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Intelligent Temperature-Controlled Poultry Feed Dispensing System with Fuzzy Logic Algorithm

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ABSTRACT

This study introduces a novel fuzzy logic algorithm tailored to the thermoneutral zone of poultry, offering a precise and adaptive approach to feed dispensation. This involved the utilization of an LCD module to present essential information such as the selected age, real-time ambient temperature, current time, and the dispensed feed quantity. Data gathered during the process were stored in a memory device. The design of the fuzzy logic algorithm centered on the thermoneutral zone of the chicken serves as the determinant for feed dispensed by the system. It's crucial to note that while the system lacked artificial intelligence (AI), its logical analysis operated based on the fuzzy logic algorithm. Rigorous testing ensued, encompassing the comparison of feed dispensation between automated and manual systems and the assessment of feed waste and broiler weight. Significant feed waste reduction in the first week demonstrated the efficacy of the fuzzy-based method, with consistently low p-values of 0.00069, 0.015195, and 0.034 across subsequent weeks confirming the consistent outperformance in broiler weight compared to the traditional feeding technique. The findings contribute to the advancement of temperature-based poultry feed systems, addressing key challenges in optimizing feed quantity. The study successfully met its objectives, demonstrating the system's capability to dispense feeds effectively across varying ambient temperatures. Notably, the study revealed a consistent alignment of system outputs with those obtained from a digital thermometer and digital weighing scale, confirming the accuracy and reliability of the temperature-based feed dispensing system.

1. Introduction

Poultry farming is an important sector of the global food business, experiencing ongoing development and research of innovative approaches to boost production and efficiency [1]. A key component of poultry management is ensuring that the chickens receive the appropriate amount of feed and that their surroundings, specifically temperature, are suitable for their development and overall welfare [2], [3]. The distribution of financial resources in poultry management reveals a significant financial commitment, as feeding expenses account for seventy-five percent of total production costs [4], [5]. This large sum emphasizes the importance of proper feeding process in operating productive poultry farms.

The feed intake of chickens is subject to notable effects from the ambient temperature and their thermoneutral zone [6], [7]. The most minor temperature within the thermoneutral zone is the lowest critical temperature (LCT). If temperatures drop below a certain level, chickens will use energy from their feed to maintain their body temperature, resulting in an increase in food intake. In contrast, the most significant temperature within the thermoneutral zone is the highest critical temperature (HCT) [6]-[8]. According to Wang *et al.* (2020), the lower critical temperature (LCT) for hens is ten degrees Celsius, while the higher critical temperature (HCT) is set at a minimum of fifty degrees Celsius. This term encompasses the effect of ambient temperatures and thermal zones on poultry wellbeing [9].

The comfort zone in poultry refers to the optimal temperature range within which chickens can regulate their body temperature without exerting unnecessary effort, considering factors such as feeding techniques and housing locations [10]-[12]. Beyond this zone, noticeable behavioral changes can be detected, such as increased respiration rate and changes in body posture in response to temperature thresholds [13]. When the ambient temperature exceeds a certain threshold, hens are unable to disperse heat efficiently, resulting in a reduction in meal intake [14]. Under certain conditions, leaving an excessive amount of food for chickens is not suggested due to the possibility of overfeeding or selective feeding, which can result in significant feed waste [4], [15].

Olejnik *et al.* (2022) investigate the significance of ambient temperature in home environments as a non-dietary variable influencing feed conversion [16]. Malini *et al.* (2023) carried out a study that highlighted the importance of programmable parameters for feed dispensing for broiler and egg-laying chickens [17].

Another noteworthy advancement is observed in the study on computer-controlled systems for temperature regulation and feed dispensing in chickens carried out by Malika *et al.* (2021). The study describes a unique mechanism designed to allow for the regulated delivery of feed at predefined time intervals. Incorporating temperature regulation with feed dispensing shows a comprehensive approach to animal husbandry, emphasizing the importance of technical improvements for enhancing feeding methods and environmental conditions [18].

Poultry farming has been greatly impacted by the growing prevalence of automation and technological advancements, which has improved many aspects of poultry management [19]. This method exerts to improve poultry management by providing precise control mechanisms for environmental parameters, with a focus on temperature regulation. This component is crucial since it has a direct impact on the general health and growth of poultry [19], [20].

The development and application of a fuzzy logic algorithm in a temperature-based poultry feed distribution system has captured the interest and relevance of poultry producers as a solution to this problem [21]. This goal was achieved to meet the needs of the poultry farming industry. Abreu *et al.* (2019) successfully integrate fuzzy logic concepts with poultry management, resulting in a versatile and adaptable method to chicken feed regulation [22].

Fuzzy logic is well known for its ability to properly manage imprecise and uncertain data [23]. Fuzzy logic controls' diverse capabilities and user-friendly qualities have contributed to its widespread acceptance across a wide range of domains. According to Srivastava and Bisht's (2019) study, there are several uses for it in decision-making processes, such as identification, time series analysis, pattern recognition, control, and optimization [24].

Furthermore, fuzzy logic control has recently gained prominence in environmental monitoring and greenhouse management [25]-[27]. Alpay *et al.* (2018) conducted a comprehensive examination into the usage of fuzzy logic in the context of temperature regulation within greenhouses. This work demonstrates the growing recognition of fuzzy logic's versatility in addressing the complex difficulties provided by ecological systems, particularly in the agriculture business [28].

Automated systems are of great interest, particularly in the advancement of fuzzy logic algorithms used in temperature-based chicken feed distribution systems [29], [30]. Bala *et al.* (2019) successfully used fuzzy logic to improve the efficiency of poultry feeding in their study. The researchers demonstrated enhanced feed dispensing accuracy by incorporating temperature parameters into the control system. This demonstrates fuzzy logic's ability to effectively adapt to the dynamic environmental conditions prevalent in chicken farming [31].

The contribution of the research is to increase the efficiency and accuracy of environmental monitoring and enhancing temperature-based chicken feed distribution control systems through the implementation of a fuzzy logic algorithm. While the automated feeding system's lack of artificial intelligence (AI), it depends more on preset rules and algorithms than on experience-based learning. The fuzzy logic algorithm helps the system negotiate difficult settings with a degree of sophistication and flexibility, which adds to its success in feeding process optimization. This approach responds dynamically to changing conditions, promising a new era of poultry management with improved efficiency, sustainability, and economic viability. Fuzzy logic, renowned for its ability to handle imprecise data, is a well-suited solution for the dynamic and complex environment of poultry farming. Our research harnesses the adaptability and precision of fuzzy logic to revolutionize temperature-based chicken feed distribution systems, contributing to the broader goals of sustainable and economically viable poultry farming. Implementing this comprehensive system in chicken farming has the potential to radically revolutionize the sector, improving efficiency, environmental sustainability, and economic viability.

2. Method

2.1. System Overview

The study created and implemented a fuzzy logic algorithm, a key factor in the system, that dynamically adjusts the quantity of chicken feed dispensed based on real-time ambient temperature [32]. This algorithm interfaces with the controller unit, enhancing the adaptability and precision of the feed distribution process. It used an LCD module and keyboard as the user interface, and it showed the amount of feed the system was dispensing, the selected feeding program, and the current ambient temperature and clock. Data logging was also generated by the system and stored on an SD card. Fig. 1 shows the conceptual framework of the system. The system block diagram is shown in Fig, 2. The control unit is responsible for determining the quantity of chicken feed to be distributed by the system.

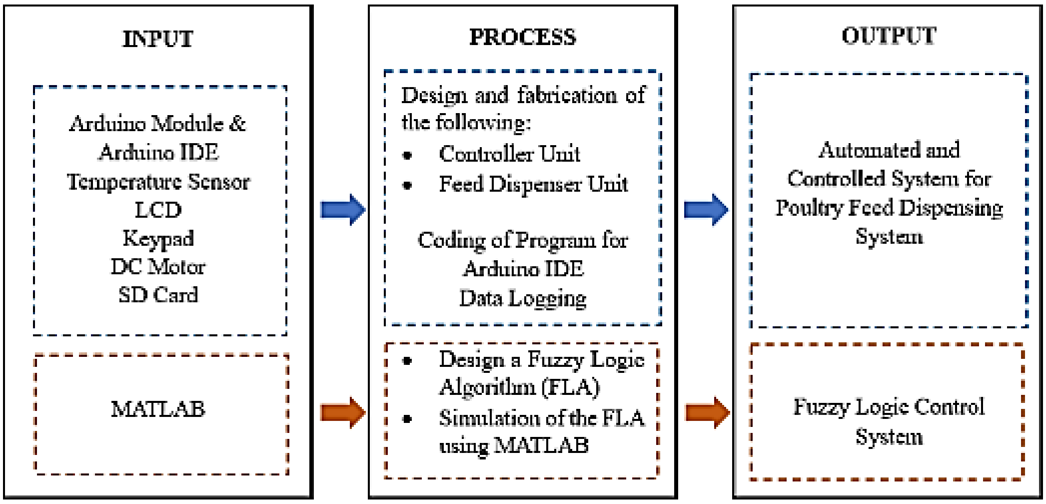


Fig. 1. The conceptual framework of the system

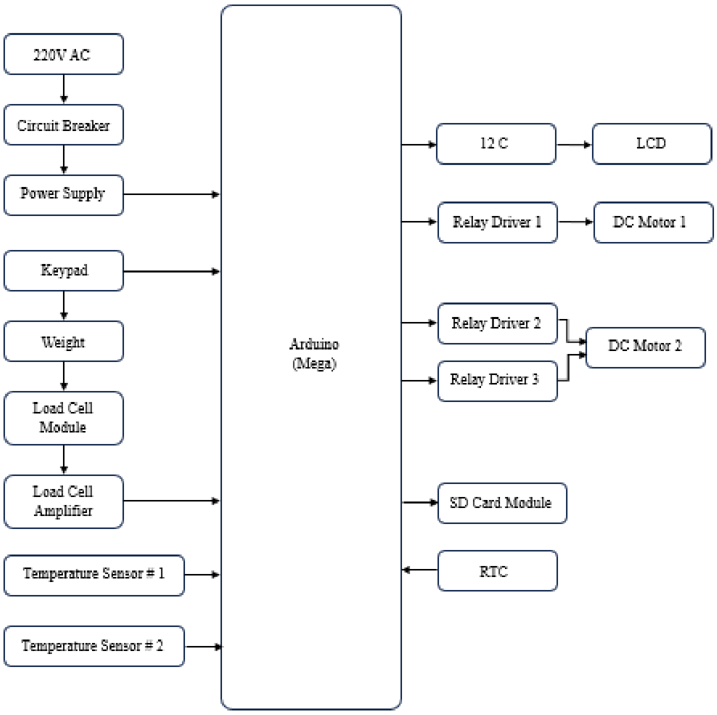


Fig. 2. The block diagram of the system

2.2. Design of the Controller Unit

The study utilized the Arduino Mega (ATmega2560) microcontroller as a pivotal component in the system, responsible for processing analog information derived from the temperature sensor. The Arduino functioned as the central component, receiving and processing user inputs through a keypad and presenting pertinent data on an LCD interface. The program developed for the Arduino Mega ATmega2560 not only facilitated communication with various system modules but also orchestrated the decision-making process [33]. User inputs, age, and quantity of poultry triggered the determination of a suitable feeding schedule, with real-time temperature data influencing the fuzzy logic algorithm to dynamically compute the quantity of feed to be dispensed. Incorporating a Real-Time-Clock (RTC) facilitated accurate scheduling for feeding schedules [34]. An optimally positioned temperature sensor effectively detected the surrounding temperature, while digital thermometers were used to verify the temperature consistency of the modules. In order to retain the extensive data collected, a memory card was employed. Fig. 3 illustrates the schematic representation of the controller unit.

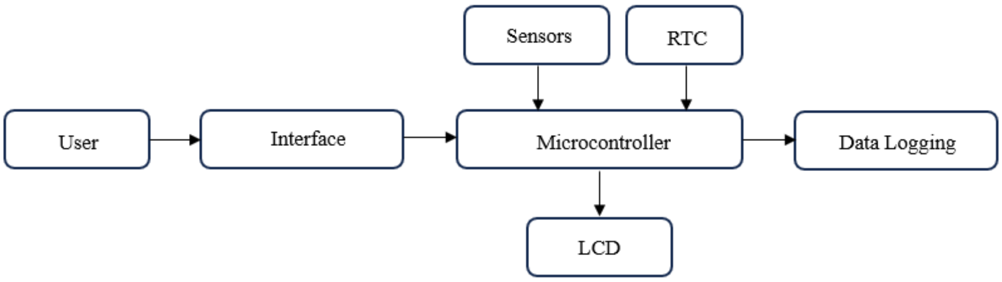


Fig. 3. The block diagram of the controller unit

2.3. Design Process of the Poultry Feed Dispenser

The control mechanism for the chicken feed dispenser was designed to be operated by the Arduino ATmega2560 microcontroller. Fig. 4 clearly depicts the logical procedure involved in the operation of the feed dispenser unit. The hopper within the apparatus incorporates a direct current

(DC) motor responsible for operating the dispensing mechanism. After the temperature sensor has gathered the necessary data, the Arduino analyzes this information and sends the suitable signal to the motor. The 12V direct current (DC) motor demonstrates a uniform velocity throughout a wide range of loads. As the motor's load increases, there is a corresponding rise in armature current, resulting in amplified torque production. The DC motor is closely connected to the screw conveyor inside the hopper, employing its rotational motion to distribute feed at a pre-established pace. Integrating a load cell module enables the measurement of dispensed feeds until the desired quantity is reached, upon which it is subsequently discharged into the primary hopper [35]. Following this, an additional direct current (DC) motor is utilized to distribute the feed from the hopper to the pan feeder.

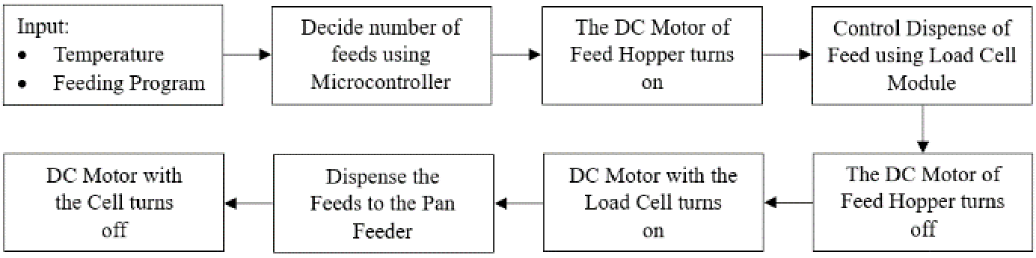
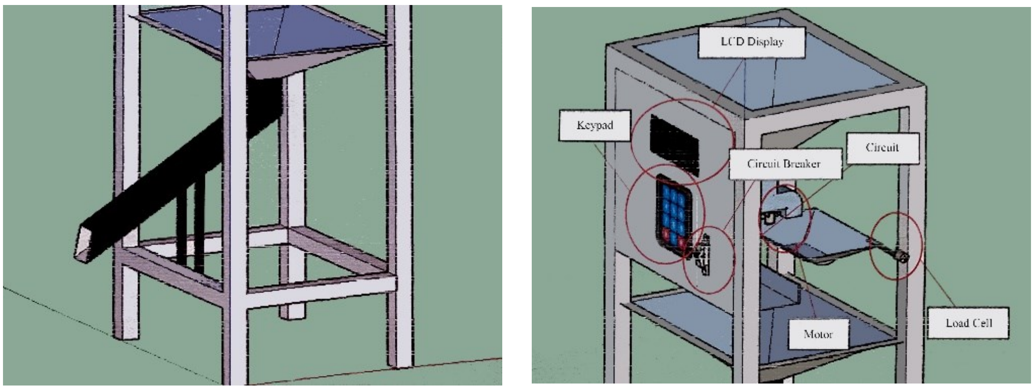


Fig. 4. Process flow diagram of the poultry feed dispenser

2.4. Physical Design

The physical arrangement of the system was established based on the dimensions of its components and the poultry enclosure. The dimensions of the dispenser were precisely measured to be 55.12 inches in length, 7.87 inches in width, and 7.87 inches in height. The hopper's DC motor was connected to a spring, which assisted the dispensing of feeds. A load cell module and amplifier were added to the system to measure the weight of dispensed feeds before their release into the feeder. A different DC motor was employed to rotate the weighted feeds into the feeder. The length of the feeder was adjusted to meet the specific spatial needs of feeding broilers. Fig. 5 depicts the upper and lower components of the system, respectively.



(a) (b)

Fig. 5. (a) Upper and (b) lower part of the poultry feed dispenser

In order to enhance the system's resilience, a protective aluminum enclosure was utilized for the circuit box, effectively safeguarding it against external influences that could potentially undermine its operational efficiency. The circuit box included the controller unit and power supply of the system. The physical interface utilized by the user, as illustrated in Fig. 6, consisted of a power button, keypad, and LCD that were seamlessly integrated with the circuit box. This configuration allows users to manipulate the system and oversee the diverse factors essential to its operation [36]. Fig. 7 provides a comprehensive representation of the system's overall dimensions.

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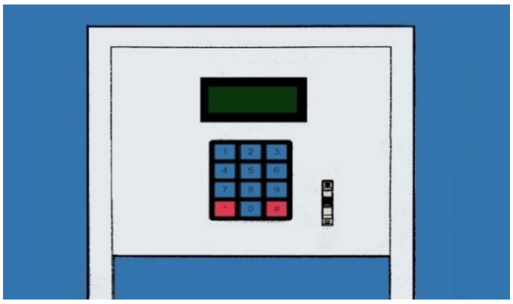


Fig. 6. Physical interface of the system

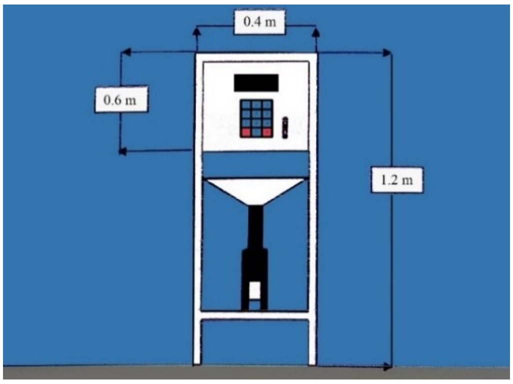


Fig. 7. The dimensions of the system

2.5. Design of the Fuzzy Logic Algorithm

The fuzzy logic algorithm incorporated in the system involved careful selection and design of fuzzy rules, membership functions, and parameters using the MATLAB Fuzzy Logic Toolbox [37]. The Rule Editor was employed to fine-tune rules, ensuring precise control objectives based on the ambient temperature within the chicken enclosure [38]. Fig. 8 illustrates the sequential procedure in formulating the feed dispenser's fuzzy logic control algorithm. Temperature was identified as the essential factor in determining the control objectives, as it directly influences the amount of feed that needs to be dispensed. The process of determining input and output variables entailed selecting a specific midpoint, obtained by defining the thermoneutral zone of the chicken, which was subsequently utilized to establish the range. Developing membership functions was conducted with great attention to detail using the MATLAB Fuzzy Logic Toolbox. The Rule Editor played a crucial part in designing, altering, or removing rules, contributing significantly to the development of fuzzy rules [39]. The Sugeno Fuzzy Inference Method was chosen as the inference method for the Fuzzy Logic Controller (FLC). The defuzzification procedure utilized in the simulation was employed to ascertain the feeding percentage, which represents the data considered for the dispensation of feed by the system [40].

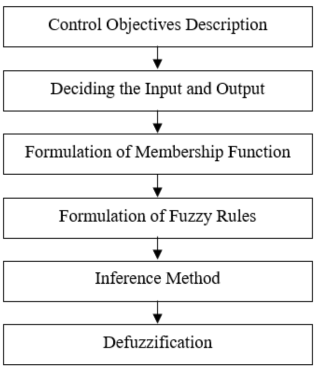


Fig. 8. Design process of the fuzzy logic algorithm

2.6. Development of the Program to Control the System

The Arduino Mega ATmega2560 was programmed using the Arduino 1.6.5 software, facilitating smooth communication between the controller and other modules inside the system. Upon initiating the device, users were prompted to enter the age and quantity of the poultry they had. Afterward, the system successfully determined the suitable feeding schedule, and the temperature sensors initiated the collection of data from the enclosure's surroundings. The LCD exhibited the computed quantity of feed, which was determined using the collected data. If the predetermined criteria were satisfied, the system commenced dispensing to a load cell. The load cell module accurately measured the weight of the feeds until the desired quantity was achieved. The load cell's motor subsequently enabled the weight feed transfer to the feeder. The act of dispensing feed occurred thrice a day, precisely at 6:00 AM, 12:00 PM, and 6:00 PM. The system exhibited the present time date and detected temperature during inactivity.

3. Results

3.1. Presentation of the Fuzzy Logic Algorithm

The Fuzzy Logic method was developed to determine broilers' feed requirements under varying ambient temperatures. The MATLAB Fuzzy Logic Toolbox was utilized for algorithm design. In deciding the input and output variable, the target midpoint was 30.8°C. The range used was the lowest critical temperature of the chicken, which is ten °C and its highest critical temperature, which is 50°C [41]. Dispense more, dispense exact, and dispense less are the chosen expected output responses for the system. The assignment of input and output variables are listed below:

"LCT" = "Lowest Critical Temperature" input temperature

"TZ" = "Thermoneutral Zone" input temperature

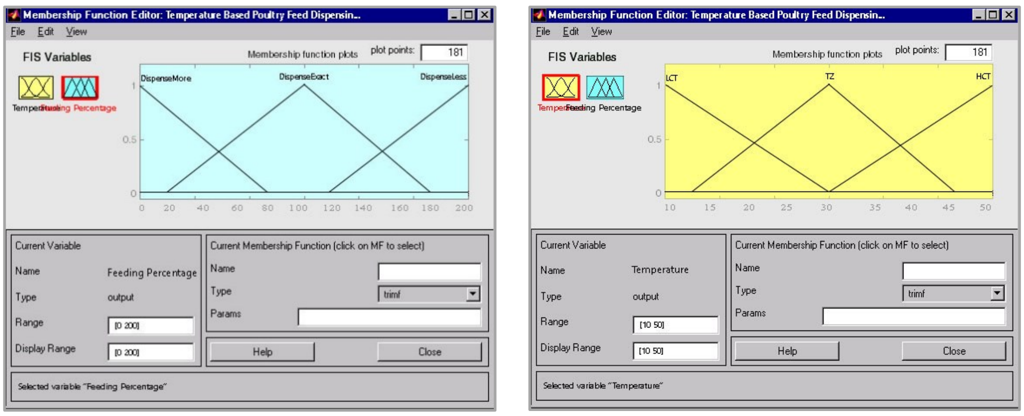
"HCT" - "Highest Critical Temperature" input temperature

"DispenseMore" = "Dispense More" output response

"DispenseExact" = "Dispense Exact" output response

"Dispenseless" = "Dispense Less" output response

The formulation of the membership function was created at the MATLAB Fuzzy Logic Designer. The trapezoidal membership functions from the poultry feed dispensing system's rule structure was shown. Fig. 9 shows the input and output membership function for the fuzzy logic algorithm of the temperature-based poultry feed dispensing system. The output was the feeding percentage to be dispensed with a range of 0 to 200.



(a) (b)

Fig. 9. Membership function of the (a) input and (b) output

The Rule Editor is where rules can be created, changed, or deleted and used in formulating fuzzy rules. Fig. 10 shows the rule viewer of the fuzzy logic algorithm. There was a total of three regulations drafted. The Fig. 10 shows the fuzzy rule editor for the poultry feed dispensing system, constructed using a look-up table. It has been verified that at a median temperature of 30.8°C, the amount of feed to be dispensed is at one hundred (100) percent. Therefore, the total amount of feed will be dispensed by the system.

The inference method used was the Sugeno Fuzzy Inference Method. In the defuzzification, the feeding percentage was determined in the simulation, and the data to be considered on the amount of feed to be dispensed by the system. The recorded temperature was in degrees Celsius (°C).

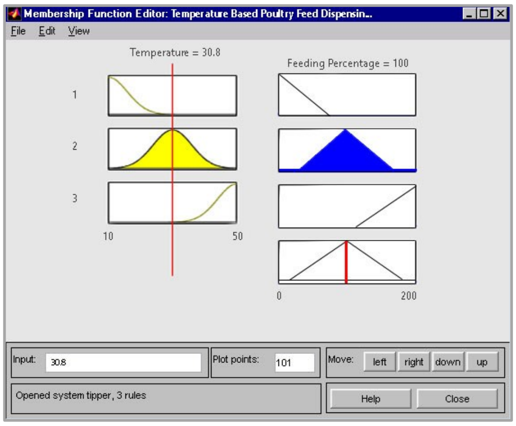


Fig. 10. Rule viewer of the fuzzy logic algorithm

3.2. Presentation and Analysis of the design

The system comprised a microcontroller, temperature sensor, DC motors, load cell module, RTC, and SD card module. It also includes a keypad LCD for the interface. The control unit of the system shown includes an Arduino microcontroller that served as the system's brain, which was all inside the device. Fig. 11 shows the placement of the keypad and the LCD of the feed dispenser.

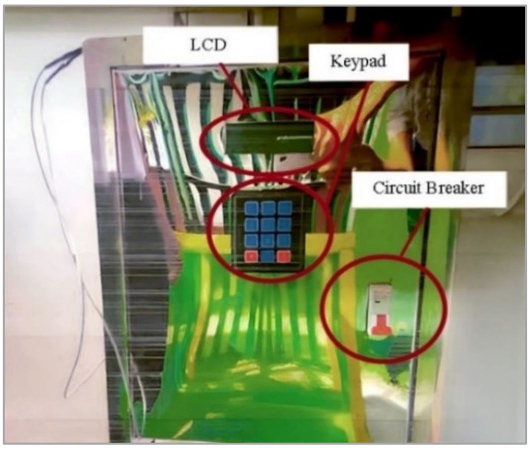


Fig. 11. The front view of the fabricated poultry feed dispenser

The circuit structure was established by integrating various components into the device. This involved inserting the sensor into the device, combining the motor, and producing the feed dispenser. According to the data presented in Fig. 12, the microcontroller exhibited connectivity with various devices. The microcontroller was interfaced with multiple components, including the Real-Time Clock (RTC), the SD card module, the relays, the keypad, the Liquid Crystal Display (LCD), a buzzer, and the sensors. A circuit was designed to implement a fuzzy logic algorithm within a temperature-based chicken feed dispenser system.

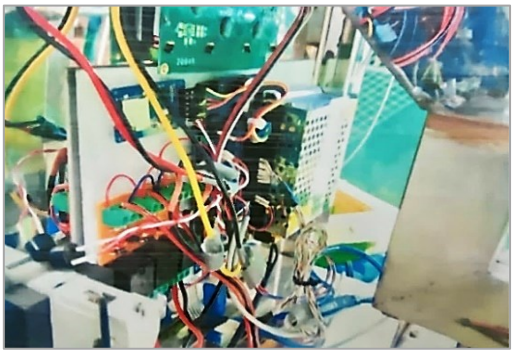


Fig. 12. The circuit of the system

Fig. 13 shows that the load cell, DC motors, and limiting switch were integrated into the Arduino Mega. The 220V supply from the external source was connected to the circuit breaker for circuit protection before going to the power supply with an output of 12V DC. Most components require a 5V DC supply and were provided by the 5V DC-DC converter. The DC motors were integrated into the microcontroller for the dispensing mechanism and flipping of the load cell. DC motors are connected to relay drivers for switching purposes.

Three (3) relay drivers were used in the study for the dispensing mechanism. One (1) relay driver dispensed feed from the hopper, while two (2) relay drivers were used for rotating the pan up and down. The lilting of the pan was controlled by two (2) limiting switches to pour the feeds strategically at a right angle. They were placed near the control unit of the device and were not affected by the dispensing process. The microcontroller controlled the relay drivers and connected to analog pin 9, pin 10, analog 11, and 12V supply and the ground.

A load cell and load cell module were used to get the right amount of feed out. The load cell can hold one (1) kilogram at the most. It must be linked to the load cell module to process the data. The 5V source and ground were hooked to the load cell module. It was connected to a load cell amplifier, which in turn was connected to the microcontroller's analog pins 4 and 5, as well as to the ground and the 5V supply.

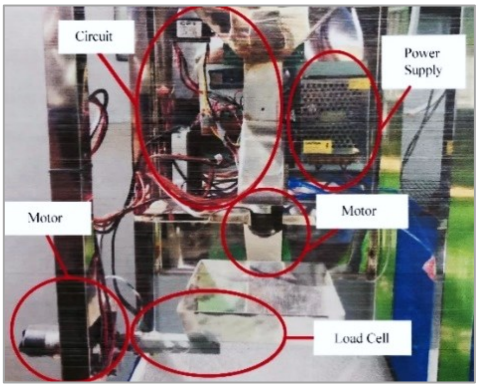


Fig. 13. Connection of components to the microcontroller

3.3. Testing and Evaluation

One of the study's main objectives was to conduct a comparative analysis between the outcomes of controlled feeding and manual feeding. The system evaluation spanned twenty-one (21) days, taking place at Poblacion IV, Indang, Cavite, Philippines. Two chicken feeders were constructed and placed on the veranda, with appropriate roofing and walls. One feeder was designated for controlled feeding, while the other was intended for manual feeding. The pens were erected under the prescribed standard dimensions for ten (10) broilers in the Philippines. The evaluations were conducted near the researchers' facility to assess the system's performance and ensure adequate care of the twenty grill chickens utilized in the study.

The temperature played a crucial role in operating the temperature-based chicken feed distribution system [42]. The design involved a temperature assessment of the pen to ascertain the device's functionality. An experiment was conducted to determine the temperature measurement accuracy obtained from the sensor. In verifying the accuracy of the temperature measurement, a comparison was made between the temperature perceived by the temperature sensor and the temperature reading obtained from the digital thermometer.

Table 1 presents a comparative analysis of the temperature readings obtained from the sensor and the digital thermometer. The observed variation spans from 0.77°C to 2.58°C. The temperature variations between the digital thermometer and the chicken pen's thermometer in the automated feeding system are important for optimizing poultry farming. Calibrating the system to minimize discrepancies ensures accurate temperature regulation, positively impacting chicken well-being, growth, and overall production efficiency. Consistent monitoring and maintenance contribute to sustainable farm management [43].

Table 1. Comparison of temperature reading of the system to digital thermometer in °C

Trials	Chicken Pen's Temperature (°C)	Digital Thermometer (°C)
1	28.35	26.9
2	30.83	28.4
3	26.52	25.2
4	31.27	30.5
5	28.59	27.1
6	28.54	26.8
7	29.63	27.9
8	30.32	29.5
9	24.15	23.3
10	26.96	25.5
11	30.22	28.9
12	31.78	30.2
13	25.83	24.7
14	27.88	25.3
15	27.52	25.1

Table 2 presents a comparison between load cell and digital weighing scale measurements, revealing discrepancies ranging from 0.48g to 3.3g with an average difference of 2.59g. This analysis assesses the accuracy of measurement methods, helping to identify and address potential calibration or instrumentation issues.

Table 2. Comparison of the weight measurement by the load cell to a digital weighing scale in grams

Trials	Weight measured by the Load Cell (g)	Digital Weighing Scale (g)
1	63.67	60.21
2	60.69	61.33
3	109.24	108.17
4	111.38	109.54
5	112.45	107.41
6	107.10	105.7
7	180.61	177.31
8	177.30	173.20
9	165.20	161.67
10	172.98	171.11
Average	**126.16**	**123.57**

Table 3 provides a comprehensive overview of the average quantities of feeds dispensed by the system, comparing the fuzzy-based and manual feeding methods in accordance with established broiler production guidelines in the Philippines. The data reflects the outcomes of seven repetitions conducted weekly, aligning with the number of days in a week.

On the first week, the observed range of feed variances between the system's dispensation and manual feeding was 3.67g to 8.72g. This range expanded in the second week, with variations ranging from 6.78g to 11.38g. The third week exhibited further diversity, with feed discrepancies ranging from 5.2g to 20.6g. This detailed breakdown of feed quantities and discrepancies over the three weeks adds granularity to the evaluation of the system's performance.

Table 3. Average feeds dispensed by the system in controlled and the average feeds given to manual in grams

Trials	6:00 A.M.		12:00 P.M.		6:00 P.M.	
Week	Fuzzy Based (g)	Manual (g)	Fuzzy Based (g)	Manual (g)	Fuzzy Based (g)	Manual (g)
1	66.09	60	63.69	60	63.69	60
2	115.62	100	108.23	100	108.23	100
3	179.19	160	165.41	160	165.41	160

The chickens were subjected to weight measurements on the eighth, fourteenth, twenty-first, and twenty-eighth days. The initial weight of the chicks varied between 16g and 24.5g over the average weight suggested for broilers in the Philippines, which is established at 74g. During the conclusive weigh-in of broilers subjected to automated and manual feeding, a notable variation in weight was observed, ranging from 40.6g to 72g. Table 4 displays the average weight of chickens under two feeding conditions: fuzzy-based feeding and manual feeding.

The weight assessments performed are intended to track the growth of chickens exposed to fuzzy-based and manual feeding [44]. It evaluates the efficiency of each method by comparing average weights under these conditions, aiming to understand their impact on optimal growth and weight gain. The variations in weight observed during the final weigh-in offer insights into potential distinctions between automated and manual feeding methods. This examination holds significance for refining nutrition strategies, enhancing economic efficiency, and improving overall outcomes in broiler production. In assessing the effectiveness of the feed distribution system, a critical parameter examined was the amount of feed waste, quantified and documented for both fuzzy-based and manual feeding methods [45].

Table 5 provides an overview of the mean feed wastage, revealing valuable insights into the efficiency of each feeding approach. Notably, the data highlights that the recorded feed waste reached its highest levels during the initial week, with an average range of 15g to 21.43g. The discrepancy in feeding quantities between the controlled fuzzy-based system and the manual method ranged from 0g to 6.43g. Intriguingly, as the study progressed, there was a discernible reduction in feed waste, and by the final week, no instances of feed waste were recorded. This trend suggests that the fuzzy-based feeding system may have demonstrated increased precision and adaptability over time, minimizing unnecessary wastage in comparison to manual feeding practices.

Table 4. Average chicken weight on controlled and manual feeding in grams

Trials	Average chicken weight on Fuzzy-based Feeding (g)	Average chicken weight on Manual Feeding (g)
Starting Weight	94.5	90
Week 1	214.5	186.5
Week 2	387.5	368.5
Week 3	700.5	664.6

The observed patterns in feed wastage provide crucial information about the comparative efficiency of the two feeding methods. The substantial reduction in feed waste over the study duration implies a potential advantage of the fuzzy-based system in optimizing feed distribution, leading to more economical and resource-efficient poultry farming practices.

Table 5. Average feed waste on controlled and manual feeding

Trials	Average feed waste on Fuzzy-based Feeding (g)	Average feed waste on Manual Feeding (g)
Week 1	15	21.43
Week 2	10	15
Week 3	0	0

4. Discussion

4.1. Statistical Analysis of the Design

The study applied inferential statistics, notably utilizing the Paired T-Test, to analyze and compare the outcomes of two unique methods: the fuzzy-based and manual feeding approaches [46]. T-tests were used to analyze the distributed feed during the first, second, and third weeks to examine any significant changes between fuzzy-based feeding and manual feeding in terms of feed waste and broiler weight throughout the evaluation period.

The analysis of feed dispensing data over the initial to third week indicated noteworthy distinctions between the fuzzy-based and manual feeding cohorts. In contrast to manual dispensation, the quantity of feeds dispensed exhibited variations, ranging from 0.84% to 19.07% in the first week, 6.56% to 17.25% in the second week, and 3.20% to 13.92% in the third week. The findings conclusively establish the significance of the feed dispensed by the fuzzy-based system.

On the other hand, the broiler weight measured during the first to third week revealed significant differences between the fuzzy-based and manual feeding groups. The p-values for the t-tests were 0.000346255, 0.151950488, and 0.030467862, indicating significant differences in weight variances. The p-value for the second t-test was also below 0.05, confirming a significant difference in mean weights. Broilers in the fuzzy-based group had an average weight of 214.5 grams compared to 186.5 grams in the manual group for the first week, 387.5 grams for the fuzzy-based group and 368.5 grams for the manual group in the second week, and finally, 700.5 grams for the fuzzy-based group and 664.6 grams for the manual group in the third week. This suggests that the fuzzy-based system promotes higher average weight gain.

4.2. Outcome of the Fuzzy Logic Algorithm

Fig. 14 depicts the result of the fuzzy logic algorithm design for the temperature-based poultry feed dispensing system. Notably, the feeding percentage displays variability in response to fluctuations in temperature. More precisely, an increase in temperature is associated with a drop in the feeding percentage [47]. Each data point represented on the graph corresponds to a temperature increase of 1°C, ranging from 10°C to 50°C.

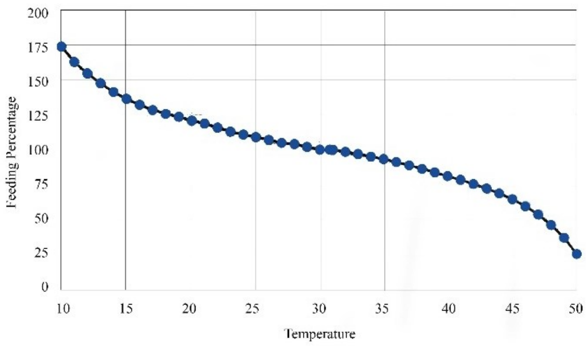


Fig. 14. The result of the fuzzy logic algorithm

The graphical representation of the relationship between temperature and feeding percentage is illustrated in Fig. 15. The temperature range depicted in this illustration varies between 22°C and 31°C. The observed trend is consistent with the predictions made by the fuzzy logic system, suggesting a decline in the feed proportion as the temperature increases [48]. The trend line employed in this visualization is based on a quartic polynomial regression.

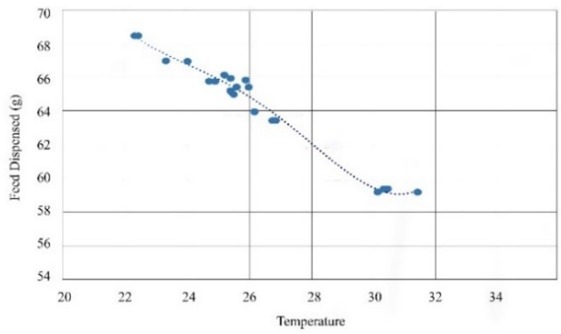


Fig. 15. Relationship of the feed dispensed and temperature

Fig. 16 depicts the disparity between the feed distributed according to the theoretical calculations and the actual feed dispensed by the system, which is determined by the temperature results. The observed trend in this comparison is consistent with the anticipated outcomes of the fuzzy logic system, suggesting a decrease in feed dispensation as temperatures rise [49]. The observed results exhibit a high degree of similarity. It is worth mentioning that the amount of feed provided was more than the suggested standard for broilers, as the recorded temperatures were below the thermoneutral zone.

The critical components of the poultry feed distribution system were evaluated, resulting in the following findings: (i) In the instance of the temperature sensor, a comparative analysis was conducted between the recorded temperatures obtained from the sensor and the measurements obtained from the digital thermometer. The observed temperature disparities exhibited a range of values from 0.77°C to 2.58°C. (ii) Concerning the load cell, the weight measured by the load cell was compared to the data acquired from the digital weighing scale. The observed weight disparities ranged from 0.48g to 3.3g, with a mean divergence of 2.59g.

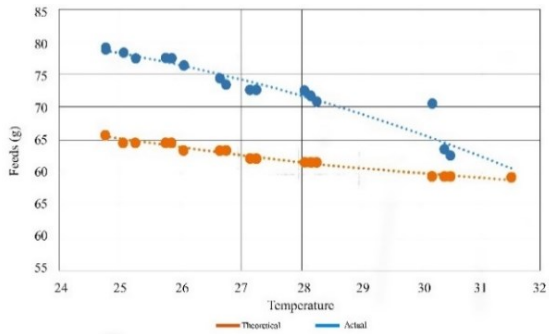


Fig. 16. Theoretical versus actual feed dispensation to temperature

4.3. Evaluation

The evaluation of the device lasted for twenty-one (21) days, consisting of three repetitions each day at 6:00 a.m., 12:00 p.m., and 6:00 p.m. During this period, the cumulative volume of feed distributed by the system was 1363.38g at 6:00 a.m., 2246.3g at 12:00 p.m., and 3341.24g at 6:00 p.m.

Fig. 17 illustrates the system's feed distribution fluctuations compared to manual feeding over the initial week of assessment. The automated distribution system demonstrated a high degree of accuracy compared to the manual feeding method, adhering nearly to the suggested standard set by the Philippines. The observed disparities between the two methods ranged from 0.84% to 19.07%. During two out of fifteen experimental trials, it was seen that the automated system dispensed smaller quantities than the standard, indicating the presence of increased temperatures during those specific trials, which exceeded the thermoneutral zone of the broiler. Notably, the feeds distributed at 6:00 a.m. and 6:00 p.m. surpassed the recommended standard, although the system reached the standard at the 12:00 p.m. schedule.

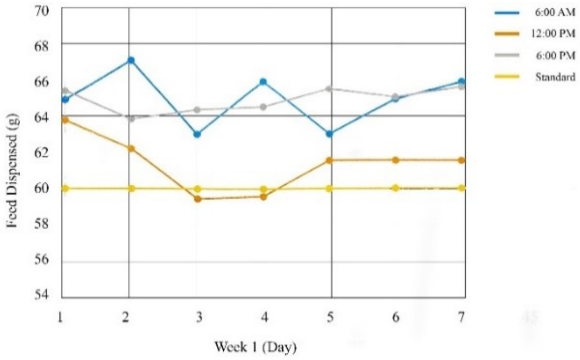


Fig.17. Comparison of feed dispensed on first week in terms of feeding schedule

Fig. 18 depicts the disparities in feed distribution between the automated and manual systems during the second week of the assessment. The automated system demonstrated a discrepancy range from 6.56% to 17.25%. This implies that temperatures experienced during this specific time frame were below the thermoneutral zone for broilers, leading to increased feed being provided compared to the standard. The feed distribution followed the prescribed daily feeding schedule, with quantities during the 6:00 a.m., 12:00 p.m., and 6:00 p.m. intervals above the acceptable norm yet maintaining proximity to it.

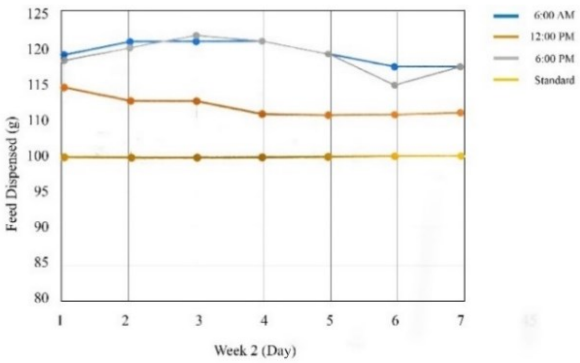


Fig. 18. Comparison of feed dispensed on second week in terms of feeding schedule

Fig. 19 illustrates the system's feed dispensation fluctuations compared to manual feeding during the third week of the experiment. The automated system displayed a discrepancy range of 3.20% to 13.92%, indicating that temperatures during this period were below the thermoneutral zone for broilers. Consequently, there was an increase in feed dispensation compared to the standard. The feed distribution followed a pattern corresponding to the daily feeding schedule, with quantities during the 6:00 a.m., 12:00 p.m., and 6:00 p.m. intervals above the required standard while maintaining proximity to it.

Fig. 20 depicts the measured amount of feed waste in automated and manual feeding methods. Significantly, the automated system demonstrated reduced feed waste compared to manual feeding, indicating that the dispensed feeds were optimized. Furthermore, no discernible alteration was observed between the eleventh and twenty-first day of the assessment period.

Fig. 21 illustrates the final weight of broilers, as recorded through the utilization of both automated and manual feeding methods. The data collected suggests that the weight of broilers in the automated feeding condition was higher than in the manual feeding condition. This means that the feeds provided through the automated system were optimized, leading in an increase in broiler weight.

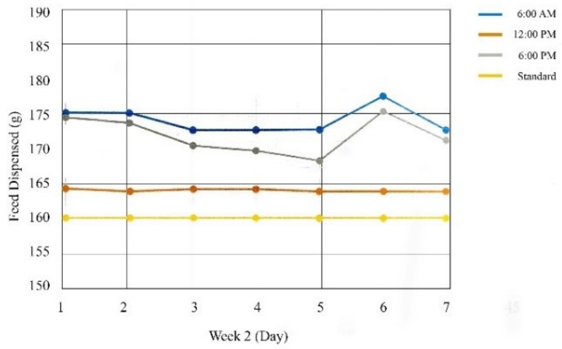


Fig. 19. Comparison of feed dispensed on final week in terms of feeding schedule

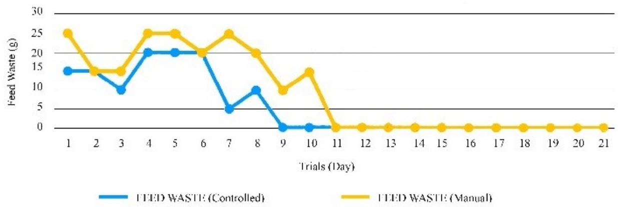


Fig. 20. The feed waste measured during the evaluation

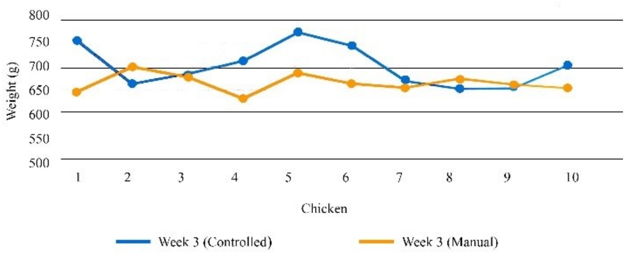


Fig. 21. The broiler weight measured during the final week of evaluation

4.4. Efficiency of the Fuzzy Logic Algorithm

It may be concluded that the fuzzy-based system is more efficient than manual feeding based on the observed output variables, such as feed dispensed, feed waste, and broiler weight [50]. The study's verification was carried out using inferential statistics. The modification of poultry feeds resulted in reduced feed waste and increased broiler weight [51].

5. Conclusions

The design and implementation of a fuzzy logic algorithm for a temperature-based chicken feed dispensing system can replace the traditional feeding pattern with a performance larger than the latter, based on the data, observations, computations, and results achieved. One essential component of the temperature-based chicken feed distribution system was temperature. The temperature recorded by the sensor and the digital thermometer were compared to confirm whether the digital thermometer provided an accurate reading. The difference ranges from 0.77°C to 2.58°C, which is an appropriate result because it is near to the true ambient temperature. The load cell's measured weight and the weight obtained from the digital scale were compared. The difference is between 0.48 and 3.3 grams. The system's reliability can be inferred from the slight variation in data.

The adoption of the Philippines' suggested standard for broiler production provided a benchmark for evaluating the system's efficacy in feed dispensing. As compared to manual dispensing, the amount of feed dispensed in the first week was 0.84% to 19.07%, in the second week it was 6.56% to 17.25%, and in the third week it was 3.20% to 13.92%. Feed waste and broiler weight were weighed in and recorded to determine whether the feed that was dispensed was optimal. Statistical analyses revealed strong significant levels, indicating the superiority of the fuzzy-based approach in achieving optimal broiler weight and minimizing feed waste.

The data shows that compared to manual feeding, feed waste is continuously reduced in the fuzzy-based approach. This implies that the fuzzy-based system's feed dispensing procedure has been improved. Significant differences in feed waste were seen within the first week, which demonstrated the efficacy of the fuzzy-based method during this period. The low P values of 0.00069, 0.015195, and 0.034 for the first, second, and third weeks, respectively, show that the statistical analysis of the broiler weight data revealed a strong significant level. These results imply that the broiler weight attained by applying the fuzzy-based approach consistently outperformed the weight attained by using the traditional feeding technique.

While the study presents promising results, it is essential to acknowledge certain limitations. The research primarily focuses on a controlled environment, and the scalability of the system to larger poultry farms warrants further investigation. Future research in this domain could explore the integration of machine learning techniques and real-time data analytics to enhance the system's adaptability. Addressing limitations such as the study's focus on a controlled environment and investigating the scalability to larger poultry farms would contribute to a more comprehensive understanding. The economic feasibility, potential challenges, and impact on commercial-scale applications should be explored to facilitate practical implementation.

In conclusion, this study significantly contributes to the poultry farming domain by introducing and validating a fuzzy logic algorithm for temperature-based chicken feed dispensing. Based on the gathered data and relationship between temperatures and feed dispensed, in can be concluded that during the feeding schedule of 6:00 a.m. and 6:00 p.m., feeds to be dispensed must be greater than Philippine recommended standard since the temperature is lower than the thermoneutral zone. For the 12:00 p.m. schedule, feed must be limited to minimum since temperature is above the thermoneutral zone, hence, feed consumption is decreased. Optimum feed consumption took place on the feeding schedule of 6:00 a.m. and 6:00 p.m.

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