} \\
 &= (\text{Length} \times \text{Breadth} \times \text{Height}) + ((\text{Cross-sectional area}) \times \text{Length}) \\
 &= (\text{Length} \times \text{Breadth} \times \text{Height}) + \left(\left(\frac{1}{2} \times \text{Base} \times \text{Height} \right) \times \text{Length} \right) \\
 &= (250 \times 200 \times 250) + \left(\left(\frac{1}{2} \times 250 \times 100 \right) \times 200 \right) \\
 &= 12500000 + \left(\left(\frac{1}{2} \times 25000 \right) \times 200 \right) \\
 &= 12500000 + 2500000 \\
 &= 15000000 \text{ mm}^3 \\
 &= 0.015 \text{ m}^3
 \end{aligned}$$

ASSUMPTION:

Dry fish feed 14g occupies 21.650mm^3

$$\text{Dry density} = \frac{\text{mass}}{\text{volume}} \quad (2.1)$$

$$\frac{14 \times 10^{-3}}{21.650 \times 10^{-6}} \\ 646.651 \text{ kg/m}^3$$

Choosing a moisture content of 15% wet basis

$$M = (15\text{ of } M_i) + M_i$$

$$(15\text{ of } 14) + 14$$

$$2.1 + 14$$

$$16.2\text{g}$$

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

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

$$748.268 \text{ kg/m}^3$$

Recall:

$$\text{Volume of the hopper} = 0.015\text{m}^3$$

Mass of feed that the hopper can accommodate will be:

$$\text{Mass of feed} = \text{Wet Density} \times \text{Volume of the hopper}$$

$$M = \rho \times V \quad (2.2)$$

$$748.27 \frac{\text{kg}}{\text{m}^3} \times 0.015\text{m}^3$$

$$11.224\text{kg}$$

2.5. Design of the Feed Metering into the Drum/Barrel

The hopper inclination which was considered an important design factor in feed metering into the barrel (opened hopper) was determined using the expression:

$$a = \tan^{-1} \mu \quad (2.3)$$

Where:

a = angle of inclination

μ = coefficient of friction

An angle of 19.7° was obtained for the hopper inclination using 0.36 as the value for coefficient of friction between orange and galvanized steel.

2.6. Design of the Shaft

The weights of the pulley, the fruits, the conveyor belt and the materials being processed all act on the shaft which is the main part of the machine. The shaft transmits power being generated by the gear reduction motor to the conveyor belt when the machine is in operation. The diameter of the shaft was derived from equation (2.4) to prevent torsional and bending stress [8].

$$d^3 = \frac{16T}{0.27\pi\delta_0} \quad (2.4)$$

Where;

d = Shaft diameter in m,

T = Torque transmitted by the shaft in Nm,

δ_0 = yield stress for mild steel in N/m² and

π = constant = 3.142.

If T = 100 Nm, δ_0 = 200 N/mm² and π = 3.142, hence, d = 10 mm. Therefore, a mild steel rod of diameter 10 mm and length 260 mm was used for the shaft.

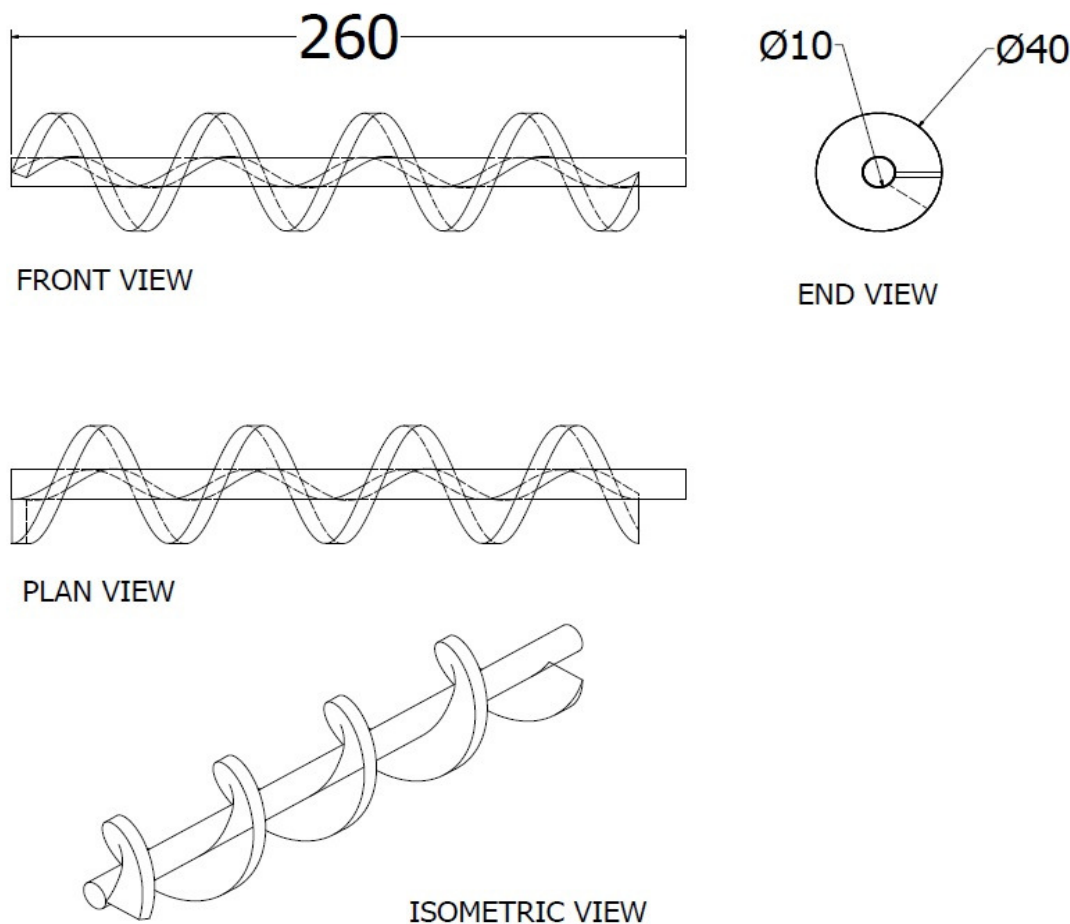


Figure 3 Shaft and screw auger

2.7. Auger Design

This conveys the feed along the shaft pressure plate (die). The pitch of auger must be approximately equal to the screw diameter; therefore the screw length chosen was 225mm. The design formula for auger is given as:

$$P_x = \frac{4DL}{\pi(D-d)N} \quad (2.5)$$

P_x = pitch screw

V = inlet velocity

L = Length of shaft

The inlet velocity (V) is given by;

$$V = \frac{P\pi(D^2+d^2)N}{2DL} = 0.6\text{m}^3/\text{sec} \quad (2.6)$$

2.8. Critical Speed of Shaft (Ws)

The weight of shaft and the weight of screw had an effect on the critical speed of the shaft

$$W_s = \sqrt{\frac{48EI}{ML^2}} \quad (2.7)$$

Where,

E = Modulus of elasticity of steel = $2 \times 10^5 \text{ N/mm}^2$

I = Moment of initial = $\frac{d^4}{64}$

L = Shaft length = 260mm

M = Mass of the shaft = ?

To calculate mass (M) of shaft,

Form "AGE 515" a piece of steel 1m^2 area, by 1m long has a mass of 0.785kg .

$$\begin{aligned} \text{Area of the shaft} &= \frac{d^2 \times 10^2}{4} \\ &= 78.55\text{cm}^2 \end{aligned}$$

Since 1dm^3 of steel has a mass of 0.785 kg/dm^3

$$\begin{aligned} \text{: Mass of the shaft} &= 4\text{dm} \times 4.9\text{dm}^2 \times 0.785 \text{ kg/dm}^3 \\ &= 15.4\text{kg} \end{aligned}$$

$$\begin{aligned} \text{I = Moment of initial} &= \frac{d^4 \times 0.10^4}{64} \\ &= 4.91 \times 10^{-6}\text{m}^4 \end{aligned}$$

Therefore, critical speed of shaft

$$W_s = \sqrt{\frac{48 \times \left(2 \times 10 \frac{\text{kg}}{\text{m}}\right) \times (4.91 \times 10^{-6}\text{m}^4)}{15.4\text{kg} \times 0.4^2\text{m}}}$$

$$W_s = 0.27 \text{ m/s}$$

2.9. Determining the Screw Weight

Using 1.5mm thick plate (n), volume of screw per pitch is given as;

$$\begin{aligned} \text{Volume of screw per pitch} &= D^2h - d^2h \\ &= h(D^2 - d^2) \end{aligned} \quad (2.8)$$

$$\begin{aligned} &= \pi \times 0.026(0.04^2 - 0.01^2) \\ &= 1.23 \times 10^{-4}\text{m}^3 \end{aligned}$$

Since it has 4 pitches, volume of the whole screw is;

$$\begin{aligned} &= 1.23 \times 10^{-4}\text{m}^3 \times 4 \\ &= 4.90 \times 10^{-4}\text{m}^3 \end{aligned}$$

1dm^3 of steel weights = 0.785 kg/dm^3

$$\begin{aligned} 4.90 \times 10^{-1}\text{dm}^3 \text{ will weight,} \\ &= 4.90 \times 10^{-1}\text{dm}^3 \times 0.785 \text{ kg/dm}^3 \\ &= 0.38465\text{kg} \end{aligned}$$

$$=384.65g$$

$$\text{Moment of initial (I)} = \frac{(D^4 - d^4)}{64}$$

$$= \frac{(40^4 - 10^4)}{64}$$

$$=125189mm^4$$

2.9.1. Calculating the overall critical speed

From Dunkley's formula,

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

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

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

$$\omega^2 = 1661.46$$

$$\omega = 40.76$$

Since,

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

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

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

$$=389.18rpm$$

The speed of the shaft obtained was 320.41 rpm and the critical speed 389 rpm. Therefore, since the critical speed was greater than the design speed, the machine worked effectively and efficiently.

2.10. Torsional Deflection

Torsional deflection is due to the torsional load on the shaft.

$$\theta = \frac{584TL}{Gd^4} \quad (2.9)$$

Where:

$$G - \text{Modulus of rigidity} = 84 \times 10^9 N/m^2$$

$$\theta = \frac{584 \times 56.65 \times 0.45TL}{84 \times 10^9 N/m^2 \times 0.010^4}$$

$$=0.154^0 \text{ twist}$$

2.11. Design for Motor Output Power

The design for motor output power enables appropriate selection of a motor with enough power to start and run the machine at full load.

$$\text{Power (p)} = F.V \quad (2.10)$$

Where:

F = potential force acting on the shaft (N)

V = linear velocity of the shaft (m/s) but

$$F = Ma \quad (2.11)$$

Where:

M = mass of the rotating shaft (kg)

a = angular acceleration of shaft (rad/s^2)

$$a = w^2 r \quad (2.12)$$

Where w = angular velocity of the pulley (rad/s)

$$W = v/r \quad (2.13)$$

$$V = WR = 2\pi N r \quad (2.14)$$

Where N = number of revolution (rpm) and other variables are as defined earlier.

$F = ma$ from equation 2.11 and $a = w^2 r$

$$F = Mw^2 r \quad (2.15)$$

$$F = M(2\pi N)^2 r \quad (2.16)$$

From the equation 2.10 where $p = F.V$

$$p = M(2\pi N)^2 r \cdot 2\pi N r \quad (2.17)$$

$$p = M (2\pi N)^3 r^2 \quad (2.18)$$

$$p = 8M(\pi N)^3 r^2 \quad (2.19)$$

Hence, the power is a function of the radius, then

$$p = F(r) \quad (2.20)$$

$$\frac{dp}{dr} = \frac{d}{dr} (8M(\pi N)^3 r^2) \text{ Differentiation}$$

$$= 16M(\pi N)^3 r$$

At turning point,

$$\frac{dp}{dr} = 0$$

$$= 16M(\pi N)^3 = 0$$

$$-r^2 \neq 0$$

Therefore,

$$16M(\pi N)^3 = 0$$

$$\frac{d^2p}{dr^2} = +ve$$

$P = 0$, $r = 0$ at the minimum value.

Since we were designing for maximum power output

N (speed of gear box pulley) = 1337

r (radius of motor pulley) = 0.033m

$M = 660\text{g} = 0.660\text{kg}$ i.e. mass of fan and shaft substituting

$P_g = \text{SMG}$

$$= \left| 3.142 \times 1337/60 \right|^3 \times (0.033)^2$$

$$= 1973.02 \text{ watts}$$

$$= 2.645 \text{ Hp}$$

Power consumed by gear box = $F_f . V_f$

$$= M_{faf}V_f$$

$$= M_{fw}^2 r_{fr} = M_{fw}^3 r_{fr}^2$$

$$= M_f(2\pi N)^3 r_{fr}^2$$

Where M_f = mass of gear box to shaft

F_f = rotational force acting on the gear box (N)

V_f = linear velocity of the fan pulley (m/s)

a_f = angular acceleration of fan pulley in (rad/s²)

Where M_f = mass of fan + mass of shaft

$$= (270 + 390) \text{ g}$$

$$= 660 \text{ g}$$

$$N_f = \text{Speed of the shaft rps} = 1337/60 \text{ rps}$$

$$R_p = \text{radius of shaft (m)} = 0.025 \text{ m}$$

$$\text{By substitution, } P_f = 8(0.660 \text{ kg}) \times \left[3.142 \times 1337/60 \right]^3 \times (0.025)^2 \text{ m}$$

$$= 1131.9 \text{ watts}$$

To horse power (hp);

Therefore,

$$746 \text{ kW} = 1 \text{ hp}$$

$$1131.9 = X \text{ hp}$$

$$X = 1131.9/746 = 152 \text{ hp}$$

$$P_f = 1.32 \text{ kW}$$

Maximum power of blowing = $P_G + P_f$

$$= (1.97 + 1.32) \text{ kW} = 3.102 \text{ kW}.$$

2.12. Fabrication Procedure

A 12-volt DC gear motor was used in driving the feed. A 3/4-inch auger bit that fit perfectly into a housing (a 1-inch black pipe) was used in controlling the feed. First, the auger bit was cut down to suitable length, then the shaft was grinded to fit into the bearing of the gear motor to avoid unnecessary vibration which could damage the shaft of the motor. Then the centre of the black pipe was cut out, giving room for the feed hopper to be connected to the auger housing. The mounting bracket was produced using a small piece of flat bar, giving room for the motor to be attached to the shaft. The auger housing was tack-welded to the mounting bracket after carefully setting up the pieces. When the hopper was welded together, the welding tacks were grinded properly to create a smooth finish. Finally, the auger assembly was welded to the hopper. A storage tank was made by cutting 30X30-inch metal sheets with a grinder and welding them together to give a box shape.

3. RESULTS AND DISCUSSION

3.1. Results

At different times set by the operator using the built-in timer, the machine was able to feed the fishes by dispensing feed across pond for the set distance.

3.2. Operation of the Machine

The feed which comes out of the discharge outlet is gathered in the hopper, when the automatic fish feeder is switched on. The discharge is dependent on the time intervals and the throw

switches off the machine as predetermined by the user based on the schedule required per day. The needed quantity of feed is distributed into the pond after which the machine stops for pre-set hours. After the hours elapse, the machine starts and the same operation continue.

A 12V DC battery which has a life span of about 72 hours when charged completely was used to power the machine. Dry pellets of sizes ranging from 0.5mm to 12mm could be used on the machine.

3.3. Cost Analysis

Table 1 show the materials used in the course of this project and the total cost of the project.

Table 1

Cost of producing the automatic fish feeder

S/N	Material Description	Material Specification	Quantity	Unit ₦	Total ₦
1	Metal plate	800X200 (1.5mm)	1	7000	7000
2	Electrode	Mild steel	3 dozens	1000	3000
3	Solid shaft	Ø40X260	1	2000	2000
4	Electric motor	12v dc motor	1	2000	2000
5	Arduino Uno	Arduino Uno 1.0	1	4000	4000
6	Bread board	Mb-102	1	700	700
7	Labour cost			40000	38,700
8	LCD	16X2	1	700	700
9	Miscellaneous			70000	15000
TOTAL				₦73,100	

3.4. Performance Evaluation

The device was evaluated using pellet (fish feed) got from the Landmark University's Commercial Farm; Omu-Aran, Kwara State, Nigeria. To find out the distance of the fish pellets that machine will dispense, the machine had to be run a couple of times. The pellets used were of two types.

Density of smaller and large pellets used was 0.386g/cm^3 and 0.344g/cm^3 respectively. In testing the feeder, small and large pellets each weighing 10kg were used. The speed of the propeller was 250 rpm and the height of the hopper was set at 80cm, 100cm, 120cm and 140cm. Records of the maximum and minimum distance of the pellets dispensed were taken.

The length covered by the large and small pellets when dispensed at 250 rpm propeller speed from the same opening angle and at various heights is shown in figure 4 and 5. The pellet dispensed much further when the hopper was placed in higher points. It was noticed that the distance covered by the pellets was not really affected by the opening angle of the hopper. A plot of the dispensing width against the hopper height of large and small pellets for a pellet speed of 1000rpm can be seen in figure 6 and 7. Also, an increase in the height of the hopper resulted in an increase in the width of the large and small pellets dispensed.

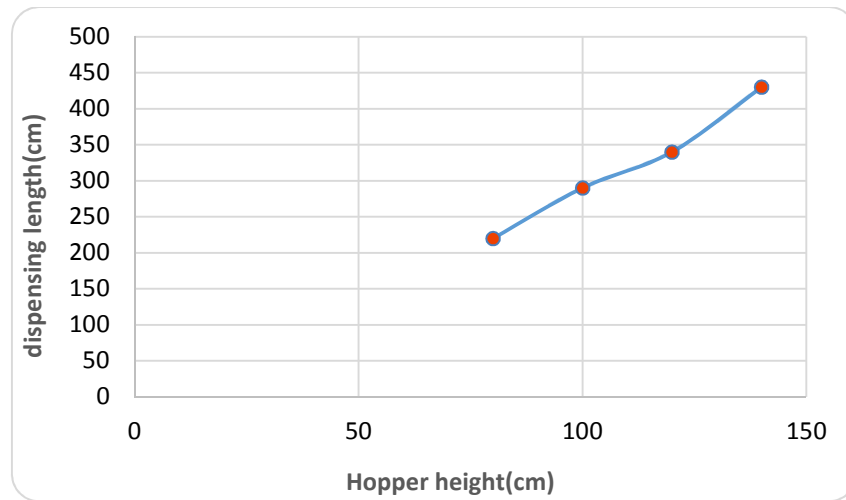


Figure 4 Dispensing length vs hopper height for small pellet

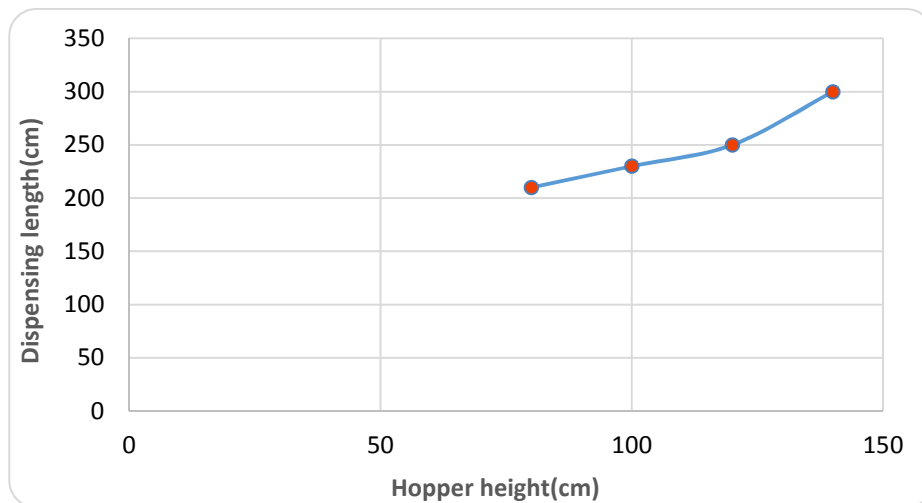


Figure 5 Dispensing length vs hopper height for large pellet

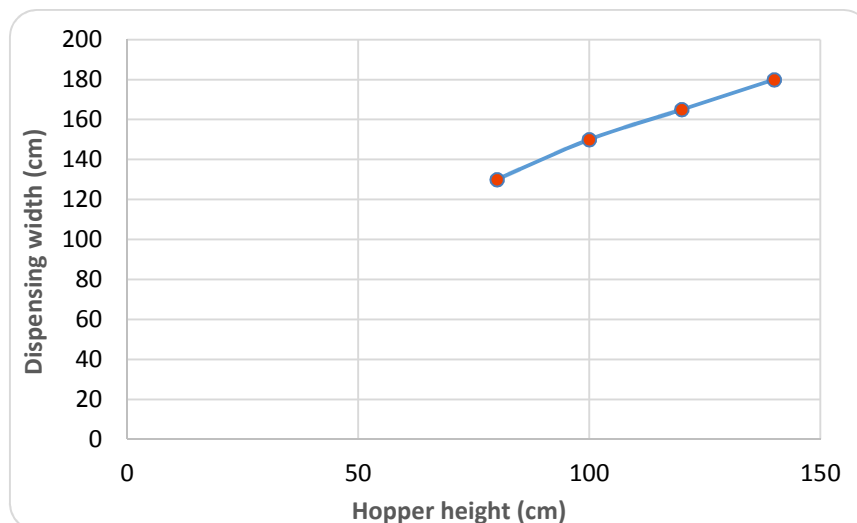


Figure 6 Dispensing width vs hopper height for small pellet

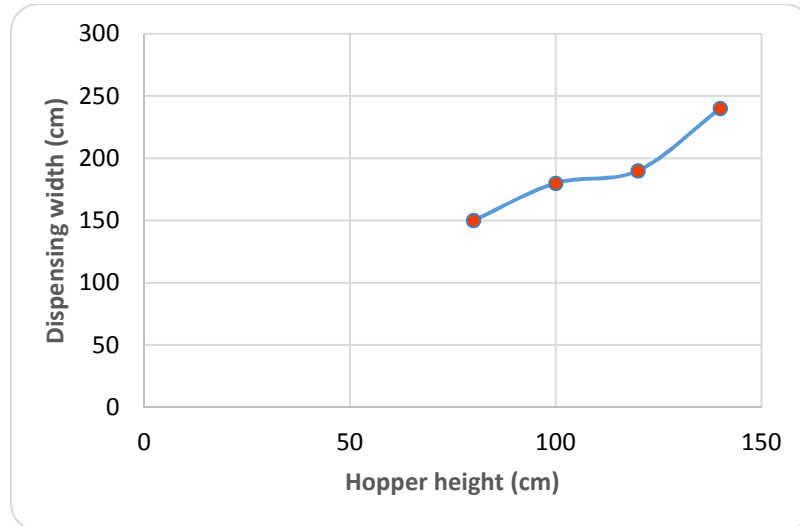


Figure 7 Dispensing width vs hopper height for large pellet

The aggregate of fish pellets dispensed at various times intervals were ascertained with the aid of distinct tests. For large and small pellets, the dispensing rates were around 200g/min and 300g/min respectively, and so we can assume the dispensing rate to be constant always.



Plate 1 Full side view of the automatic fish feeder



Plate 2 Full view showing the hopper, storage tank and the cage fish pond

4. CONCLUSION AND RECOMMENDATION

4.1. Conclusion

This research has successfully devised a means whereby fish farmers can effectively feed their fishes while cutting down on the number of workers employed in their farms, thereby reducing the cost of production. From the various analysis carried out, it can be said that the main objectives of this research were successfully achieved. 12V DC voltage motor has been used to control the rotation speed of the motor. The speed to be used will be determined by the voltage drop at the DC motor.

4.2. Recommendations

To improve the performance of this machine, the following should be done.

- I. The automatic fish feeder should be powered by solar energy.
- II. An auto efficiency check device could be developed to indicate efficiency drop overtime which will enable farmer to carry out servicing on the machine to restore its efficiency.

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