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Increasing Livestock Production in Nigeria: Development of Cost-Effective Models for Bird-Egg Incubator

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***Abstract*— This paper proffers cost-effective incubators for bird eggs hatching in Nigeria. Four models of bird eggs incubators were highlighted using three different phases of incubation technologies. Model one, a still-air, oil lamp incubator is developed to incubate considerable few numbers of eggs, while model two, a semi-electric forced-air, oil lamp incubator demonstrated an incubator's efficiency when an inherent hot-spot is diffused within the incubator box by means of a low-speed fan. This ensures that more eggs can be hatched, provided temperature and humidity are closely monitored. The third model, a semi-automatic, electrical incubator using an analogue thermostat with an improvised humidifier is constructed, eliminating constant human monitoring inherent in the previous models of incubators. The final model, an embedded computer based incubator was developed with negligible human monitoring with higher hatching capacity. Results from different models testing show that with an embedded computer-based model of incubator preset at temperature of 37◦ Celsius, humidity level of 60-75%, and proper egg turning interval, embryos' casualty level will be reduced and increased hatchability rate will be achieved, if eggs fertility rate is high. This will eventually increase the commercial production of chickens for local consumption and commercial demands in tropical country like Nigeria.**

***Keywords*—Incubator, Bird-egg incubator, Microcontroller, Electrical incubator, Oil lamp Incubator, Automatic Incubator**

I. INTRODUCTION

It is in the interest of every developmental communicator to inform and sensitise the populace on various social developments that may affect their livelihoods. Hence, there is a need to sensitise the government and its people to revisit agriculture sector to ensure food sufficiency in the nation. Even during the period of post-World War II, the sufficiency of future food supplies has been a recurrent question in the media and international debate. (McCalla, 1994).

The egg is one of nature's most incredible self-contained life capsules. Artificial incubation goes back thousands of years when the ancient Chinese and Egyptians operated large hatcheries that were quite successful. Up until ten years ago most of the scientific information concerning artificial incubation applied to precocial species important to the poultry industry. Presently large commercial poultry incubators fit tens of thousands of eggs at a time and, due to selection, most hatch (Hagen, 2010).

Incubator for egg hatching has made a great impact in the agriculture world. It increases the production of chicken, duck, turkey and their eggs to the food industry. This is happening because of the hatches percentage through the incubator are much higher than the conventional way. The incubator can save space and cost that are the major factor in obtaining good profit. Creating an efficient incubator at a moderate and affordable price is challenging because egg embryos are delicate even a slight change of temperature, humidity and ventilation can affect the timing of the hatchlings, likewise a rough turning of the egg can kill the embryo (Yusof, 2011). Therefore, with proper control of analogue parameters like temperature, humidity, ventilation and egg turning can be achieved in a single system through the provision of Computer accurate measurement as demonstrated in our fourth model to avoid casualties in the eggs.

Commercially, the minimum price of low cost incubator that have been surveyed ranged between $450 - $2000 USD, this is about N320,000 or more converted into Nigerian Naira. Mostly the temperature control of most incubators is analogue this means that the incubator must be monitored every time for temperature and humidity stability. With the development of these models of bird egg incubators, the farmer can get a user-friendly, plus a high-technology incubator with the same price as stated above, maybe lower or even more, all depends on the capacity and number of eggs such incubator can hold at a time for incubation (Yusof, 2011).

The problems of early hatching, late hatching, piped eggs with no hatching, blood rings and dead embryos at early stage of egg embryonic development are common in analogue bird-egg incubators. These symptoms are commonly caused by incorrect incubation measurements. For example, early hatching is caused by high incubation temperature while late hatching is as a result of low temperature. Piped eggs without hatching, that is, no escape from the egg shell are caused by two factors, namely; improper ventilation and insufficient moisture (low humidity). Blood rings in the eggs are caused by inaccurate incubation temperature due to manual (analogue) temperature control. Lastly, dead embryos at early stage are caused by improper egg turnings (needed three times a day) and ventilation.

The focus of this paper is to develop different cost effective models for bird-egg incubator with a precise temperature and humidity controls with an efficient egg turning precision. To realize these objectives, an embedded computer based using a low cost microcontroller was designed to monitor efficiently the operation within an incubator and make adequate responses as needed without human monitoring. Other models like still air oil lamp, force air oil-lamp, and analogue controlled semi automatic incubators were developed to give a clear demonstration of the various types of incubation technologies and to determine objectively the most efficient one out of the four models will involve minimal human monitoring, environmentally and user-friendly, and be able to hold considerable numbers of eggs for commercial purpose.

The paper is organized into five sections. Section one provides background information to the phenomenon of bird-egg incubation for the increment of livestock production in Nigeria, while section two of the paper provides literature review in the area of bird-egg incubation, and the third section discussed the material and methodology that were employed for the design, development and assembly of the four models of incubator that are proposed in this study. Section four discussed how the models were tested and finally, the fifth section provides a summary, recommendation for future possible studies in the area of bird-egg incubation.

II. RELATED WORKS

Naturally, all birds lay eggs declared Dunne and Eisenbeis (1972), but most reptiles lay eggs, even birds lay their eggs in heaps of soil or decaying vegetation and pay no more attention to them. Their young are able to fly almost at once after hatching. The process of egg incubation has left a lot for wonder.

Yet all other birds incubate their eggs by supplying heat from their bodies, and give the young devoted care. But during the incubation period, Bucher (1983) found that pre-piping and hatching levels of oxygen consumption are lower than in some precocial species.

However, it is without doubt that more benefits accrued to artificial incubation and production of eggs. But also with same token, researcher, such as Van Der Heyden (1987) claims that artificially incubating to increase egg production is risky and that many aviculturists have lost more than they've gained by it. Surrogate or foster parents have been successfully used to incubate and raise eggs (Gee, 1983; Harrison, 1987; Stoodley, 1984) with the same benefits as artificial incubation. Although evidences have shown that the production of rare species can be significantly increased by artificial incubation.

But noticeably, several factors are attributed to hatchability of eggs in the incubator. According to Abiola, Afolabi and Dosunmu (2008), citing from different researchers, temperature and humidity control, conditions of the egg, turning frequency, etc, could affect the rate of eggs hatchability. A study reported that turning in the first week of incubation enables proper formation of extra-embryonic membrane while in the last week avoids embryonic malpositioning (Tona, Onagbesan, De Ketelaere, Decuypere & Bruggeman, 2003), likewise the absence of turning resulted in presentation of the head in the small end of the egg (Elibol & Brake, 2004), while egg turning has been reported to facilitate the transfer of yolk nutrients to the embryo via the sub-embryonic fluid (Deeming, 1989a). Therefore, the importance of turning cannot be overemphasized during the incubation period. When setting in trays, the proper orientation of the egg during incubation is with the small end pointed down. The air cell should grow at the blunt end. There is some controversy over the positioning of the egg, in a tray or on rollers. Most trays are held at 45° and rotate the eggs 90° from one side to the other, although the eggs are held in the vertical position in the tray. Rollers are able to turn the eggs completely and the eggs can be set in a more natural horizontal position. But no scientific studies have compared rollers versus trays although some breeders have reported better success with rollers. Turning prevents the embryo from fusing with the eggshell membranes. If this happens the embryo will stick to the shell and development can be fatally distorted or the chick may be mal-positioned for proper hatching. The turning of chicken eggs can be stopped at 16 days (normal incubation period 21 days) without adversely affecting hatchability (Wilson & Wilmering, 1988).

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Additionally, the rate of embryonic development is dependent on temperature. Incorrect temperature may alter the timing of the hatch and may result in incomplete absorption of the yolk. Poor quality temperature measurement and control has, in the past, been responsible for most failures in artificial incubation (Klea, 1983). Ether filled wafer thermostats are affected by barometric pressure, become inaccurate with use and even when new have a greater variability than other types of control (Klea, 1983). If the wafer bellows fails the eggs could be cooked or poisoned by the released gas. Reliable solid state thermostats are now the norm on most incubators.

Forced-air incubators have a continuously running circulation fan keeping the conditions within uniform. Still-air incubators have no such fan which usually results in a temperature gradient increasing to the top of the incubator and closer to the heating element. Still-air models need to be operated at slightly warmer temperatures so that the optimum average temperature of the eggs is achieved. Each model may have different gradient or zone characteristics and this variability makes still-air incubators difficult to monitor and control at the required steady temperature. Researchers at the University of California, Davis found that incubating cockatiel eggs at a temperature of 37.5°C (99.5°F) and a relative humidity of 56% produced best results. Temperatures 1.4°C higher or lower than 37.5°C produced very poor hatchability and increased the incidence of abnormalities (Cutler & Abbott, 1986). Although, remote monitoring of egg temperatures during natural incubation has found lower temperatures than those commonly used for artificial incubation (Klea, 1987; Schwartz, Weaver, Scott & Cade, 1977). Some recommend that artificially incubated eggs be cooled once a day to recreate the natural cooling which occurs when the brooding parent leaves the nest to eat (Reininger, 1983). It was found with American Kestrel eggs that this cooling has no effect on the hatch, detrimental or helpful (Snelling, 1972). Therefore opening the incubator regularly to check fertility or for piped eggs is probably not harmful and will also bring in fresh air.

A thermometer can be used to determine the humidity by making it into a "wet-bulb thermometer". This is made by fitting the thermometer with a wet wick and noting its lower temperature due to evaporative cooling. The rate of evaporation is dependent on the humidity of the incubator. These wicks should be kept free of mineral buildup which can be avoided by using distilled water. The wet-bulb temperature can be converted to per cent relative humidity using standard tables for the particular dry-bulb temperature used.

Incubators and hatchers have pans filled with water to provide humidity. Some equipment, such as the Marsh Farms Roll-X, contains quadrants in the lower tray that are flooded to provide the humidity. The total surface area of water determines the humidity and should be adjusted until the correct humidity is achieved. Some incubators have heated water trays which can significantly increase the humidity. With these systems the correct water tray temperature needs to be set or too high a humidity may occur. The humidity can also be controlled by the size of the intake-exhaust air vents. However, proper ventilation is needed to provide O2 and remove CO2 from the incubator and restriction of this flow to increase incubator humidity is not recommended. Low (1987) advises towards lower humidity levels and provides little or no water in the incubator. This may be true for very humid areas such as Florida but in all cases the correct humidity must be established by a combination of wet bulb readings and proper egg weight loss.

Poor fertility and hatchability can be due to a number of factors including poor parental nutrition, poor parental stock (old or infirm birds), inbreeding, infection of the egg and improper incubation conditions (Flammer, 1984). Too low or too high incubation temperature and/or humidity may result in a delayed or early hatch of weak chicks with unretracted yolk sacs or death as chicks stick to the membranes or drown in excess fluid. A study of 1200 bugerigar eggs which failed to hatch found 73.3% to be infertile or clear, 14.8% as dead in shell mainly due to infections but also malposition, 11.1% because of early embryo death due to rupture of the yolk, infections or no specific cause, and about 1% due to deformed shells or lack of a yolk (Baker, 1988). Staphylococci were the most common bacteria found in infected eggs along with Streptocci, E. coli, Corynebacterium and Pseudomonas in that order of occurrence (Baker, 1988). This study shows the importance of egg sanitization to achieve maximum hatching rates.

III. Material And Methods

The materials that were used in the development of these sets of incubators can be divided into two types, namely: electrical and non-electrical materials. The electrical materials include the Microcontrollers, egg turning DC motor (with high torque), temperature and humidity sensor, low-sped axial fans, thermostat, high density cable, metal crates, and a high Wattage inverter for power substitution. As for the non-electric components, the materials include: two wooden boxes for oil-lamp incubators, insulated plastic cooler boxes for semi-electric, forced-air incubator, and a five-feet, refrigerator scrap for high capacity incubator.

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Figure 1: Still Air Model of Bird Egg Incubator

A. Model One: Still Air Oil-Lamp Model

This model is constructed from a wooden box of 25 inches by 13 inches with vertical measurement of 15 inches. The box was well insulated inside with Aluminum sheet to prevent heat loss and to allow thorough circulation of heat within the box. The box is covered with Aluminum lid on top with two 3-inches air vents cast out diagonally on top of the cover. These holes will allow for free out flow of hot air from the oil-lamp and the other hole for in-flow of cool air. Both vents are means of controlling the temperature inside the box. If the temperature is below the required level, the lid is closed slight until adequate temperature is achieved and vice - versa. A wet and dry bulb thermometer (hygrometer) is required to take proper manual measurement of temperature and humidity within the incubator box. An Aluminum water pan is placed inside the box to regulate and provide humidity inside the box. Figure 1(above) shows the still air Model of Bird Egg Incubator. This model incubator can be procured for N7000 (Seven thousand Naira only).

Figure 2: Forced Air (Oil-Lamp) Model of Bird Egg Incubator

B. Model Two: Forced Air Oil Lamp Model

This model was constructed from an Aluminum insulated wooden box of 25 inches by 16 inches with vertical measurement of 15″ and fitted with two drawers to hold egg crates. There are two compartments on both sides to hold a hurricane lantern. In addition, a low speed fan, powered with a battery (12V/18A), was installed inside the box at the top right corner of the box where the lantern would be placed. An Aluminum water pan was placed to regulate humidity in the box. A wet and dry bulb thermometer (hygrometer) was used to check the temperature and humidity measurement within the incubator box. Figure 2 (above) shows the forced air lamp model of Bird Egg Incubator. This model of incubator will cost N25,000 (Twenty five thousand Naira only).

C. Model Three: Semi-Automatic Model

This model was made from King size cooler box. The box was also well insulated inside with Aluminum sheet to allow diffusion of heat within the box. The box was divided into three parts: the lower part to hold water pan, the middle and upper parts to hold chicken net crates.

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A 220 volts axial fan was connected inside the box to hold a 60watts bulb. A Wet and Dry bulb hygrometer to measure the temperature as needed. Figure 3 (below) shows the shows semi-automatic model. This model will cost N60,000 (Sixty thousand Naira only).

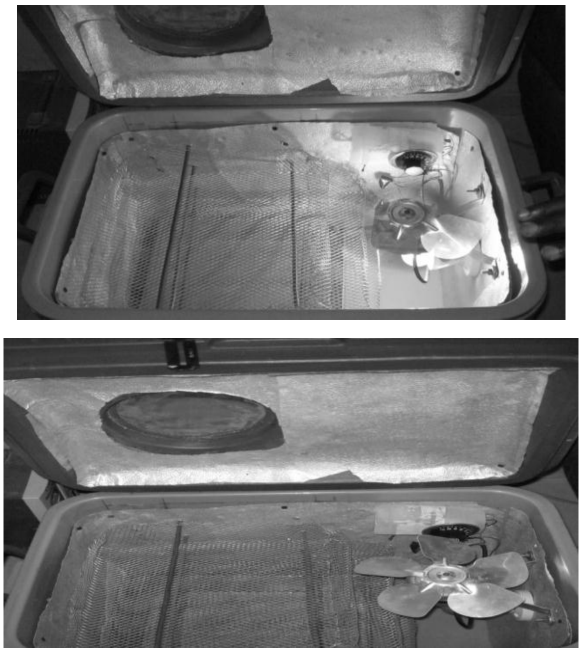

Figure 3: Semi-Automatic (Forced-air) Model of Bird Egg Incubator

D. Model Four: Embedded Computer Based Model

The final model is an embedded computer based system designed around AT89C52 Microcontroller from a scrap refrigerator box. A window hole was carved on the front, centre upper part of the door, while two ventilation holes of 4″ were carved on the upper back of the refrigerator. The two ventilation holes were fixed with 220 Volts axial fans to serves as heat and CO_2 extractor, and the other fan hole as oxygen in-let. Both of these fans work alternately. Metal trays were fitted inside to hold the eggs at a 45˚ angle as shown in Figure 3.0. The tuning 12V/4.5A DC motor was set to rotate at a very low speed of 20rpm. A 220 volts Axial fan diffuses the air in the incubator. An Aluminum water pan was placed at the bottom of the incubator to regulate humidity, and a humidifier to warm up the water, which gives off steams to regulate the humidity in the incubator as necessary and as programmed. Figure 4 shows the embedded computer based incubator model.

The embedded computer based system provides solution to egg incubation by reducing human monitoring, through an automatic control of the parameters required for egg incubation.

In this work, a coordinated network of sensors and actuator was used to constantly monitor the egg environment and egg-turning in real-time throughout the period of hatching. A microcontroller was programmed to coordinate the sensors and activate the actuators to maintain the parameters of the egg in the incubator. A temperature and humidity sensor (DHT11) was used to measure the temperature and humidity inside the incubator. If the temperature goes below the required temperature ($37\circ C$) of egg-hatching, a heating element is activated to increase the temperature of the incubator until the required temperature is reached; thus the heating element is deactivated. For egg hatching, the humidity of the egg environment must be controlled, thus to maintain the humidity, AT89C52 microcontroller was programmed to get the measurement, compare it with the preset humidity that facilitate egg-hatching and activate or deactivate a humidifier as appropriate. Egg-turning was achieved by activating and deactivating a DC motor at regular interval. The block diagram of the system is as shown in Figure 5.0. Being a fully-automatic incubator, this model will cost between N70,000 to N250,000 depending on egg capacity and without an inverter.

Figure 4 shows the embedded computer based incubator model

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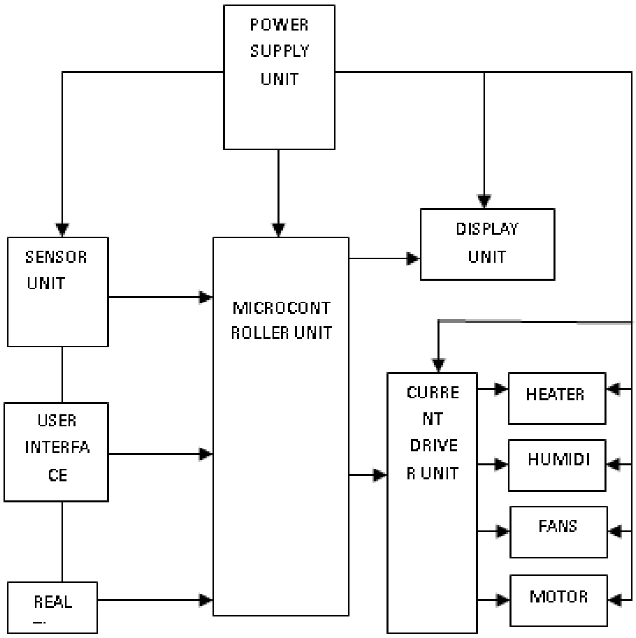

Figure 5: Block Diagram of an Embedded Computer Based Model of Bird Egg Incubator

E. Embedded System Design

To design the system whose block diagram is shown in figure 5, certain factors such as cost, availability of components, simplicity, functionality and reliability were put into consideration. The design of this system includes two parts. These are the hardware and software design considerations. For proper functionality of the system, these two parts must agree with each other. The hardware and software design are discussed as follows:

F. Hardware Design Considerations

The hardware unit consists of the following sub-unit: The sensor unit, user interface, the microcontroller unit, the real time clock, the display unit, the current driver unit, the actuator unit and the power supply unit. These units are discussed below:

G. The Sensor Unit

To design this unit, the accuracy, availability and cost of the sensors to be used was put into consideration. To make the design cost effective, an integrated sensor that has the capability to measure both temperature and humidity was selected. This make the design better as compare to previous design in Yusof (2011) that made use of separate sensor to measure temperature and humidity. The DHT11 Temperature and Humidity sensor was used for this unit as a result of its availability in local market as compare to SHT75.

The DHT11 sensor features a temperature and humidity sensor complex with a calibrated digital signal output. It ensures high reliability and excellent long-term stability by using the exclusive digital-signal-acquisition technique and temperature & humidity sensing technology. This sensor includes a resistive-type humidity measurement component and an NTC temperature measurement component, and connects to a high-performance 8-bit microcontroller, offering excellent quality, fast response, anti-interference ability and cost-effectiveness (D-Robotics, 2010).

H. The User Interface

The user interface provides the user an interface for configuration of the system. The configuration of the device includes setting the egg type to hatch, temperature, humidity, time and the incubation period. To achieve this unit, push buttons were used. Figure 6 shows the circuit connection for each of the push button.

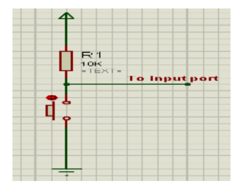

Figure 6: User Interface Push buttons Control Circuitry

The user interface also consists of the display unit. The display unit allows the user to visualize settings during configuration and the system status during operation. The current humidity and temperature measurement as well as the number of days the egg has been in the incubator are displayed. A twenty character by four lines liquid crystal display (LCD) was used for this unit. The number of information to be displayed was put into consideration in selecting the LCD. Below is the circuit diagram for the display unit.

I. The Microcontroller Unit

The microcontroller controls, schedule and directs all the activities and behaviors of this design based on the control program written for it. The following basic criteria were considered in selecting a microcontroller for the system: Ability to handle the task at hand efficiently and cost effectiveness; Maximum operating speed the microcontroller can support; Power consumption; The timer on the chip and the number of I/O pins and the easy of developing products around the chip, these include availability of assembler, debugger, compiler and technical support (Chinmayananda, 2009),

Currently of the leading 8-bit microcontrollers, the 8051 family has the largest number of diversified suppliers (Floyd, 2007). In the case of the 8051, originated by Intel, several companies also currently produce the 8051.

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Thus the microcontroller AT89C52 shown in Figure 7, satisfies the criterion necessary for the proposed application was chosen for the task.

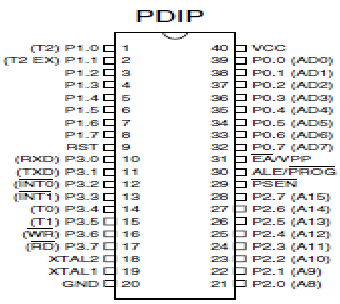

Figure 7: The AT89C52 Microcontroller Pin Configuration

J. The Real Time Clock (RTC) Unit

The real time clock (RTC) unit provides real time measure which the microcontroller used to maintain the incubation period of the egg. The DS1307 real time clock was used for this unit. It has 56-byte battery backed RAM data storage (Dallas Semiconductor (2002). The preset egg parameters are stored in the RAM location of the RTC. This help to back up the settings incase of unexpected shut down of the system.

K. The Current Driver, Actuator and Power Supply unit

The microcontroller cannot directly drive the relays to which the actuators are connected as it could not supply the required current needed to drive the relay. In designing the current driver the switching current for the relays was put into consideration. To achieve this unit, the ULN2803 Darlington driver Integrated Circuit was used due to its ability to supply a maximum output current of 600mA and 50V output voltage(SGS-Thomson Microelectronics(2010). This specification meets the requirement for switching ON the 10Amp /12V Dc Relays used for switching ON/OFF the heating element, fans, humidifier and DC Motors.

The overall circuit diagram of the entire five units is shown in figure 8.

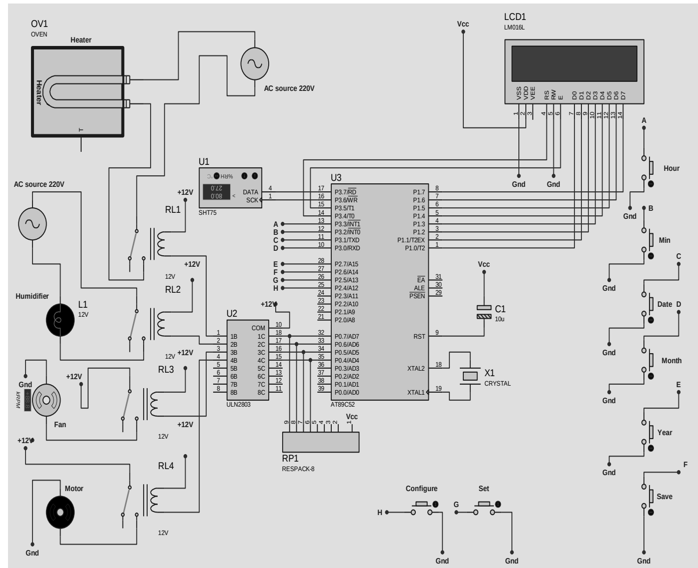

Figure 8: Overall Circuitry of the proposed Embedded Computer Based Model of Bird Egg Incubator

L. Software Design Considerations

The control program for the microcontroller was written in assembly language for code economy and speed reasons. The program was written using the Keil µvision version three Integrated Development Environment (IDE). The Keil IDE has in built editor and a debugger used to simulate and debug the program code. After successful debugging and correction of the program error, the machine code was generated with the keil software and transferred to the microcontroller using TOP2005 Universal Programmer.

M. Embedded Computer Based Incubator Model Operation

After the machine code was burned into the chip, the microcontroller was placed in the hardware circuit. All the connection from the relays was made to the respective actuators. The actuators were placed in their various positions in the refrigerator casing. The DHT11 sensor was also placed in the refrigerator casing.

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The system was powered ON. After the initialization process, the farmer receives a prompt from the display interface to configure the device. In the configuration process, the farmer selects the egg type to configure then preset all the initial settings of the egg type selected. After this, hatching process is set to begin. Once the farmer presses the start button, hatching process starts and continues till the hatching period elapse provided there is no power failure. The system operation flowchart is shown in Figure 9.0:

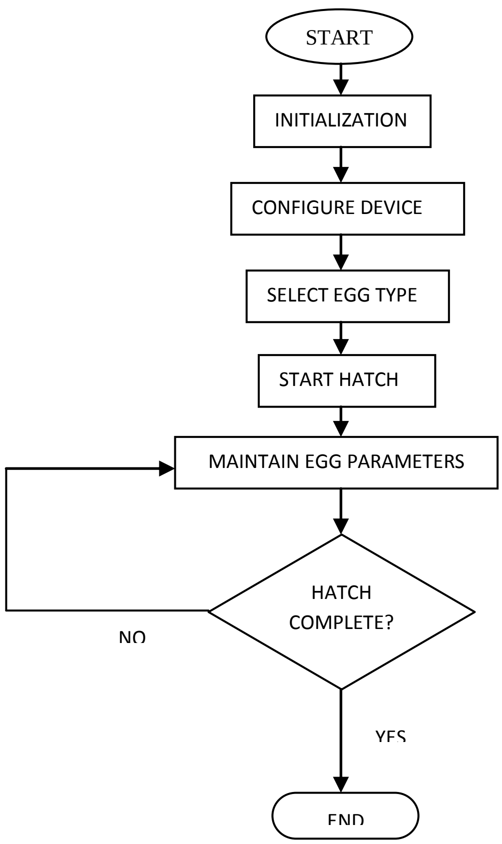

Figure 9: Operational Flowchart of Embedded Computer Based Model of Bird Egg Incubator

IV. Results And Discussion

This sub-section provides explanations concerning the results that were achieved in the process of testing the efficiency of these various models of incubators.

A. Model1: Still Air, Oil Lamp Model:

At the onset of testing this model, fifteen (15) chicken eggs were set in the incubator at 38 degree Celsius and tested for temperature stability, eggs were turned three times daily. At day 18, there was no more egg turning.

At exactly day 21, piping began and soon after five chicks hatched. The chicks were brooded in the incubator to warm up while the remaining eggs were expected to hatch, though this was not achieved. It can be deduced that still-air incubator is the most tedious process with 33% of success rate of hatchability and requires constant monitoring.

B. Model2: Semi-Electric Forced Air, Oil-Lamp Model

As for this model, the researchers, a crate (30 eggs) of chicken eggs were set in the incubator. The eggs were being manually turned thrice daily, and candling was performed after a week. At day 18, egg turning was stopped, but temperature and humidity were still constantly monitored. On day 21, chicks began piping and 25 eggs hatched successfully. This finding (83% success rate) was achieved and the researcher concluded that by diffusing hot air in an incubator through a low speed fan, hatchability can be efficiently improved. This incubator was later tested with two crates of guinea fowls eggs. Findings showed that out of the two crates, only 8 eggs failed to hatch indicating 86% success rate.

C. Model3: Semi-Automatic Model

This model 3 was powered by electricity though two 18A batteries. One crate of eggs was set in the incubator, turning was done manually thrice daily and temperature and humidity were constantly monitored until day 18 when turning was stopped. At day 21, 22 eggs hatched successfully representing 73% success rate, while 8 eggs did not hatch. Comparably, minimal monitoring was achieve through this incubator, because the thermostat has almost taken care of constant and mid-night monitoring of temperature, fear of over-heating was reduced. Findings that emerged during testing of this incubator have indicated some points for concern among the researchers which led to the development of the next model of incubator named Embedded Computer Based Model.

D. Model 4: Embedded Computer Based Model

The incubator was powered with 468 eggs in it until day 18 when turning stopped. Out of 468 eggs, 439 eggs hatched representing 94% success rate. The remaining 29 eggs were either non-fertile or died during their early stage of development.

V. Conclusion

In conclusion, this study has successfully presented four low-cost bird egg incubator models.

Compared to the rest of the models (still air oil-lamp incubator, forced-air oil lamp incubator, the semi-automatic forced air incubator), the embedded computer-based incubator model has proven far better, in terms of efficiency in hatchability rate, less human monitoring, and hassles that are involved in manual egg turning in the previous models. The embedded controller has taken care of all these problems. Although, the initial cost of the embedded computer-based is higher but it has negligible maintenance cost and better return on investment as demonstrated in 94% success hatchability rate above. The only serious challenge faced by the researchers during the process of operating this incubator model was lack of power supply, which was made up for by procuring an expensive inverter as backup. Therefore, had it been that there was an adequate power supply; this incubator model would have been one of the cheapest with manageable capacity of eggs at commercial level.

VI. FUTURE WORKS

It is expected that further studies should focus on ensuring adequate access to power supply since constant power supply would be the cornerstone for an efficient functioning of a microcontroller based bird-egg incubator. Other areas of further development include:

1. Inclusion of telecommunication module to inform the farmer the current status of the incubator and alert for necessary emergency action for an embedded computer based model.
2. Inclusion of more sensitive temperature and humidity sensor to enhance accurate measurement.
3. Inclusion of stepper motor for better angular movements of egg trays in the fourth model.

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