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Construction of Smart Automated Incubator using Inductive Heating and Renewable Energy

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Abstract
Poultry farming is one of the essential aspects in the agricultural sectors that have witnessed significant growth in recent times. However, the industry has seen a growing concern relating to the incubator. The current project aims to construct a prototyped smart, automated incubator using an inductive heating system powered by renewable energy. The incubator relies on a microcontroller to regulate and assess the temperature and humidity of the internal environment. A GSM module is adapted for calibration, data logging, and evaluation. The final testing of the device suggests that the new system is efficient and reliable for poultry farmers.

Keywords: incubator**,** inductive heating, renewable energy, temperature, humidity, GSM,

Introduction

Nigeria has witnessed a massive growth in poultry production and is now the largest poultry producer in Africa (Jatau et al., 2016). Poultry farming is one of the essential aspects in the agricultural sectors that have witnessed significant growth in recent times. The livestock industry is vital to the socio-economic development of Nigeria (Amos, 2006; Bamiro et al., 2012; Ekunwe et al., 2010; Hassan et al., 2016; Ibikunle Ogunyemi & Folorunso Orowole, 2020; Joshua Olorunwa, 2018; Kperegbeyi et al., 2009; Maikasuwa & Jabo, 2011; Onuk et al., 2017; Sanni et al., 2021) [2, 3, 11, 13, 15, 18, 20, 23, 26]. and a booming sector in Africa (Kiba et al., 2020) [16]. It contributes significantly to agricultural GDP (FAO, 2006). Poultry farming is raising domesticated birds such as chickens or turkeys to acquire meat or eggs for food. A large number of chickens are produced for meat and egg purposes. The demand for eggs and poultry meat has significantly increased in Africa due to population rise (Heise et al., 2015) [12]. Poultry egg incubation is an essential part of the poultry production system, especially during day-old chick development (Okonkwo & Chukwuezie, 2012) [32]. Poultry production begins with egg hatchery. The primary objective of a hatchery farmer is to obtain a large number of marketable chicks. Hatchability is of considerable relevance for all incubators and must be given appropriate attention (Cavero et al., 2014; Ulmer-Franco et al., 2010; Willemsen et al., 2008) [5, 31, 33]. Although, factors such as storage time, fertility, temperature, relative humidity, ventilation, the egg's position, turning, and candling have been found to influence egg hatchability. Inadequate hatchery machines are a critical factor limiting the expansion of poultry farming and making poultry products more expensive and scarce (Agidi et al., 2014) [1]. The low availability and high cost of poultry meats and day-old chicks in Nigeria may be attributed to the scarcity of commercial incubators and problems associated with the country's conventional poultry incubators, such as maintenance issues, cost of diesel, temperature, and power. Hatchery incubators require a large amount of energy to operate (Cui et al., 2019; Olorunmaiye & Awolola, 2017) [6, 22] which is in short supply in Nigeria. More so, conventional hatchery incubators have been associated with agricultural pollution (Gan & Hu, 2016; Guo et al., 2019) [9, 10].
The smart, automated hatchery method is meant for improved efficiency and increased production in the farming industry. Smart automated hatchery, apart from ensuring that economic waste is reduced, also provides cleaner energy in the United Nations Sustainable Development Goals (SDGs). This research project aims to construct a smart automated egg hatchery system with inductive heating and heat circulation system and a micro computing unit and android application for communication and user interface powered by renewable energy.

Materials and Method

The current project's primary purpose is to construct a portable incubating system that proves the possibility of an industry-standard efficient hatchery incubator with a smart temperature assessment system powered by renewable energy. The design of the system comprised the housing, mechanical, electronic, and software designs.

The housing

The housing was constructed with stainless steel plates for durability. However, the interior was coated with plywood. The internal dimensions are 507.2 mm × 507.2 mm at the base and 604.8 mm in height. The incubator contained two egg trays adequately separated to avoid contact during rotation. Each egg tray is designed to accommodate eight eggs each. A metal was fitted at the center of the floor to enable heat to radiate into the chamber. A transparent glass was fitted at the main door for inspection purposes, while the back contains a window-like opening for temperature regulation.

The egg turner mechanism

The egg tray was constructed with an iron rod with bearings attached to holes in the body frame and fixed to the turner for easy rotation. Perhaps, the egg tray is equipped with a dc motor with an automatic turning mechanism designed to rotate at an interval of 5 hours using a controller unit. The turning controller is a timer and motor speed limiting circuit programmed to power on the dc motor for an estimated period of 40 minutes and set it off for the next 5 hours. The turning intervals are set to allow the tray to rotate a maximum of 4 times per day. The CD4060 is among the popular CMOS chip with a 14-bit binary counter, an oscillator included. The oscillator is made up of inverters attached to various pins. The rotation frequency is controlled by resistor R4. The C2 and R8 are primarily responsible for the period the relay is energized. Thus, it is calculated to be energized for about six minutes. In this project, the relay is directly attached to the motor speed controller, which powers the d.c. motor with the required voltage. However, a potentiometer is used to avoid knocking the eggs for voltage and gear control.

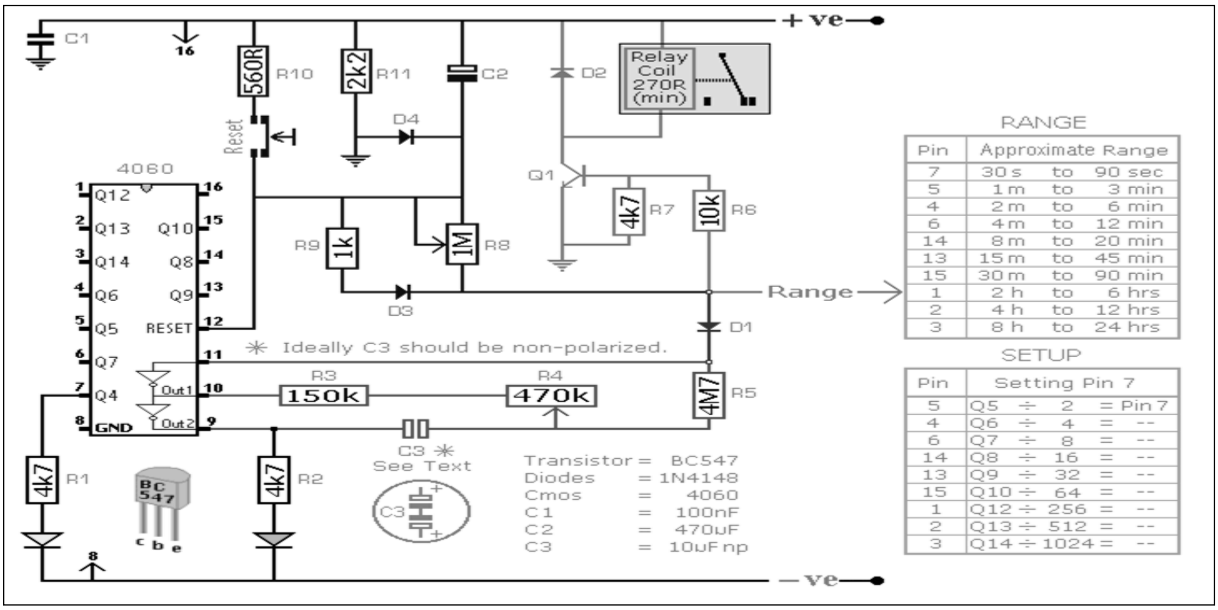

Fig 1: Timer circuit for the egg roller.

Inductive Heating System

An electromagnetic induction air heater element was adapted for connection to a source of alternating electrical current. An aluminum molded cylindrical with a loose roll of magnetizable wire mesh screen spaced apart in the adjacent position to enable an axial flow of air through to the system. The opposite ends of the heating coil were connected to the electrical current source, and a forced-air heating duct was hooked from the cylindrical box housing the heating coil to convey forced heat to the incubator. Air passed through the magnetizable cores is heated by applying alternating electrical current to an induction heating coil surrounding each magnetizable core, the coils being connected in an electrical network.

GSM Module

The GSM module for data reporting and calibration was set up with SIM900. SIM900 GSM/GPRS shield is a GSM modem with a complete Quad-band GSM/GPRS module. It delivers GSM/GPRS 850/900/1800/1900MHz performance for voice, SMS, Data, and Fax in a small form factor and reduced power consumption (SIM Com, 2013) [28]. The SIM900 has been widely integrated into electronic devices for real-time feedbacks (Pramanik et al., 2016; Satria et al., 2019; Tombeng, 2017) [24, 27, 30].

In this project, the temperature and humidity monitoring system was set up following the Munir et al. (2015) [21] description. It comprised an end device and a coordinator consisting of an XBee Pro RF module and a SIM900 GSM module. The end device sent the temperature and humidity reporting to the coordinator, and forwarded to the web server through GPRS communication using the SIM900 GSM module. Thus, making the temperature and humidity data accessible in real-time via an android application designed for the project. Also, a liquid crystal display is connected to the temperature regulator and positioned at the incubator's main door for onsite monitoring of the temperature and data logging. The system's power is sourced via a 300w/24v PV solar panel and 200ah/12v battery

System Integration and Testing

The circuits were individually tested for efficiency. Although, some critical adjustments were made. The circuit boards were embedded at the top of the housing unit and were, thus, connected to the various parts of the incubator. The temperature-GSM relation was confirmed via the Android mobile app. As expected, the egg tray turner and the fan were also tested for reliability and timing exactness, and all proved reliable. Temperature calibration, data logging, and reporting were adjusted via the Android app and confirmed over the LCD.

The system's reliability was further demonstrated following a deliberate abrupt power cut and the system's response to an unstable power supply. In all, the system was confirmed reliable for use.

Table 1: Table showing the measurements and testing performed on the incubator.

Parameters	Measured Value	Design Value
Temperature		
Maximum	39o C	40o C
Minimum	35.6o C	35o C
Relative Humidity		
Maximum	46	50
Minimum	38	40
Standby power consumption	11W	8W
Total Power Consumption	53W	48W
Input Voltage	202-218V	220-240V
Output Voltages	12V, 9V and 5V	12V, 9V and 5V

Conclusion
The current project aims to establish a smart egg incubator's functionality using an inductive heating system and powered by renewable energy. The microcontroller remains the central operating mechanism of the system. Thus, minimizing the need for hardware. The smart incubator system's completion and operational performance provide potentiality for a more extensive and industrial smart incubating system. Similar projects have been constructed (Bolaji, 2008; Kifilideen L. Osanyinpeju et al., 2016; Kyeremeh & Peprah, 2017; Radhakrishnan et al., 2014; Sunday et al., 2020) [4, 17, 19, 25, 29]. However, the current project utilized the inductive heating method. The compactness, sensitivity, and reliability of the device's operation, including the android user interface's simplicity, proved the device to be a dependable incubating system for poultry production.

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