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RESEARCH ARTICLE OPEN ACCESS

Prototype of an automatic feeder usingmicro-controlled platform ARDUINO UNO®and relay module

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ABSTRACT
The proper application of an automated feeding system provides increased productivity and feed efficiency, as well as batch uniformity andhomogeneity in sex. This study aimed to develop a prototype of an automatic feedera low cost to the industry, by means of a micro-controlled platform called ARDUINO UNO® aided by the relay module, which had the ability to supply the previously programmed parceled feed.Were used for the development of the prototype: structure for flotation and support, feed reservoir and screw conveyor, along with a motorand electronic systems.The programming language used was C, with the aid of Arduino Uno 1.0.3 software. The electronic feeding system used a rechargeable 12-volt battery with a supplying capacity of seven amps per hour. The experimental results showed that the system can obtain reliability of the equipment's precision and the feeding intervals.The automatic feeder has shown to be effective in terms of food supply and functionality throughout the test stage being a cost-effective alternative to commercial scale.

KEYWORDSaquaculture;automation; microcontrollers; feeding frequency.

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I. INTRODUCTION

The feeding of farm animals is based on a correct management where some factors are fundamental, such as choosing high-quality feeds and planning feeding times, as well as determining adequate frequencies and quantities of feed to be supplied, seen that these factors can greatly influence both the animals' performance and the economic return of the activity (Erieghaand Ekokotu, 2017). However, in most fish farms, feeding is still performed manually over excavated ponds or net-cages, which is consequently subjected to failures and losses, thus negatively affecting operational costs, the development of animals and the optimization of labor, among others (Ribeiro et al., 2012).

Food automation is beneficial for productivity, batch uniformity and for the improvement of the animals' productive performance, due to the possibility of providing a fractionate feeding, thus improving the use of feeds by the fish, as long as the machines are efficiently developed. In this sense, it acts by releasing the feed in pre-established intervals and specific portions, which is interesting especially in early development stages of fish (Tanveer et al., 2018).

The use of automated equipment animal production especially those that employ programmable logic controllers and microcontrollers, which have wide applications in industrial processes must be constantly updated to reduce production costs (Alphonsus and Abdullah, 2016). And increased productivities of in aquaculture systems can provide a better availability of individuals, thus benefiting the productive sector as a whole, and expanding the technological process of the current production (Bostock, 2011).

The Arduino microcontroller has a single open source board, which can be easily programmed, deleted and/or reprogrammed, being used in electronic processes of multidisciplinary projects as it is more affordable (Sethuramalingam and Karthighairasan, 2012). Its board has complementary components that facilitate programming and incorporation into other circuits, which can be performed from different complementary modules, controlling a variety of electronic devices (Rajan et al., 2015).

In this sense, this study aimed to develop a prototype of automatic feeder used in aquiculture, a low cost to the industryby means of a micro-controlled platform called ARDUINO UNO® aided by the relay module.

II. MATERIALS AND METHODS

The prototype was developed by the Aquaculture Management Study Group - GEMAq, of the University of West Paraná, Brazil. The feeder was patented in the register institution: INPI - Instituto Nacional da Propriedade Industrial, deposit 03/02/2017.

Developed prototype

The model consisted of a feed reservoir, motor-reducer, battery, connector, main tube, conveyor screw, floating base, and an automatic feeding system controlled by a micro-controlled platform ARDUINO UNO®, and a relay module.

Construction details

Floating Base

The floating base was made of polyethylene vinyl (PVC), which is resistant to corrosion and is adequately buoyant. Five tubes of one meter each were used, as well as two plugs and four curves of 100 mm. A 50 x 50 x 3 cm plastic flooring was used (four pieces for 1 m^2 area), made of high-density polyethylene (HDPE).

Feed Reservoir

The reservoir was developed in fiberglass material with a lid, in dark color to prevent the oxidation of the hormone17-α-methyltestosterone. The dimensions of the reservoir were 45 cm height, width with larger radius of 11.5 cm and shorter radius of 2.5 cm, with a total storing capacity of 5.92 kg of bran feed (which may be altered due to the diet's grain size).

Connector

The connector was made of PVC and used to connect the feed reservoir with the main tube of the conveyor screw. It has three cylindrical sections (58, 50 and 30 mm), of which two are joined by non-toxic plastic adhesive and the third has its inner area screwed, in order to enable the insertion with the feed reservoir.

Conveyor Screw

The conveyor screw was machined on a nylon mechanical lathe with a 37 mm external diameter, 25 mm internal diameter and a thread pitch of 24 mm. Nylon was used because it does not corrode or oxidize. A screw-motor connection piece was manufactured on its edge for its normal functioning.

Main Tube

The main tube was manufactured with PVC material with a diameter of 40 mm and 37 cm in length. The conveyor screw is located inside the tube, while in its edges there are T-type connections, both being responsible for the input and output of the feed, respectively. In one of the edges, there is a set of bushings and a bearing with the function of supporting the end extremity of the conveyor screw. The other extremity is responsible for the circumference of the connector screw-motor, where this does not have physical contact.

Battery and D.C. Motor

The battery used was a valve-lead acid type, with an average working voltage of 12 volts and a load capacity of seven amperes per hour. Its average weight is 2 kg, with the following dimensions: 15 cm length, 6 cm width and 10 cm height.

The motor is a direct current type with brushes and permanent magnets. It has a reducinggearbox that reduces the output rotation and increases torque. Regarding its technical characteristics, the D.C. motoroperates at 12 volts, being compatible with the tension provided by the battery, and displaying an average empty working current of 0.8 amperes.

Micro-controlled Platform Arduino Uno®

The choice for the ARDUINO UNO® micro-controlled platform was due to the fact that the micro-controller Atmega 328 has sufficient processing characteristics for the time counting used in the system, a working load higher than necessary for the activation of peripherals, and its programing is based on simplified codes for the use of libraries that are implemented and open for modifications (Arduino Uno, 2015).

Relay Module

This two-channel 5-volt relay module was the best alternative for the representation of a compact, high-quality module to be used in projects with Arduino Uno®and other controllers. The module was equipped with high-quality transistors, connectors, LEDs, diodes and relays. Each channel has a LED to indicate the output state of the relay (Módulorele, 2014).

Electrical Circuit

The electrical circuit consisted of a micro-controlled platform ARDUINO UNO® fed by a 12-volt battery (Figure 1). The 5-volt output of the

Arduino Uno, together with pin eight and ground (GND), were connected to the respective pins of the relay module. When the module receives the signal from the micro-controller Arduino Uno, it closes the circuit that activates the continuous current motor (motor CC). This motor has its GND connected directly to the battery and its positive pin connected to the normally open contact of the relay module, while the GND of the module is connected to the 12-volt pin of the battery. When the Arduino Uno sends a signal to the relay module, it activates the motor by closing the normally open contact. Due to the potential difference provided by the battery applied to the D.C. motorterminals, this begins functioning.

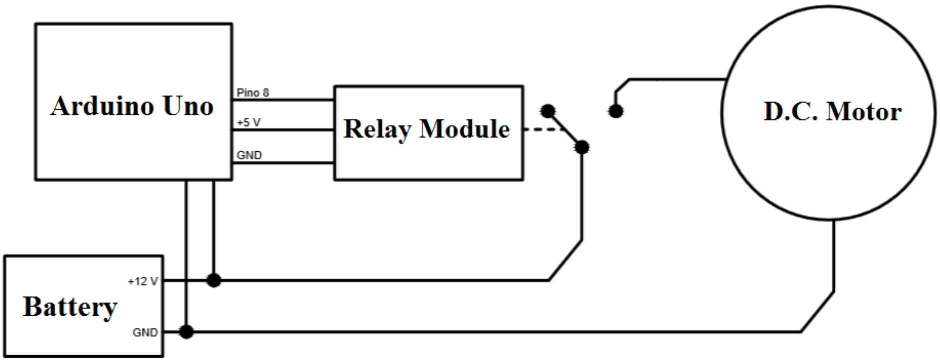


Fig 1 Electrical circuit responsible for the switch controlling the continuous current motor

Programming

The feeder’s programming was developed in C programming language, with the aid of the software *Open Source* (open code), supplied by the manufacturer of the micro-controlled platform ARDUINO UNO®, which is explained in Figure 2.

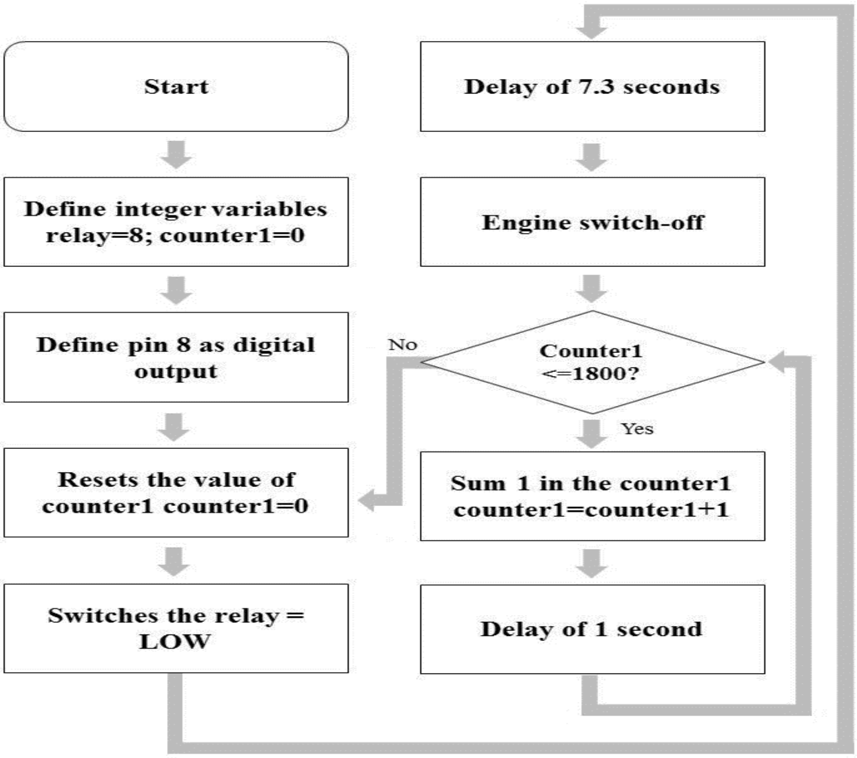


Fig 2 Flowchart of the systematic detailed description of the developed programming

Two variables were initially assigned in the programming of the feeder, the first of which was identified by an integer relay with value 8, while the second with a value 0, called counter 1. Both variables aided the system's configuration and control.

The second step of programming regarded gates configuration, i.e. the step where the following were defined: input, output and analog or digital; therefore, the relay variable was a digital output. This meant that as the relay variable has value 8, it became an output. In this sense, pin 8 of the I/O's became a digital output.

Subsequently, the main program was elaborated. The first step was to reassign value 0 for the variable counter 1. Then, the triggering of the relay was initiated by activating the digital output 8, which started the motor. As a waiting period of 7.3 seconds with the motor turned on should be obtained, the delay method with 7.3 milliseconds (ms) was performed. After this waiting period, the motor was turned off with the command that deactivated the digital output of pin 8. As the next feeding cycle, a feeding frequency with 30 min interval was performed, we opted for the utilization of the "while" command, by means of the integer variable counter 1, as the "delay" method did not allow wide values in milliseconds.

In this programming step, the program verified the high value of the integer variable counter 1, and such verification supervised if the counter 1 was lower or equal to 1800. In the first moment, the value of the counter 1 was 0, then the "while" command added a unit of the current value of the counter 1 and waited one second for the "delay" method (1000 ms), then it verified whether the counter 1 value was lesser or equal to 1800 ms. This cycle occurred 1800 times in succession, causing the program to wait 30 minutes to continue. When the 1801 ms was reached, the program returned to the start, resetting the value of the counter 1, starting the motor and continuing the programmed cycle.

The data obtained for the operation test were submitted to both a descriptive statistical analysis and a distribution of the normal standardized frequency, with the aid of the software Statistic 7.0®.

III. RESULTS AND DISCUSSION

Calculation of the Reservoir Volume

Equation (1) presents the calculation of the reservoir volume, while equation (2) presents the density of the powdered feed and equation (3) the real volume of the powdered feed (kg) that fits in the reservoir.

(1) $V= \pi.H/3.(r^2+r *R+R^2) = 9,23$ l

Where:
r: 2.5 cm - 0.025 mm.
R: 11.5 cm - 0.115 mm.
H: 45 cm - 0.45 mm.

Calculation of the Density of the Powdered Feed

(2) $M= m/v$

$Mesp= 34$ g/53 ml = 0.6415*1000 ml = 641.5 g/l

Where:
m: 34 grams of powdered feed.
v: 53 ml.
Mesp: 641.5 g/l.

Calculation of the Real Volume of the Powdered Feed in the Reservoir

(3) $M= m/v$

m= M.v = 641.5 g/l*9.23l.= 5.921 kg of powdered feed.

Mesp: 641.5 g/l.
v: 9.23 l.
m: 5.921 kg of powdered feed.

Based on the results of the calculation of the reservoir volume, it can be considered that the prototype stores a volume of 5.921 kg of powdered feed.

Feed Volume Loaded by the Conveyor Screw

By means of the equation (4), it is possible to calculate the feed volume transported by the screw per turn.

(4) $V= (\pi/4). hi. (D^2 - d^2) = 1.4017x10^{-5}\ m^3$

Where:
D: external diameter: 37 mm.
d: internal diameter: 25 mm.
hi: thread pitch: 24 mm.
M: 641.5 g/l.
V= m/v.
$v= 1.4017x10^{-5}\ m^3*641.5$ g/l.
v= 8.391 g/round.
Where:
$V: 1.4017x10^{-5}\ m^3$
M: 641.5 g/l
v: 8.391 g/round.

As seen in the calculation of the feed volume loaded by the conveyor screw, it was observed that in each complete round, the dispersion of 8.391 g of feed occurs.

Assembly Autonomy (Battery/D. C. motor)

When subjected to a full system load, it consumesa current of 4.9 amperes. Therefore, equations (5) and (6) present the calculation of the assembly autonomy.

(5) $C = I* t =35.77$ As = 0.00993 Ah

Where:
C: consumption
I: D. C. motor's current: 4.9 A
t: time (7.3 s)

(6) a = B/C = 704.93 cycles

Where:
a: cyclic battery life
B: battery load capacity: 7 Ah
C: consumption: 0.00993 Ah

When analyzing the autonomy of the battery/D.C motor, it presents a full charge current of 4.9 amperes, thus this assembly has the capacity of developing 704.93 cycles. The cycles are enough for 14 days of work, being triggered 48 times a day without the necessity of recharge or battery exchange, as shown in equation 7.

(7) T = Ci* Di =48*14 = 672 cycles

Where:
T: total of cycles
Ci: operation cycles of the device
Di: days

Statistical Test

Fifty feed samplings were performed with the functioning equipment during five seconds, in order to measure the reliability of the equipment's precision (Figure 3).Adjustments can be made for different time intervals according to the duration and number of feeding per day.The sample was tested in super intensive production system of the Nile tilapia larvae in cages.

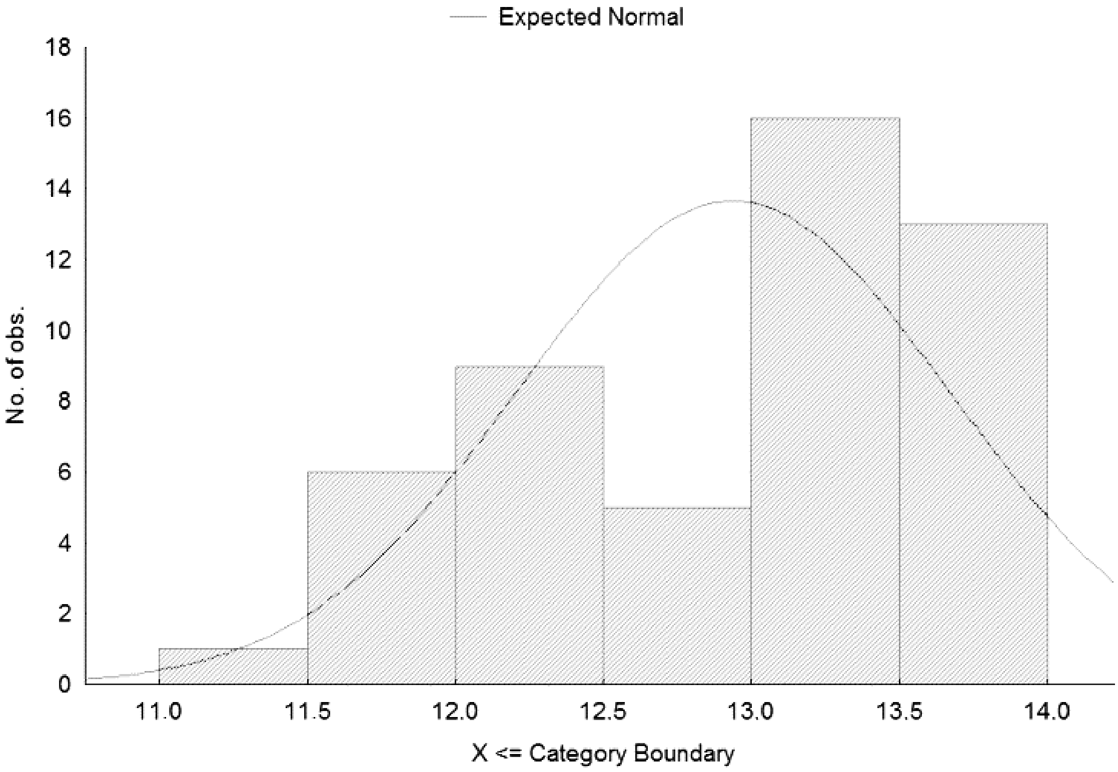


Figure 3. Histogram of the number of samplings in relation to mass.

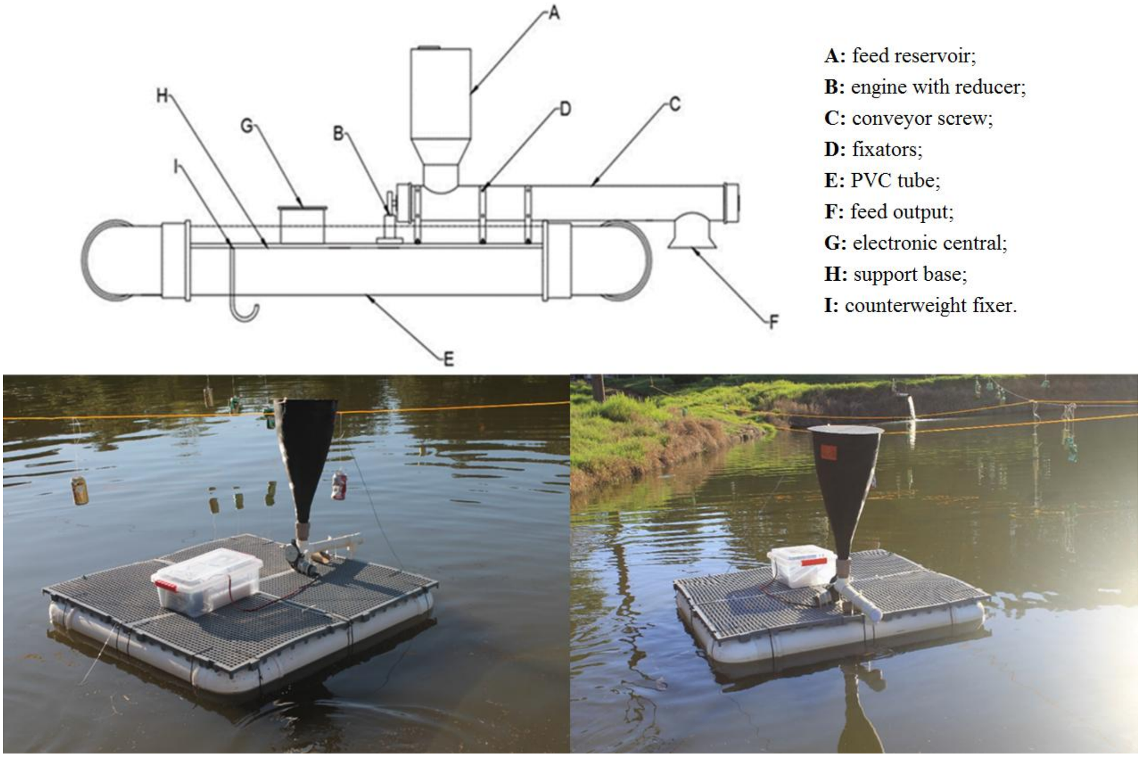
The statistical evaluation demonstrates the efficiency of the prototype concerning the reliability of its functioning and the feeding intervals (Table 1).

Table 1. Statistical data of the 50 feed samplings performed in a time interval of five seconds being turned on and 10 seconds turned off.

Variable	N° of samplings	Mean	Confidence -95%	Confidence +95%	Minimum	Maximum	Standard deviation
Feed	50	12.93853	12.73102	13.14602	11.3658	13.9814	0.730157

By means of the 50 samplings performed with the equipment, the observed mean was 12.94 ± 0.73 g of feed in five seconds. Considering a normal standardized distribution and considering a confidence level of 95%, it was observed that the values found within the interval 12.73 and 13.14 were statistically similar. The maximum observed value was13.98, while the minimum was 11.36 and the median 13.14. The interval between 13 and 13.5 was the most observed, presenting 32% of the total observations.

The prototype of the automatic feeder (Figure 3) performing a complete round of the conveyor screw in 3.24 seconds, releases 8.39 grams of powdered feed. In five seconds, it releases an average of 13.0 grams, while in 7.3 seconds, 18.9 grams are released, demonstrating that the equipment is aligned with the feed's portioning in small quantities and a high feeding frequency.



A: feed reservoir;
B: engine with reducer;
C: conveyor screw;
D: fixators;
E: PVC tube;
F: feed output;
G: electronic central;
H: support base;
I: counterweight fixer.

Fig 3 Prototype of an automatic feeder for Nile tilapia larviculture stage, descriptive and *in loco* controlled by a micro-controlled platform ARDUINO UNO®

For the prototype's development, it was necessary to acquire several components. However, the most cost-effective components were chosen due to their cost-benefit, linked to the high quality and performance of the system.

Regarding the cost of the prototype, the highest individual values are the ones that required a pre-project (Template), for example, the conveyor screw and the feed reservoir, which used a template for its manufacture and became more expensive, representing 37% of the project's overall cost. The final cost of the equipment (prototype) was US$166.24.

The electrical system's costs as a whole were not high, because in addition to these being of easy access and accessible cost, the programming software is free and open code. It is noteworthy that the prototype has in its electronic system other inputs and outputs, which allows the increase of peripherals, such as temperature, pH and dissolved oxygen sensors, wireless communication modules, among others.Another important issue refers to the structuralsystem. It was developed with a flotation system, but it also allows the development of a fixed system in a terrestrial medium.

The feeding frequency, rate and period are determinant factors for the optimal productive performance of fish. An increased feeding frequency, performed in accordance to the animals' developmental stages, can improvefish's performance in terms of growth, uniformity and survival (El-Husseiny et al, 2004;Kumar and Angle, 2016; Lanna et al., 2016).

Li et al. (2014), propose that feeding frequencies of 3 to 5 times a day increase the growth of juveniles of *M. amblycephala* and that frequencies greater than 5 times and less than 3 times result in lessened development, increasing oxidative stress, immunosuppression and higher risk of disease. However, according to Souza et al. (2012), tilapia feeding frequency influenced the performance of juveniles when using the frequency of one feeding per hour during 24 hours per day, with a 7.5% increase in fish growth, when compared to fish fed only at a time during the day. Moreover, automated feeding maximizes the process of feeding the fish during the reversal process, which can enhance the reliability of the reversal process with the use of hormones.The importance of nighttime feeding as a great ally for the productive development of species for fish's is also emphasized(Brito et al., 2017).

In *Sparus aurata*larviculture, an automated system was developed with a programmable logic controller (PLC), which controls a peristaltic pump and transfers live feed from the feed container to the larviculture tanks, allowing an efficient access to feed and, consequently, providing greater uniformity of larvae’s growth (Papandroulakis, 2002).

The implementation of automation and improvements in technology are beneficial in several productive stages and are fundamental to increase fish farming’s profitability and sustainability. In this sense, it is possible to make production more efficient, by minimizing productive cycles and labor costs(Kumar, Engle and Tucker, 2018).

IV. CONCLUSION

The proposed prototype presents a system controlled by a micro-controlled platform ARDUINO UNO®, which allows feeding to be portioned and pre-programmed according to the demands of each producer.It is proven that technology is stable, reliable with timely command response, provide technical support and reference for the cost reduction in the manufacture of automatic feeders assisting the aquaculture.

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