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Development and Performance Evaluation of an Automatic Fish Feeder

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Abstract

Aquaculture, the process of raising aquatic animals in ponds, is gaining more attention in recent times. The feeding system is an important aspect of aquacultural practice. A simple, relatively inexpensive automatic fish feeder was designed, constructed and evaluated. The operation of the feeder does not require highly technical expertise. This paper reports the design considerations, materials used and the effectiveness of the device, based on analysis of manual feeding and automatic feeding. The main features of the device are: hopper (stainless steel), bi-directional motor, feed platform and electrical control box. The design was based on specific parameters which included capacity of culture tank, stocking density, fish biomass, diameter of the feed, angle of repose and bulk density (of the feed). The total cost of the device was 17,000 naira (approx. 106 U.S. dollars). The device was tested under two culture tanks (0.75 m^3 each) with 10 kg-33 juvenile cat fish (*Clarias gariepinus*) placed in each tank with one feeding automatically and the other, manually. The feeder evaluation was based on feed conversion ratio (FCR) and feeding efficiency (FE).

The total average gain in weight per fish was higher in the automatic feeding (89.50 g) than in manual (78.50 g). An FE of 20.9% was obtained in the automatic feeding and 18.6% in manual, in relation to their FCRs. A t-test, conducted at 5% significance level, indicated a significant difference in the two feeding methods.

Keywords: Automatic feed dispensers; Aquaculture; Fish ponds; Feeding; Catfishg

Introduction

Aquaculture (fish cultivation), a rapidly- growing entrepreneurial activity, contributes to food security and poverty alleviation in many developing nations. Feeding is one of the most important aspects of fish growth and production. A major challenge facing aquaculture development is the management of feeding systems. Feed adjustment to meet fish requirement is very important for income/benefit maximization. Feeding frequency is thus an essential consideration. Aderolu et al., [1] studied the effect of feeding frequency on growth performance, feed utilization and economic viability of African catfish (*Clarias gariepinus*).

The efficiency and profitability of aquacultural practice could be enhanced with improved technology. This has necessitated the design, development and construction of automatic feeding devices to meet feeding needs and to reduce labor requirements, thereby reducing the cost of fish production.

Mohapatra et al., [2] developed and tested a demand fish feeder, fabricated with Fibre Reinforced Plastic (FRP) material. The feeder was specifically for carp, and was tested in outdoor culture systems. Demand feeders, controlled by the fish needs, could be bait- rod (pendulum)-type or submerged plate-type [3]. Tadayoshi [4] developed an automatic fish feeder which had the capability of sensing uneaten feed. Noor et al., [5] designed an automatic fish feeder using PIC microcontroller. The basic components of the feeder are pellet storage, former, stand, DC motor and microcontroller.

While several automatic fish feeders are available in developed nations, they are scarce in Nigeria and other developing countries (e.g. Anyadike et al., [6]), mainly attributable to the cost of importation. In their design, Anyadike et al., [6] utilized a plastic hopper, with a galvanized-metal discharge chute and a valve attached. The device is capable of discharging 240 g of pelleted feed in 120 seconds. The objective of this work was to develop and evaluate the performance of an automatic fish feeder- to enhance aquacultural practice.

Materials and Methods

Design considerations

Some properties of the feed pellet considered were: angle of repose, specific gravity and bulk density. Also, parameters considered were:

1. Culture system
2. Capacity of the pond (culture tank)
3. Stocking density
4. Average feed requirement
5. Capacity and shape of the hopper
6. Discharge rate through the outlet of the hopper
7. Power requirement by the motor
8. Operation time and operation interval.

Fish biomass=capacity of the tank × stocking density (1)

Daily Feed Need=fish biomass x % of the body weight feeding (2)

$$\text{Amount of feed needed per operation} = \frac{\text{Daily feed need}}{\text{number of operation per day}} \quad (3)$$

Discharge rate through the outlet of the hopper [7], $Q = \frac{\pi g}{16k} \rho D^3$ (4)

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Where:

Q=volumetric flow rate, m^3/s

D=orifice diameter, m

g=acceleration due to gravity, m/s^2

k=coefficient of drag

ρ=bulk density, kg/m^3

Mass flow rate=volumetric flow rate x average density of the pellet (5)

Time of operation=amount of feed needed per operation/mass flow rate (6)

$$\text{Operation interval(OP)} = \frac{\textit{number of hours per day}}{\textit{number of feedings per day}} \quad (7)$$

Design of control box (Timer)

The 555 timer IC can be configured in three different modes: astable, monostable and bistable. The astable and monostable were adopted for this project. These devices are precision timing circuits capable of producing accurate time delays or oscillation. In the time-delay or monostable mode of operation, the time interval is controlled by a single external resistor and capacitor network. In the astable mode, the 555 timer acts as a "one-shot" pulse generator. The time of operation was calculated to be 3 sec, and the range of the operation was assumed to be 1 to 10 sec. The variable resistor that can delay for this period was calculated from the equation.

Monostable (Timer)=1.1RC (8).

Description of the device

Figures 1 and 2 shows the general features of the automatic fish feeder. The component parts of the machine (device) include: the hopper, top cover (LID), the base (comprising the motor and feed platform) and the electrical control box. The hopper is made of stainless steel (1mm thickness) and it is of composite shape (cylindrical and fulcrum). The top cover is made of the same material as the hopper and it protects the feed from rain and contaminants. The base consists of 6V, 3W bi-directional motor and feed platform attached to it. The feed platform opens and closes the discharge outlet as the motor rotates. The electrical control box controls and regulates the feeding operation and the frequency.

Operation of the machine

The hopper contains the feed which comes out through the discharge outlet. When the machine is switched on and reset, the feed platform moves in bi-directional (to and fro) motion, during which there is opening and closing of the discharge outlet for pre-determined period. The desired amount of the feed would be dispensed into the pond and this completes an operation. After the operation is completed, the machine will automatically stop for preset hours (1, 2, 3............ hrs) based on the number of operations needed per day. When the hours are completed, the machine will start again and dispense the same amount of feed as in the previous operation, and the operation continues.

The machine is powered by electricity and it has a back-up (6V battery) which can last for at least 3 days (72 hrs) when fully charged. The device can be used for both local and imported dry pellet of size 0.5 mm-9 mm. The cost estimate for the production of the machine was ₦17,000 (approx. US $106). The construction materials and the Bill of Engineering Measurement and Evaluation (BEME) are shown in Tables 1 and 2, respectively.

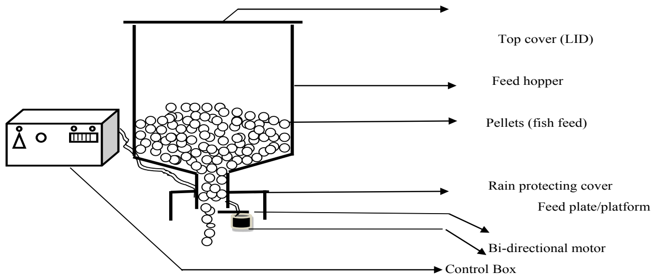

Figure 1: The Automatic Fish Feeder.

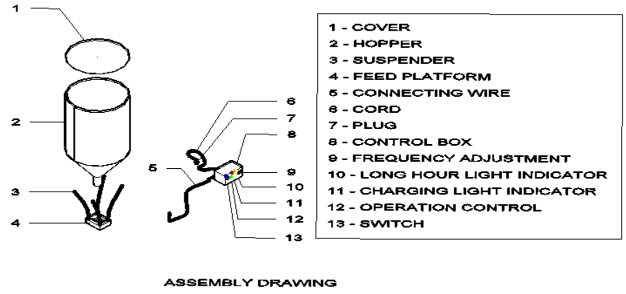

Figure 2: Assembly drawing.

Performance evaluation

The performance evaluation of the device was conducted using a recirculatory aquaculture system (RAS) located behind the Department of Agricultural and Biosystems Engineering, University of Ilorin; Ilorin, Nigeria.

Ilorin (longitude 4°35'E, latitude 8° 30'N), the capital of Kwara State of Nigeria, has two main seasons: wet (March-October) and dry (November-February). The experiments were conducted from April to June, 2013, involving two culture tanks, each of 0.75 m^3 volume, with 10 kg-33 juvenile catfish (*Clarias gariepinus*) placed in each tank with one feeding automatically and the other, manually.

"Durante" fish feed, weighing balance and meter rule were also used in the investigation. The feeder was placed over a stand fixed at the corner of the culture tank. Growth rate of fish was estimated by sampling 10 fishes from the rearing tank every week (7 days interval). The feed conversion ratio (FCR) and the feeding efficiency (FE) were used for the performance evaluation:

$$FCR = \frac{\textit{total amount of the feed given}\,(\text{gram})}{\textit{total gain in weight by the fish}\,(\text{gram})} \quad (9)$$

$$FE = \frac{1}{FCR} \quad (10)$$

Results and Discussion

Tables 3 and 4 show the catfish growth rate for automatic and manual feeding, respectively.

For the automatic feeding (Table 3);

Components	Materials Used	Dimensions	Remarks
1. Lid	Stainless steel (1 mm thickness)	260 mm (diameter)	Cut out and folded to make a cover
2. Upper Cylinder	Stainless steel (1 mm thickness)	300 mm x 790 mm	Cut out and folded to form a cylinder of 250 mm diameter
3. Frustum	Stainless steel (1 mm thickness)	195 mm x 790 mm	Cut and folded to form a frustum of upper diameter of 250 mm and base diameter of 30 mm, height of 150 mm. The frustum joined to the upper cylinder at an angle of 50°.
4. Base Cylinder (outlet)	Stainless steel	50 mm x 95 mm	Cut and folded to form a cylinder of 30 mm diameter. Then welded to the base of the frustum.
5. Base	PVC, motor and wire		PVC used to cover the motor, also as feed platform. The wire connects the base to the control box. The base was suspended to the feed hopper using copper wire.
6. Control Box	PVC, veroboard, resistors, capacitors, transistors, relays, 555 timers, transformer, diodes and regulator.		PVC used for casing. The components were laid on the veroboard.

Table 1: Construction materials.

Materials	Quantity	Unit cost (₦)	Total cost (₦)
Stainless steel	¼ sheet	4,000 (1/4 sheet)	4,000
Acrylonitrile plastic steel	½ sheet	1,000 (1/2 sheet)	1,000
Transformer (220-9V)	1 piece	500	500
Resistors (R1,R2,…R9)	....	500	500
Capacitor (C1, C2, …C9)	....	500	500
Bi-directional motor (6V-3W)	1 piece	2000	2000
LED (D1, D2, D3)	....	200	200
Integrated Circuit (IC1, IC2 and IC3)	....	1500	1500
Regulator (RG1,RG2)	....	500	500
Relay (RL1, RL2 and RL3)		1000	1000
Variable Resistor	....	300	300
Hopper construction workmanship and other costs			5,000
Total			17,000

Table 2: Bill of Engineering Measurement and Evaluation (BEME).

S/N	Date	Number of Fish	Average weight of fish (g)	Total feed consumed per fish (g)	Average gain in weight per fish (g)
1	16/04/2013	10	300.00	0.00	0.00
2	23/04/2013	10	305.00	42.00	5.00
3	30/04/2013	10	313.50	43.00	8.50
4	7/05/2013	10	323.00	44.50	9.50
5	14/05/2013	10	335.50	46.00	10.5
6	21/05/2013	10	345.50	47.00	10.30
7	28/05/2013	10	355.53	49.00	9.80
8	04/06/2013	10	365.80	51.10	10.5
9	11/06/2013	10	377.20	52.00	11.40
10	18/06/2013	10	389.20	53.40	12.00

The total average of feed consumed per fish during the period of the experiment = 428.00 g
The total average gain in weight per fish during the period of the experiment = 89.50 g

Table 3: Growth rate of catfish for the automatic feeder.

$$FCR = \frac{428}{89.5} = 4.78$$

$$FE = \frac{1}{4.78} = 20.9\%$$

For manual feeding (Table 4);

$$FCR = \frac{421.50}{78.50} = 5.37$$

$$FE = \frac{1}{5.37} = 18.6\%$$

A t-test was also used in analyzing the data. Table 5 shows the result of the statistical analysis, at 5% significance level.

Conclusion

An automatic fish feeder was designed, constructed and evaluated. Its main components are: hopper, bi-directional motor, feed platform and electrical control box. The device was incorporated into a recirculatory aquaculture system (RAS) and the evaluation was based on feed conversion ratio (FCR) and feeding efficiency (FE) using juvenile catfish (*Clarias gariepinus*). The feeding efficiency was higher in the automatic feeding (20.9%) than in manual (18.6%). Use of the automatic feeder will improve aquacultural practice.

S/N	Date	Number of Fish	Average weight of fish (g)	Total feed consumed per fish (g)	Average gain in weight per fish (g)
1	16/04/2013	10	300.00	0.00	0.00
2	23/04/2013	10	304.00	42.00	4.00
3	30/04/2013	10	312.50	44.00	8.50
4	7/05/2013	10	320.20	45.00	7.70
5	14/05/2013	10	329.00	46.00	8.80
6	21/05/2013	10	335.00	46.50	8.00
7	28/05/2013	10	344.50	47.00	9.50
8	04/06/2013	10	354.70	49.00	10.20
9	11/06/2013	10	365.50	50.00	10.80
10	18/06/2013	10	376.50	52.00	11.00

The total average of feed consumed per fish during the period of the experiment=421.50 g

The total average gain in weight per fish during the period of the experiment=78.50 g

Table 4: Growth rate of catfish for manual feeding.

Feeding Method	Mean gain in weight per fish(g)	Standard deviation (g)	t-test value
Automatic feeding	8.95	3.57	1.077
Manual feeding	7.85	3.23	0.973

The mean gain in weight per fish in automatic feeding was higher than in manual.

Table 5: Result of statistical analysis.

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