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DEVELOPMENT OF A MICRO-PHYSICAL ELEMENTS MONITORING DEVICE FOR A TROMBE WALL SOLAR ENERGY POULTRY BROODING HOUSE

BY

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Abstract
An Internet of Things (IOT) data acquisition logger for micro-physical elements monitoring of a Trombe wall powered poultry day-old chicks' brooding house was developed locally at the Department of Agricultural and Bioresource Engineering, University of Nigeria, Nsukka, Nigeria. The IOT data acquisition device was used to monitor a 24 hours daily behaviour of temperature and relative humidity regime of the poultry brooding house. The IOT data acquisition device consists of two ESP32 microcontrollers and two DHT22 (sensors), Max6675 K-type thermocouples sensors, a network router which communicates to cloud at any point. The data acquisition device was powered by 100 mono-crystalline solar PV module and a 100 Ah deep cycle battery storage that ensures steady power supply at zero power outage. The data logger was used to monitor the physical elements profile of the poultry brooding facility use for poultry brooding operation. The results of the test performance evaluation obtained showed that temperature and relative humidity regime of the brooding house were between 28 – 35^{o}C and 56 – 82% while the ambient conditions were observed to be between 20 – 33^{o}C and 56–95% temperature and relative humidity respectively. Maximum and minimum solar radiation intensities were 993 w/m^2 and 0 W/m^2. The use of ESP32 microcontroller showed that data acquisition using the device could be could eco-friendly. With the device, the micro-physical environmental elements of the poultry house could be accessed at any point in time irrespective of location and distance. The Internet of Things data acquisition logger is user friendly. It solved a major problem of 24 hours drudgery of monitoring and data measurement at intervals usually encountered by researchers and scientists in studies of like manner.

INTRODUCTION

Internet of Things (IoT) is a growing network of connections that would be able to collect and exchange data in real time using embedded sensors to improve operational efficiency. The utilization of Internet of Things (IoT) data monitoring aids maximize production output.

Knowing the environmental conditions in experimental studies is very crucial for process analysis and mechanics of systems operations. The reliability and accuracy of measuring instruments when monitoring the parametric conditions in an environment is a factor of consideration for understanding the principles at which system operates. Many measuring instruments are available in the market ranging from simple ones like analogue mercury in glass thermometer to more complex ones of digital data loggers. While some of these instruments may be reliable to an extent the cost of acquiring them for systems instrumentation becomes prohibitive for local users. This is particularly prominent in agricultural production systems where climatic conditions are absolutely necessary for system optimization and efficiency. Many of the existing instruments for data gathering of temperature and relative humidity alike require intermittent measurements and adjustment for data capturing. This is known to have resulted in many occasions to inaccuracy and unreliability of the measured data. The use of internet of things (IoT) through could computing has in some measures reduced to fear of measure data unreliability and inaccurate measurements.

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Performance in poultry production systems for example could lean on the technological solution of IoT for improved operational efficiency in the production value chain.

Monitoring the environmental qualities of micro-physical elements of poultry production systems is a crucial factor determinant of success level of birds' performance. IoT sensor networks allow for real-time data collection on temperature, humidity, light, among other key indicators in poultry production systems. According to Victor (2023) Internet of Things (IoT) sensor network monitoring is a valuable tool to achieve this.

Environmental operating conditions are very crucial in ensuring optimal performance of birds' growth and health. With the global chicken market expected to eclipse a valuation of USD207 billion by 2027 (Jason,2023), IoT would enhance biosecurity, data-driven decision, production of healthy and happy chicks as well as protection of birds from harmful germs in the poultry production value chain.

Additionally, IoT sensor networks also enable monitoring of water and feed quality, which is essential in preventing disease and ensuring the quality of poultry products. With IoT technology diseases and pathogens can be dictated at early stage allowing for preventive measures that could stop further spreading of significant damage in poultry production. Internet of things (IoT) sensor network monitoring is essential for poultry farming, allowing farmers to make informed decisions and improve efficiency, health, and product quality. It also helps reduce environmental impact and improve sustainability in the poultry industry (Victor, 2023). Environmental monitoring of temperature and relative humidity are very important critical factors in poultry production systems. Fluctuation below or above the thresh holds could be detrimental to poultry birds' health. Temperature and relative humidity monitoring for optimum performance in poultry production systems is very important. Instruments for monitoring these parameters in poultry houses have been one major problem facing poultry farmers. The available imported monitoring devices are expensive or locally made ones are unreliable. Cloud monitoring of micro-physical elements in poultry systems could assist farm holders understand real-term operational conditions of the systems at a comfort distance.

Methodology

Description of the Trombe Wall Poultry System

The poultry facility used in the experimental study was the solar energy powered poultry day-old chicks brooding house designed and developed at the Department of Agricultural and Bioresources Engineering, University of Nigeria, Nsukka, Nigeria. The poultry brooding system is capable of brooding about 300 pullet day-old chicks or 200 broiler day-old chicks for a brooding period of seven (7) weeks or five weeks respectively depending on the type f bird. The system is made of concrete, block walls, pebble bed filled with stones, roofing sheets and transparent glass cover. The stones and Trombe wall collect and store solar heat. The stored heat is disseminated into the day-old brooding room for improved thermal conform in the space.

Micro-physical Elements Monitoring of Poultry Brooding House

Micro-physical elements monitoring of the Trombe wall solar energy powered poultry house was conducted and this involved real-time measurement of ambient and the brooding house temperatures, the relative humidity and daily solar radiation using the data logger developed for the purpose. For successful day-old poultry brooding operation, temperature and relative humidity range of 28 – 35 ^{o}C and 50 – 85% are required. Higher or lower brooding condition leads to heat or cold stress that may result to birds' mortality. Normal monitoring of these micro-physical elements entails 24 hours manual measurements at intervals by using thermometers and thermocouple wires. The drudgery in this method of measurement is enormous and tasking. Inevitable human and machine errors are frequent occurrences by accessing the point of measurements. Okonkwo and Akubuo (2007) report temperature and relative humidity range of 26 – 34 ^{o}C and 45 – 83% respectively. Varied brooding conditions exist however dependent on the heat source. Energy supply in poultry production is very important and a determinant factor in temperature fluctuation in poultry production systems (Okonkwo et al, 2022). The real-time data logger (microprocessor) interfaced with a computer facility developed to measure and monitor the micro-physical elements was incorporated with the Trombe wall poultry brooding house. The parameters measured include the ambient and brooding room temperatures, relative humidity and solar radiation parameters respectively.

Description of the Data logger

Fig 1 below shows the setup of the microprocessor networking developed to monitor the micro-physical elements of the Trombe wall poultry brooding house. The network (Fig. 1) is linked to the cloud to compute the real-time conditions within and outside the Trombe wall solar powered poultry brooding house.

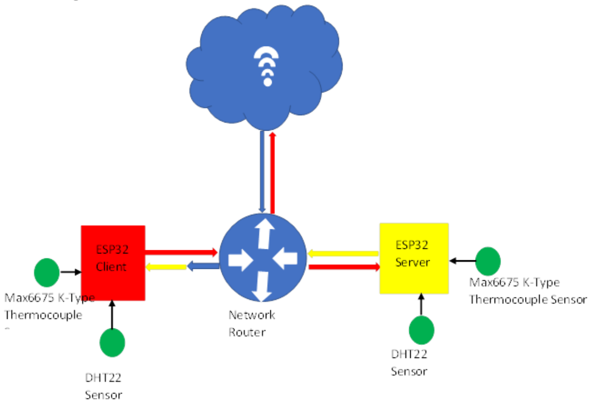

Fig. 1: Micro-physical elements monitoring device networking

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Working Principle of the Data Logger and Component Units

Fig 1 above shows the component units of the microprocessor linked to the cloud while Fig. 2 below shows the nodes as connected. The set up was configured and programmed and interfaced with a computer facility that monitors at intervals the micro-environmental conditions of the Trombe wall solar powered poultry house. The ESP32 microcontroller module is equipped with the ability to connect to a Wi-Fi network. This module serves as the centre of a node. The node is made up of ESP32 interfaced with DHT22 temperature and humidity sensor, Max6675 K-type thermocouple (for measuring through contact). The nodes are located at different locations to gather and monitor the conditions (parameters) inside the brooding room, and the outside the Trombe wall poultry house. The nodes were designed to update the same channel in thingSpeak could. These nodes communicate with each other locally to lump their readings together for a single update. In order to communicate with each other one of them serves as a server and second one as a client. The client which acts as gateway to the cloud sends series of http requests to the server node; the server node in return replies it with the sensor readings of ambient and brooding room temperatures, humidity conditions inside and outside in plain text. The ESP32 client updates thingSpeak (cloud computing) channel with these data including the one it read directly like room temperature and humidity, and radiation intensity. These nodes are as shown in Fig. 2. The arrows entering each node indicate the ones that can communicate with each other. ESP32 client communicate with the ESP32 server and the cloud while the ESP32 server communication is restricted to the ESP32 client. The arrangement is further explained in block with Fig. 3.

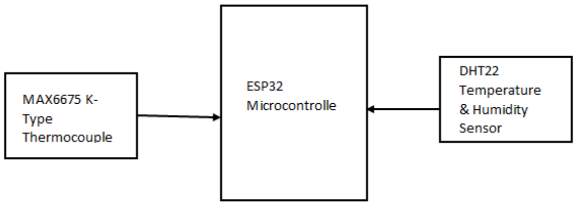

Fig 2: Block diagram of a Sensor Node

Instrumentation and Measurement

Before the present study mercury in glass thermometer, thermocouple wires and readers, relative humidity sensors were in use to monitor and measure the operating conditions of our poultry brooding facilities. The inherent technical and human errors associated with these instruments have some poor influence on data collection and the birds' overall performance. The data logger developed to help monitor the poultry brooding facility 24 hours on daily basis operated without interruption. Using mercury in thermometer and other instruments required physical presence and frequent opening and shutting entrance door in order to access the brooding space. Rea-time measurements and recording of the strategic measurement points was difficult to capture simultaneously. This method introduces multiple errors. Introduction of data logger as a real-time measuring device eliminated the frequency of door opening and closure. Use of data logger interfaced with a computer enhanced the quality of data monitoring at real-time. With this, the operating conditions of the poultry brooding house was monitored at comfort zone without being physically present by the experimenter in order to access the records. However, a major challenge of the new method is it can only operate where there is a network. The use of Internet of things clouds computing eliminates the drudgery of human errors associated with frequent opening and closure of poultry house. The technology is time saving and user friendly.

Monitoring the Operating Conditions

The test performance evaluation of the solar powered Trombe wall poultry brooding house was carried out at the Department of Agricultural and Bioresources Engineering, University of Nigeria, Nsukka. The data logger designed for measuring the operating physical conditions was used to monitor and measure the micro-climatic elements – temperature, relative humidity and solar radiation respectively.

Ambient and brooder room temperatures

Figs. 3 and 4 show the mean ambient and brooding room temperatures profile at different time during the experimental studies as recorded by the data logger. The minimum and maximum temperatures were recorded at the hours of 1 am and 1 - 2 pm respectively. The average environmental temperatures fluctuate between 20^{o}C minimum and 33^{o}C maximum while the brooding house operating conditions were maintained between 28 – 35^{o}C and 56 – 82% within brooding enclosure while ambient conditions were 20 – 33^{o}C and 53 – 95% temperature and relative humidity respectively. The result of the present study could be useful to poultry breeders and a useful tool to field scientists and policy making bodies towards developing rational policy that would improve the generality of poultry production and climate change mitigation in the poultry production industry.

Solar radiation

Figure 5 shows the typical mean, clear sky, cloudy and raining day solar radiation measurements recorded during the period of the experimental study. The measurements 548, 993, 372 W/m^2 were the maximum solar radiation intensities obtained at between the hours at 1 pm and 2 pm for mean, clear sky, cloudy and raining day while the minimum radiation intensities were all zero recorded during the off-sunshine hours. It was observed that during the raining hours solar radiation intensity drooped to zero point. The zero drop hours of solar radiation intensities did not however affect the performance of the poultry brooding house. The temperature and relative humidity remained within the permissible operating range during the period. The indication is that the Trombe wall solar powered poultry system maintained the required thermal load leveling operating conditions pre-requisite for day-old chicks brooding operation. This was evident at zero radiation intensity of the sun especially during the night hours when there was no radiation further indicating the ability of the Trombe wall solar energy collector to store,

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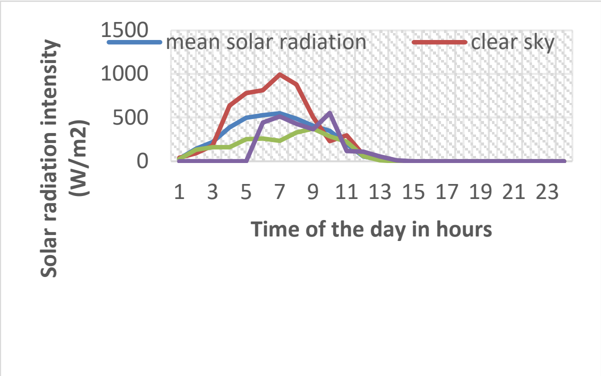
conduct and discharge heat at a moderate rate into the brooding space.

Fig. 3: Mean ambient and Trombe wall poultry house temperature Fig. 3: Mean ambient and Trombe wall poultry house relative humidity



CONCLUSION

A data acquisition logger of internet connectivity that uses *wi-fi* in operation was designed and developed in this study. The Internet of things (IoT) sensor network monitoring device was used to monitor the micro-climatic elements measured as temperature, relative humidity and solar radiation of a solar powered Trombe wall poultry day-old chicks' brooding house. The measured temperature and relative humidity ranges were between 28 – 35 ^oC and 56 – 82% while ambient conditions were 20 – 33 ^oC and 53 – 95% respectively. Maximum and minimum solar radiation were 993 and 0 W/m^2 respectively. The instrument is considered essential for parametric monitoring of poultry operating conditions in real-time for optimum performance of birds. It allows poultry farm holders to make informed decisions that improves efficiency, health, and product quality in poultry production. The Internet of Things (IoT) data logger is farmer friendly and recommended to every poultry farm holder for efficiency and increased productivity in the poultry production industry.

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