Microcontroller-driven Feeding Management and Automation for *L. vannamei* Shrimp Aquaculture

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Abstract— **Shrimp is highly valued in the seafood industry by many people worldwide. This study aims to properly designate the correct amount of shrimp feed based on sampling the shrimp farm in proportion to the age and weight of the L. *vannamei* and deploy a system that will automate the proper feed distribution through the integration of microcontrollers. This study also includes a pond monitoring system to ensure that the pond's water quality is adequate for the shrimp's cultivated health and development. The researchers compare shrimp development in culture ponds using an automated feeder and a manual feeding approach to determine the efficiency or effectiveness of the computerized feeder for managing feeds. The growth analysis is divided into two ponds (1 and 2). For measuring shrimp development, the automated feeder favored pond 1, whereas pond 2 for manual feeding. This study found that utilizing an auto feeder increased shrimp growth rates by ensuring they were adequately fed based on the average body weight of shrimp every sampling and made them healthier by using sensors to monitor the pond's water quality. The researchers successfully developed the automated feeder and tested it many times, obtaining a total accuracy of 96.21%.**

***Index Terms*— Feeding Management, Automation, Automated Feeder, Microcontroller-driven Feeding Management, Automatic Feeder with Pond Monitoring System**

I. INTRODUCTION

Since shrimp aquaculture began in the Philippines in the 1980s, the Philippines has become one of Asia's leading shrimp producers. In December 2013, the Philippines' Bureau of Fisheries and Aquatic Resources (BFAR) registered 271 brackish water shrimp farms (with a total area of 3,617.8 ha) [1].

Penaeus monodon (Tiger Prawn) and L. vannamei (Pacific White Shrimp) are the two most common farmed shrimp varieties. Penaeus monodon, also known as P. monodon, is grown in 48 percent (1,772.6 ha) of the country's shrimp farms. The L. vannamei is cultivated on 27% (909.4 ha) of shrimp farms, while other shrimp varieties, including the Endeavor shrimp, are grown on the remaining 25% (935.8 ha). Due to the difficulties of raising P. monodon, farmers have shown an interest in cultivating pacific white shrimp. Disease issues have afflicted the P. Monodon culture, and farmers have had trouble finding pathogen-free seeds. Rising feed and electricity prices are also issues. Because of its resistance to specific diseases, low nutrient demand, and competitive rates in the domestic market, the species L. vannamei is attractively marketable [2].

Due to its higher growth rate of 1.0 to 1.5 grams (g) per week relative to P. monodon's growth rate of 1 g/week, many farmers in the Philippines are now choosing L. vannamei over P. monodon. L. vannamei shrimp are often more standardized in size at harvest, eliminating the need for sorting before distribution to the market [3]. Several factors, such as the harvest ton, mean body weight, survival rate, and feed conversion ratio, can all be used to quantify shrimp growth and production. According to previous research, the shrimp feed conversion ratio should be proportional to their mean body weight [4]. This variety of shrimp also consumes feed regardless of light and dark conditions, according to research that looked at the feeding pattern of L. vannamei [5]. Floods, typhoons, and monsoon rains may all significantly impact shrimp farming. Shrimp development has slowed, disease resistance has increased, and mass fatality has occurred because of pollution from watershed activities and self-generated organic load [6]. The shrimp aquaculture industry depends upon the proper feeding and harvesting techniques. The first step in appropriate feed management at the farm level is choosing and buying a feed that will expand production under the cultivated shrimps [7]. Traditionally, the shrimp needs to feed 1-4 times a day. Still, the advent of automated feeders has enabled farmers to increase the number of feedings without raising the labor needed [8]. However, Ullman et al. (2018) presented that feeding six times compared to 2 times increased significantly. Theoretically, increased feeding frequency results in higher nutritional feed content because nutrient leaching is reduced [9].

The nutritional performance of a shrimp feed depends upon five interconnected factors, namely: the nutrient content and composition of the diet fed, the physical properties and water stability of the diet provided, the transportation and storage of the diet before giving feed on the farm, the feeding method employed for feed application and usage on the farm; and the farming system, stocking density, water management, and availability of natural foods [10]. Shrimp feeding is essential to avoid losing profits due to the high cost of shrimp feeds. It can minimize feed cost in L. vannamei culture. The feed conversion ratio would be low for the duration of cultivation by appropriately implementing the prescribed feeding guide and selecting the proper feed to utilize. However, the variability in behavior and feeding patterns of shrimp raised in shrimp culture ponds is still poorly known. Adopting good feed management practices will help to reduce water quality problems and increase shrimp production success. Diets are used in semi-intensive cultures to boost production beyond the pond's natural productivity standards, which can take up to 85 percent of the shrimp's diet. However, it's crucial to specify how feeding rates affect survival, weight gain, growth, productivity per hectare, and the total biomass [11]. According to Fox et al. (2001), The farmer will apply the feed regularly and only in the amount consumed rapidly to maximize growth and minimize waste. Historically, farmers applied the feed; consumption tracked using manual labor to spread and inspect feeding trays [12]. Automatic feeders are becoming more popular because of their ability to provide more feedings per day while requiring less labor than manual feeding [13]. Another advancement is using hydrophones to track the shrimp's feeding response in the pond to assess the feeding activity and then provide based on that response [14]. All these technological advancements can benefit both productivity and water quality.

This study aims to properly designate the correct amount of shrimp feed based on sampling the shrimp farm in proportion to the age and weight of the L. *vannamei* and deploy a system that will automate the proper feed distribution through the integration of microcontrollers. It also includes a pond monitoring system to ensure that the ponds' water quality is adequate for the shrimp's health and development while cultivating.

This application will help the shrimp industry of the Philippines to maintain the ranks of worldwide shrimp aquaculture by helping shrimp farmers be more efficient and technologically precise through accumulated data of feeding practice. This study will reduce the cost of cultivating shrimp farms by ensuring that overfeeding, feeding waste, and water and soil quality deterioration will not improve shrimp development. This new project will be a milestone in technology and aquaculture. This study would become an excellent reference for future computer engineers dealing with the fusion of aquaculture and technology.

For this study, the preferred feed for L. *vannamei* is Blanca Vannamei Feeds from Charoen Pokphand. Foods Philippines Corporation. The meal provides precise essential amino acids, vitamins, minerals, and other vital nutrients for optimum growth and enhanced immunity against stress. This preferred feed is according to the product guide given by manufacturers [15].

The extent of this research covers the classification of the current weight and age of the shrimps in correlation to the correct feeding guide of the preferred brand by local farmers. This research also covers the automation of the feeding process but not in real-time. This system is a prototype and will not be industrial-sized. The stocking of feed will be done manually and not include the harvesting process.

II. MATERIALS AND METHODS

For this study, applied research is an outline for the whole duration. It aims to develop a system that will determine the correct amount of shrimp feed and automate the feeding process via microcontroller data comparison and manipulation.

For the development of the system, knowledge in circuitry, electronics, and microcontroller programming is involved.

A. Conceptual Framework

Fig. 1 shows the conceptual framework of the study. The input is the weight of the shrimp concerning the age of the shrimp. It will undergo the process of the pond monitoring system that determines the water temperature, pH acidity, and water level of the pond. Determining the feed amount and feeding schedule based on the input and conditions of the software. These processes will yield a system that automates proper feed distribution.

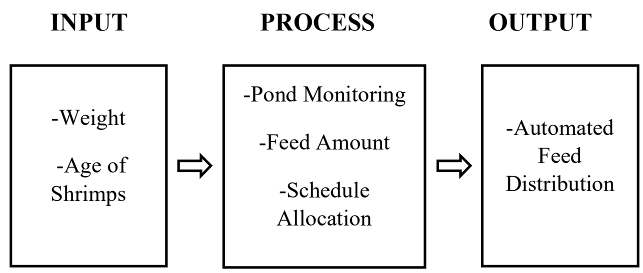

Fig. 1 Conceptual Framework

B. Material and Resources

The design involved three parts of the mechanical system: the shrimp feeds container, automated supporting system, and disseminator—the shrimp feed container designed with two parts. The first part is the container attached to the second part (mechanical supportive system). Fig. 2 shows the whole system.

The shrimp feed container is made of a steel plate 0.8 mm thick, 12 x 10 inches in width, and 17 inches in height. The feed container can have 2 kg feeds in it. The researchers used Visual Studio software to design the research's user interface, and a series of codes will be implemented using the VB.NET language. All codes from the pond monitoring system to an automated feeder will be coded separately to quickly detect software errors when debugging and troubleshooting. The proponents built the device with a steel container with an acrylic glass design to ensure good feed storage. The feed's vitamins, minerals, and other essential nutrients will not be degraded and help deter birds and pests.

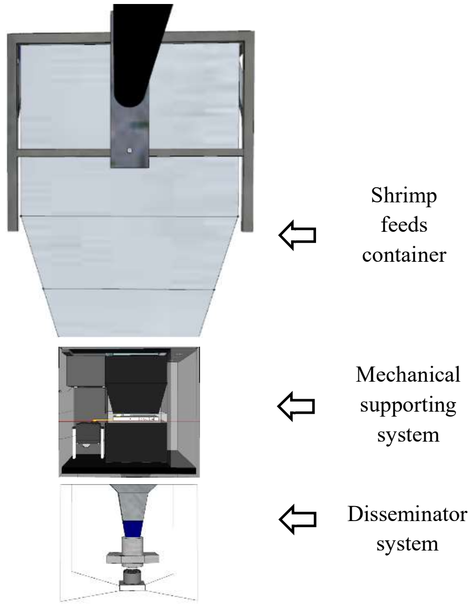

Fig. 2 Feeds Container and Disseminator System

The mechanical supporting system is divided into two parts. The first part is the first servo motor that holds the plate to control the feeds going to the second part. The second part is the second servo motor that carries the load cell to manage the number of meals before disseminating. Fig. 3 shows the mechanical supporting system attached to the bottom part of the container.

The researchers installed CZL639HD loadcell to properly weigh the feeds given to the shrimps in time of feeding based on the average body weight of every sampling.

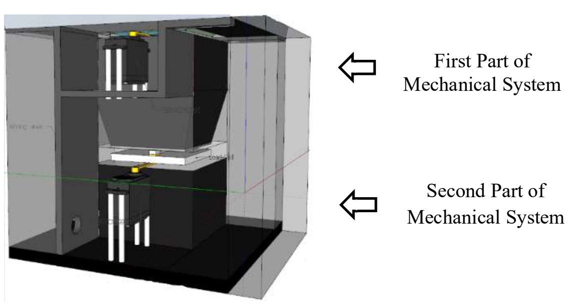

Fig. 3 Inside the Mechanical Supporting System

To install the automated feeder in the L. vannamei pond needs a supporting system. All mechanical systems shown in Fig. 2 are attached to the support system shown in Fig. 4.

The supporting system has two poles. The first pole is about 19.6 ft (6m) long and is buried about 6 ft (2m) in the ground, while the second pole that holds the feed container is about 6 meters long. The circuits were placed in the small box beside the system unit for the pond monitoring. The automated feeder is connected and will work using the laptop and the program installed in the software. The 5 volts dc motor speed can be controlled by manipulating the 5 volts two-channel relay installed in the Arduino Mega, and it is operated from 0 up to 1,000 rpm. With this variable speed, the distance of feed throwing can cover all the vital areas of the pond.

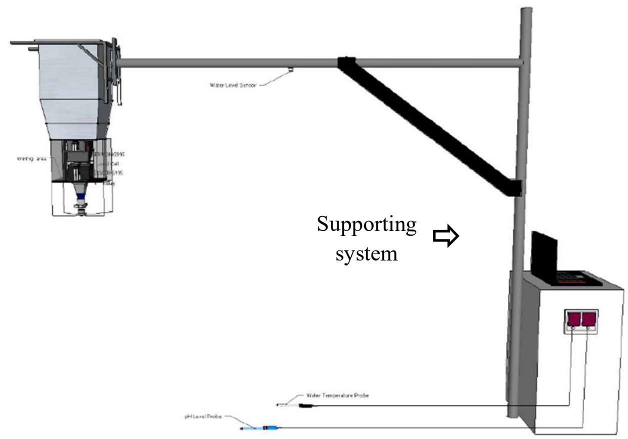

Fig. 4 Feeds Container, Disseminator, and Its Support

The software system also continuously determines the pond's water temperature, pH acidity, and water level using the Arduino Uno placed inside the box. For water temperature, the system utilized a DS18B20 sensor, Arduino pH sensor for pH acidity, and ultrasonic sensor for water level; near the supporting system of the device placed the package. The system block diagram for monitoring the shrimp production habitat's water quality is shown in Fig. 5.

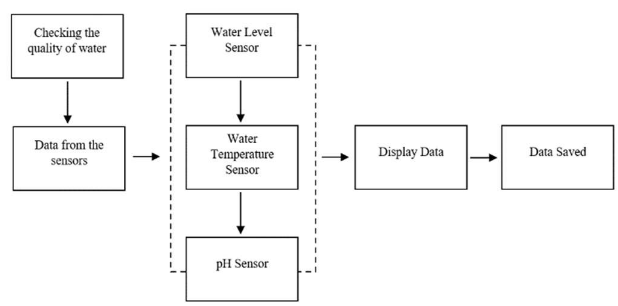

Fig. 5 Block Diagram of Pond Monitoring

C. System Flow

First, a sample L. *vannamei* shrimp will be weighed. After the weight is determined, the system will cross-reference it with the feeding guide and the cycle schedule of the aquaculture. The flow will result in getting the precise feed amount and schedule. After this, the automatic feeding process will commence by the program using the manipulation of the microcontrollers and relays to control the mechanical part of the system. Then the system will display the current activity status of the feeder. It will also prompt for feed. Stock refill when necessary. Fig. 6

below illustrates the system's flow to accomplish the study's objectives.

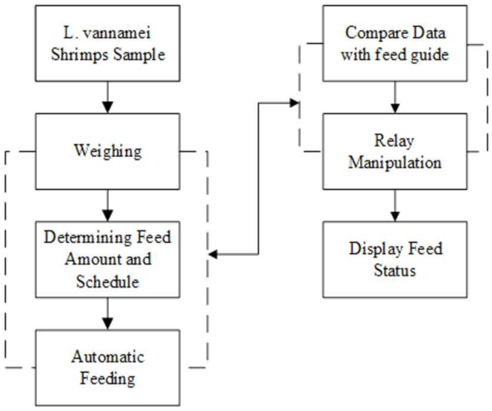

Fig. 6 Device System Flow

The research object was created using tools made with an Arduino Uno and equipped with a temperature sensor to measure pond water temperature, a pH sensor to measure pH balance, and a 0-100g loadcell to determine the weight of the shrimps to be sampled. The automatic feeder connects to the Arduino Mega, equipped with an ultrasonic sensor to measure water level and a 0-100g to determine feed weight. Fig. 7 below illustrates the flow of the hardware system.

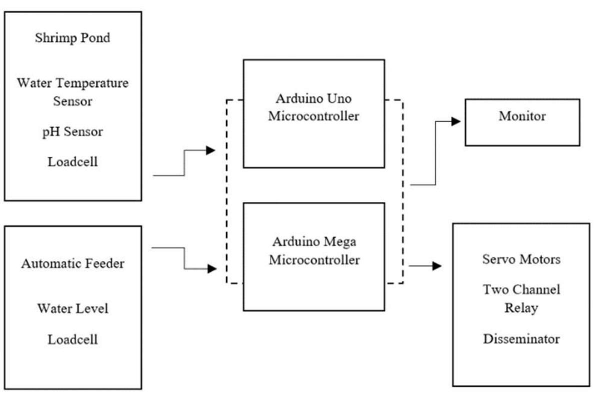

Fig. 7 Block Diagram of the Hardware System

II. RESULTS AND DISCUSSIONS

Fig. 8 below shows the actual design of the device wherein the connections of the main components are inside the hardware. The automated feeder comprises three MG 995 servomotors, a load cell, and a dc motor connected to an Arduino Mega placed on the left side of the mechanical supporting system. It also includes the device's supportive system and Arduino Uno for pond monitoring located inside the box. A laptop displays the output of the pond monitoring sensors and the feeding process status when an automated feeder is in use. The pond monitoring sensors, which consist of a DS18B20 water temperature sensor, Arduino pH sensor/meter kit, and an Arduino ultrasonic, are used to monitor the pond's water quality to ensure shrimp's health and development while being cultivated.

Fig. 8 Actual Design of the study

The researchers compare shrimp development in culture ponds using an automated feeder and a manual feeding approach to determine the efficiency or effectiveness of the computerized feeder for managing the feeds. The experiment was conducted at Kitagas, Sarangani Province, from May 22, 2021, to July 31, 2021. The growth analysis is divided into two ponds (1 and 2). Pond 1 measures shrimp development using an automated feeder, whereas pond 2 uses manual feeding.

Water quality parameters in the culture ponds are shown in Fig. 9. The system device will automatically record the water level, water temperature, and pH value for the water quality of both ponds every after seven days. The pond water temperatures ranged between 27—83 °C and 32.19 °C. The pH value of both ponds ranged between 7.51 and 8.19.

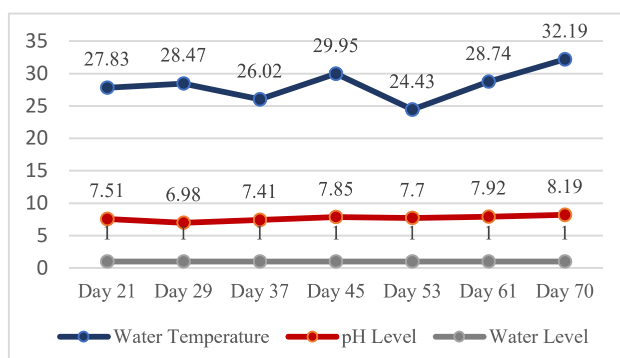

Fig. 9 Water Quality of 2 ponds during the culture period (May-July 2021)

Fig. 10 below shows the number of shrimps that survived by the stocking population. The researchers determined the total number of mortalities for the automated pond and manual pond after 70 days of cultivation. Out of 200 pcs, the number of shrimps survived in automatic feeding is 177, while manual feeding is 135.

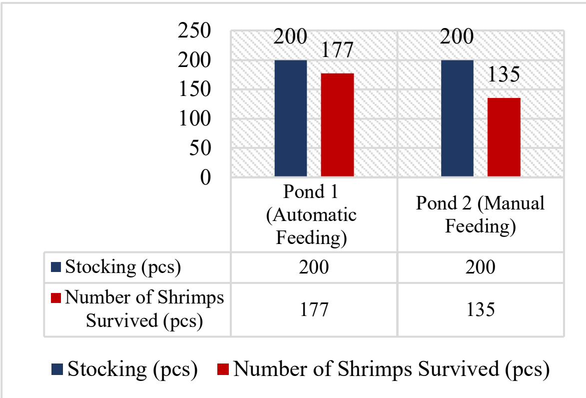

Fig. 10 The Graph of Number of Shrimps Survived about the Shrimp Population

Fig. 11 below shows the natural survival rate for automated feeding, which is 88.5%, with a total mortality rate of 11.5% compared to the survival rate for manual feeding is 67.5%, which has a real mortality rate of 32.5%. Pond 1 had a 21% better survival rate compared to pond 2.

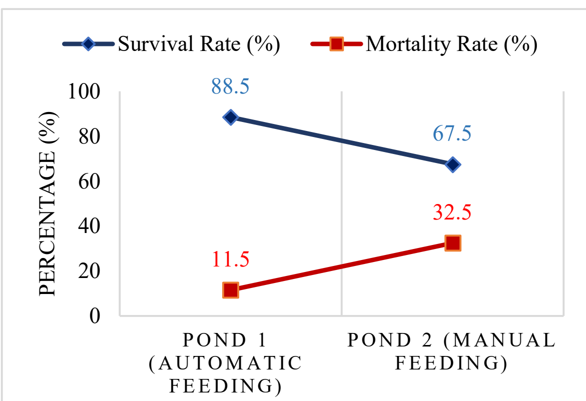

Fig. 11 The Graph for Survival Rate and Mortality Rate

The outcomes of shrimp development achieved throughout the culture period are detailed in (Table 1). Regardless of the feeding period, greater feed levels improved average body weight, survival, biomass, and production output. The automatic feeder utilized pond demonstrated higher average body weight growth after 70 days of cultivation, although the FCR was very good compared to the manual feeding pond.

Table 1: Detailed Outcomes During Culture Period.

Parameters	**Pond 1 (Automatic Feeder)**	**Pond 2 (Manual Feeding)**
Area (m)	2 x 2.5	2 x 2.5
Stocking (pcs)	200	200
Stocking Date	May 22, 2021	May 22, 2021
Harvest Date	July 31, 2021	July 31, 2021
Culture Period (d)	70	70
Average Body Weight (g)	20.01	19.96
Number of Shrimps Survived (pcs)	177	135
Survival Rate (%)	88.5	67.5
Mortality Rate (%)	11.5	32.5
Shrimp Biomass (kg)	3.542	2.695
Total Feed Used (kg)	3.615	3.623
FCR	1.02	1.34

Fig. 12 below shows the result of standard and experimental feed from the device given to the shrimps every seven days.

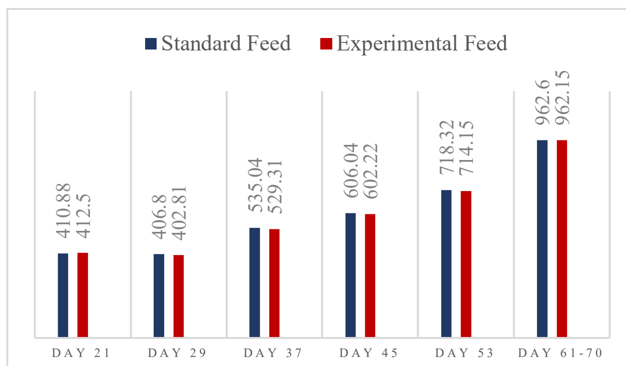

Fig. 12 Graphical Statistical Analysis

The study shall be using the t-test analysis in which the control group will be the standard computed value of the amount of feed. In contrast, the experimental group will be the feed generated by the feeding system produced in this study. The researchers obtained a total accuracy of 96.21% based on the calculation provided by the standard t-test formula. Therefore, the shrimp's weight after 70 days of cultivation using manual feeding and the feeding device are not equal. There is a significant difference between the feed amount generated using manual feeding and the feed amount generated by the feeding system.

III. CONCLUSIONS AND FUTURE WORKS

According to the findings of this study, more efficient feeding management through daily feeding quantity, effective feed distribution, and interval of feeding about the frequency utilizing automatic feeders would promote continuous shrimp development. Feeding management using an automated feeder should provide the lowest FCR to maximize shrimp development and minimize feed waste accumulation at the pond bottom. Increasing feed efficiency through lower FCR is critical for shrimp farmers to reduce costs and maximize profits. The shrimp growth, survival rate (SR), and feeding efficiency were satisfactory during the culture phase. Overall, utilizing an automated feeder provides a healthier shrimp by improving water quality, ensuring continuous feeding, and avoiding overfeeding. Improved water quality, appropriate feeding management, and installing pond monitoring sensors reduce the danger of mortality or disease breakout, resulting in higher profitability and lower labor and production expenses.

For future development, adding specific modules and sensors may enhance or expand the dimension and material of an automated feeder. For pond monitoring, we recommend adding water quality parameters such as dissolved oxygen (DO sensor), water salinity sensor, and alkalinity sensor to maintain the excellent water quality of the pond, which enables shrimps to develop faster. In addition to future automated feeder development for feeding management, we suggest installing a sensor to detect the state of feeds within the container, whether empty or complete, and sending the information via the Global System for Mobile Communications (GSM Module).

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