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Research Article
Solar-Powered Trombe Wall Brooding of Day-old Poultry Chicks

[1]W.I. Okonkwo, [1]Emenike Ejiogu, [1]O. Ojike, [1]G.I. Ezenne, [2]I.K. Idika and [3]A.U. Onyechi

[1]World Bank Africa Centre of Excellence for Sustainable Power and Energy Development, University of Nigeria, Nsukka, Nigeria
[2]Department of Veterinary Parasitology and Entomology, University of Nigeria, Nsukka, Nigeria
[3]Department of Nutrition and Dietetics, University of Nigeria, Nsukka, Nigeria

Abstract

Background and Objective: The importance of heat supply in regulating the body temperature of poultry day-old chicks' during brooding operation can never be overestimated. In developing countries, small and medium poultry farms often use kerosene bush lamps or stoves to regulate the body temperature of brooding day-old chicks. Energy poverty and high heating costs often limit the scope of poultry farming, despite the fact that there are many poultry farmers. Using solar energy to brood day-old chicks has proven to be a reliable and attractive solution for sustainable poultry production. Solar energy offers cheap and clean energy in comparison to conventional methods for brooding poultry. This study was designed to develop a solar-powered Trombe wall poultry brooding system for day-old chicks. **Materials and Methods:** The system consists of a Trombe wall solar energy heat collector, a pebble bed heat storage unit and a brooding room that can handle 300 day-old chicks. The poultry brooding system was coupled with a purposeful built-in data logger powered by a 100 W mono-crystalline solar panel with an Arduino-mega microcontroller. The purpose was to monitor the real-time brooding conditions in the brooding system. Three hundred day-old chicks were used in an experiment to evaluate the physical and biological performance of the poultry brooding system. **Results:** Results of the experiment showed that the temperature was between 28-35°C and relative humidity was between 56-82%, while the ambient temperature was ranged from 15-33°C and the relative humidity was ranged from 53-95%. Minimum and maximum values of solar radiation intensity was ranged from 0-548 W/m^2 during the evaluation period. The result of the biological performance showed a 2% mortality rate at the end of a nine-week brooding session. In poultry brooding operations, solar energy reduces greenhouse gas emissions. Healthy and lively chicks were produced under solar energy brooding conditions. They attracted higher commercial value over the conventional brooded chicks. **Conclusion:** In poultry production, the use of solar energy can help revolutionize the present-day poultry production industry. Using the results of the study, field scientists, government officials and decision makers may develop rational policies to improve and boost poultry production in general.

Key words: Brooding heating system, poultry, solar energy, trombe wall

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Corresponding Author: Okonkwo, W.I., World Bank Africa Centre of Excellence for Sustainable Power and Energy Development, University of Nigeria, Nsukka, Nigeria

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

A major challenge in poultry production is the ever-increasing costs of energy, which place a significant financial burden on poultry farmers. The survival of day-old chicks depends on the quality of the energy supply during brooding. Inadequate energy supply results in a high mortality rate. Because of this, in Nigeria, most small and medium local poultry farm owners often use kerosene bush lamps or stoves to supply heat for day-old chicks' brooding operation while only some numbers use grid electricity in the brooding process. Though the farmers are in the majority, their operations are often limited due to high cost of heating power or the total absence of it[1]. Fossil fuel and electricity-based poultry systems are characterized by environmental pollution, fire outbreaks and high cost and unavailability in many localities. Currently, the cost of kerosene-powered poultry systems is on the rise due to the rise in fossil fuel prices and other competitive usages. In Nigeria, currently the price of a litre Kerosene is about US$1 (N1,500). This amount is high and very expensive and most poultry farmers in the region would not be able to afford such an amount. As a result of high production costs and the folding up of some farms, other production input costs are also increasing. The use of carbonized fossil fuels results in greenhouse gas emissions. The current situation has led researchers and poultry farmers to look for alternative methods to reduce the high production costs associated with current brooding methods. Among varying options, solar energy is environmentally friendly and less expensive than other alternatives, it is the most viable option for lowering production costs[2].

Although solar energy is not commonly used on poultry farms, it appears to be the best option for replacing the existing fossil fuel-powered poultry systems. In poultry production, solar energy has a higher comparative advantage than conventional energy sources. It offers cheap, clean and sustainable energy resource that is widely available in the tropics[3]. The availability in this region makes it unique for poultry farming with high marginal profits. However, the major impediment to its widespread usage among poultry farm owners has been the poor information spread of the harvesting technology for poultry production. Poor information dissemination about the harvesting technology for poultry production has prevented its widespread use among poultry farm owners.

There are many poultry farm-holders who are unaware of the technology and its benefits in poultry production. Trombe Wall solar-powered poultry production technology offers poultry farmers-owners a low-cost, sustainable method of poultry production in a sustainable environment. The Trombe wall technology can moderate the brooding space temperature suitable for the development of poultry day-old chicks. During brooding operations, baby birds need a warm environment of between 28-35 °C depending on the age of the birds to survive[4]. In most cases, the ambient temperature falls as low as below 15 °C, especially during the night periods. A high mortality rate will result if the birds are not given the right temperature.

Many studies have been carried out on the use of solar energy in poultry production systems. These include studies on solar poultry incubators and passive solar poultry brooding systems using water heat storage systems[1,5]. A comparative study was conducted by Okonkwo *et al.*[6], according to their results the mortality rates were 22.38, 12.17 and 2.97% and cost of production were US $474.54, 456.34 and 49.1 for brooding 1000 broiler day-old chicks in one year using kerosene, combined electric/kerosene and solar energy respectively. Using kerosene and combined kerosene/electricity or gas heating system is a huge financial burden for most poultry farmers that needs an urgent solution. Trombe walls are currently attracting some attention due to their simple design and lower cost compared to other heating devices for poultry production. The Trombe wall technology has been used to brood day-old broiler chicks at the University of Nigeria, Nsukka[3]. However, there is limited information about its potential application to raising other kinds of birds, such as day-old chicks and turkeys etc. Therefore, this study aimed to develop a solar-powered Trombe wall poultry brooding system for day-old chicks.

MATERIALS AND METHODS

Description of the trombe wall poultry system: This study was carried out at the Department of Agricultural and Bioresources Engineering, Faculty of Engineering, University of Nigeria, Nsukka, Nigeria (Lat. 7.39° E 6.86° N). Figure 1 shows a cross-sectional view of the Trombe wall solar-powered poultry brooding system for day-old chicks used in this study. The system is a poultry brooding house with solar energy collection and solar heat storage device. The system is made up of three (3) compartments-a Trombe wall solar energy heat collector, a pebble bed heat storage unit and a brooding room that can accommodate 300 pullet day-old chicks for a brooding period of about 9 weeks. The Trombe wall solar heat collector and a pebble bed heat storage unit were covered with transparent glass cover to maximize collection efficiency. The brooding house was constructed with conventional building materials made of concrete and standard solid blocks. The pebble bed is filled with pebbles while the house is sealed with roofing sheets. The pebbles and Trombe wall collect and store solar energy in heat form. The brooding room was heated by conduction, convection and

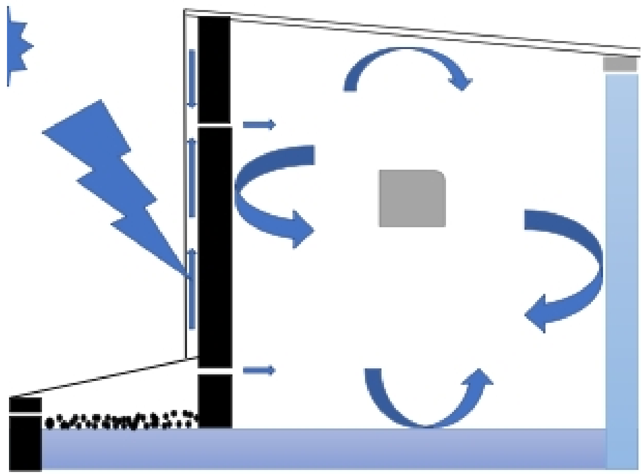

Fig. 1: A cross-sectional view of the Trombe wall solar-powered poultry brooding system for day-old chicks

radiation where the baby birds were housed for 9 weeks of brooding operation. In order to monitor micro-physical elements in real time, the brooding house was equipped with a purposeful built-in data logger constructed with an Arduino-mega microcontroller, thermocouple sensors and a network router. The data logger was interfaced with a cloud computing device to monitor the environmental brooding conditions of the brooding room. The data-collecting device was powered by a 100 W Mon-crystalline solar PV panel and a 100 Ah deep cycle storage battery.

Sizing the brooding house: Trombe wall is a wall system specially designed for solar heat collection and storage. The heat load and the space requirements for brooding 300 pullet day-old chicks for nine weeks were estimated. For these estimating the heat contributions coming from the Trombe wall system, heat storage pebble bed and metabolic heat production of the chicks were put into consideration. These combined gave the overall heat load of the brooding system. Solid blocks of 15.24 cm (18'') thickness (local standard size) painted with black colour was used in the construction. The overall heat balance equation of the system as described by Okonkwo *et al.*[1] is given below:

$$Q_b = Q_{Ls} - (Q_T + Q_{CK}) \quad (1)$$

where:
Q_b = brooding room heat load, W
Q_{Ls} = total heat loss from the brooding room, W
Q_{CK} = metabolic heat production of chicks, W
Q_T = total heat supplied into the brooding room, W

Based on the space required for each bird, the brooding space was determined. A brooding space of 0.046 m^2 was chosen for the design. For 300 birds the overall brooding space was 15.18 m^2 plus 10% space (1.5 m^2) for poultry equipment. An overall brooding space of 16.7 m^2 was determined and used for the brooding operation. The metabolic heat contribution (Q_{CK}) of the chicks was determined using the following equation:

$$Q_{CK} = q \times N \quad (2)$$

where:
q = metabolic heat production rate of a chick, W

Cloud computing monitoring of micro-physical elements: A microcontroller data logger purposefully designed, developed and coupled to the Trombe Wall solar-powered poultry brooding system was used to monitor the micro-physical elements of the Trombe wall poultry brooding system in real-time. The microcontroller was connected to a Wi-Fi network and temperature and relative humidity sensors. The data logger was interfaced with a computer to record the brooding room air temperature, relative humidity and ambient conditions during the experimental set-up. For day-old poultry chick brooding operation, temperature and relative humidity range of between 28-35°C and 60-85% are required for successful brooding operation. Cloud monitoring of the brooding system showed the micro-physical elements regimes of between 28-34°C and 56-82% while ambient conditions were 15-33°C and 53-95% temperature and relative humidity respectively while solar radiation intensity was between 0-548 W/m^2. Monitoring of micro-physical element levels in poultry brooding facilities is a necessity for understanding the response of birds in poultry brooding environmental conditions. The drudgery of 24 h physical manual monitoring of a brooding room can be enormous, tedious and time-consuming. The frequent manual monitoring of the temperature and relative humidity demands that the experimenter be on the ground for 24 h to monitor and record the operating physical conditions of the brooding condition. The manual monitoring method introduces operational and human errors in the process of data collecting. The data logger, however, offers a real-time measurement that eliminates the drudgery associated with manual data collection. Interface with wi-fi and computer makes it easier for the experimenter to monitor the brooding room at his convenience.

The birds were fed *ad libitum* with commercial starter mesh bought from a local feed vendor. Good drinking water was provided to the birds while disease-preventive medication was given to the birds as prescribed by veterinary personnel when it was necessary. The Performance parameters measured were the body weight and feed consumed at one-week intervals for nine weeks. The average body weight ($_{av}$BW), average weight gain ($_{av}$WG), Cumulative Weight Gain (CWG), feed consumption rate, cumulative weight consumption and feed conversion rate were measured and determined. The measurements were conducted using a digital weighing balance of the order ±0.0001 error sensitivity. Solar energy was the only source of heat for the brooding operation.

RESULTS AND DISCUSSION

Average weight measurement of chicks: Figure 2 shows that at the end of the nine-week brooding period of the experimental study, the average final body weight was 720 g/bird, weight gain was 71 g/bird and cumulative weight gain was 695 g/bird. Results of the present study showed that the body weight was 650 g/bird measured at the 8th week of brooding operation. In agreement with the current results Yerpes *et al.*[7] recorded the body weight of 608 g/bird and Odeh *et al.*[8] measured the growth performance of pullet chicks from 0-8 weeks in the tropics and recorded the body weight of 580 g/bird. Observation shows that solar-brooded pullet chicks show higher performance indicators within the same length of brooding operation. The highest weight gain was 130 g/bird recorded on the 8th week of the brooding operation.

Feed consumption: Figure 3 shows the cumulative weight gain, feed consumption rate and cumulative feed consumption of the birds while Fig. 4 shows the feed conversion ratio. At the end of the nine-week brooding session, a Cumulative Weight Gain (CWG) of 695 g/bird was recorded while the cumulative feed consumption rate (CFR) per bird within the period of the study was 303 g/bird. Average weight gain (avWG), Cumulative Weight Gain (CWG) and Cumulative Feed Consumption (CFC) were 71, 695 g/bird and 303 g, respectively whereas at the beginning of the study average body weight ($_{av}$BW) was 25 g/bird while the Feed Conversion Ratio (FCR) was between 0.29-0.44 recorded at the end of the nine weeks of the brooding operation (Fig. 4). Feed Conversion Ratio (FCR) is a measure of how well a flock converts feed intake into live weight. Lower FCR values indicate higher efficiency. The FCR value of up to 2.0 is permissible in poultry production. In this study, FCR was used to measure the relationship between the amount of feed each bird ate and the amount of meat it produced under solar-powered poultry brooding system.

It was observed that the feed consumption rate (FCR) increased with the age of chicks. At the age of 1, 5 and 9

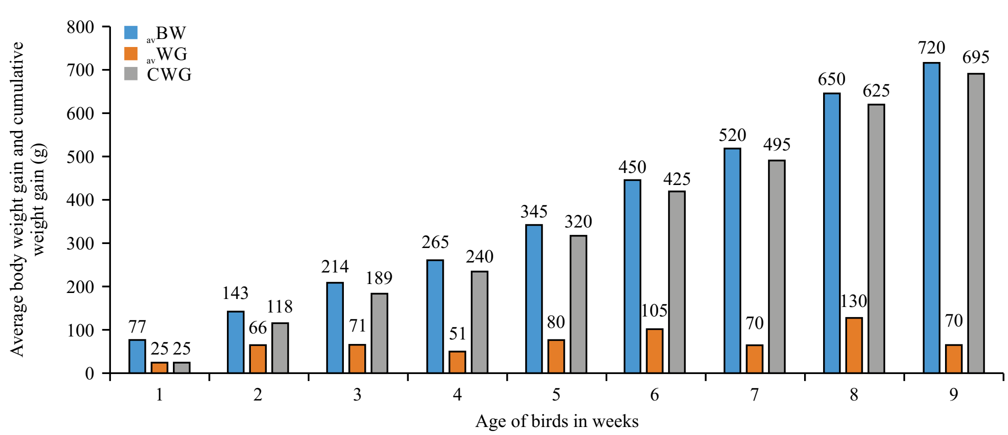

Fig. 2: Average body weight, weight gain and cumulative weight gain (g)

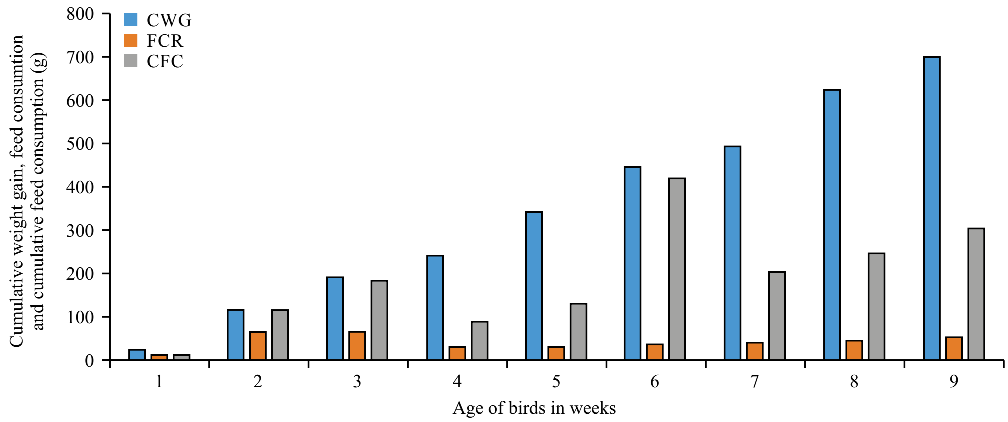

Fig. 3: Cumulative weight gain, feed consumption rate and cumulative feed consumption (g)

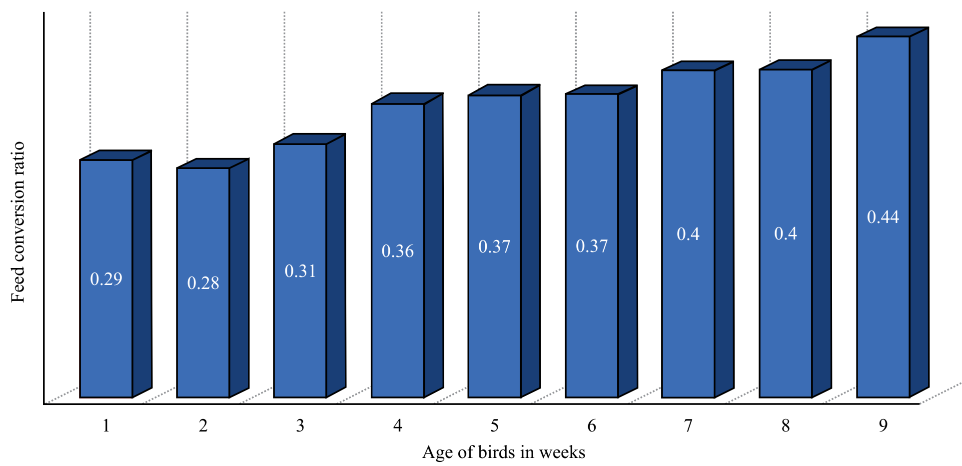

Fig. 4: Feed conversion ratio versus age of birds

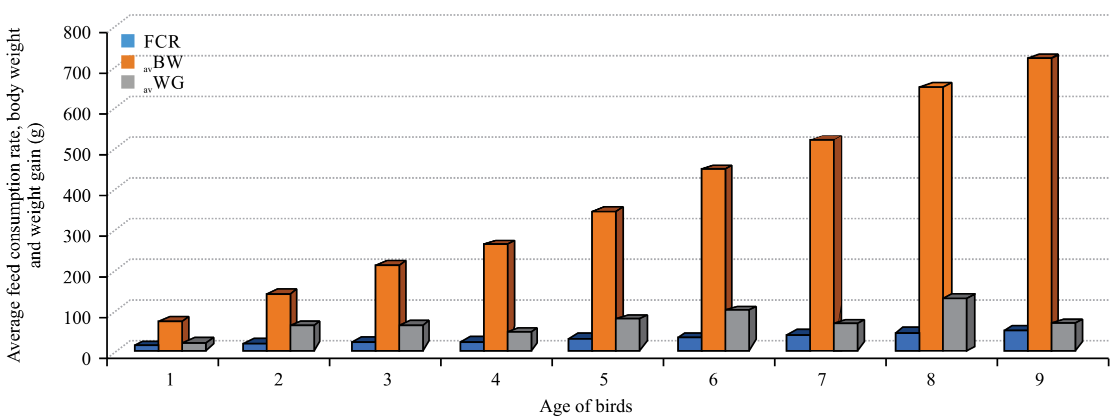

Fig. 5: Feed consumption rate, average body weight, average weight gain versus age of birds

weeks, the Cumulative Feed Consumption (CFC) was 15, 119 and 303 g, respectively while Fig. 5 shows the relationship between feed consumption rate, average body weight and average weight gain.

At early stage the birds consume less feed as shown in Fig. 5. Feed consumption increased as body weight ($_{av}$BW) and weight gain (avWG) increased. However, this trend is in line with birds brooded on conventional energy sources[9].

Mortality: Day-old chicks are very frail, especially during the brooding period of life. Hence, sound management to keep them healthy and alive is very important. Irrespective of the quality of the chicks, early mortality cannot be avoided entirely[10]. According to Yerpes *et al*[7], in a poultry farm the mortality rate of 1-5% is normal. In this study, out of 300 pullet day-old chicks, 6 died at the end of the brooding session of nine weeks representing a 2% mortality rate. According to Okonkwo and Ukachukwu[9] solar brooding systems have a 3% mortality rate, compared to 7 and 10% for kerosene- and grid power-supplied poultry brooding, respectively. This shows that solar energy brooding system has higher performance efficiency.

CONCLUSION

The temperature of solar-powered Trombe wall poultry brooding system was maintained between 28-35°C and relative humidity was between 56-82%, while the ambient temperature was ranged from 15-33°C and the relative humidity was ranged from 53-95%. Average body weight, weight gain, cumulative weight gain and cumulative feed consumption was 720, 71, 695 and 303 g/bird, respectively while a 2% mortality rate was recorded at the end of the brooding session. A solar-powered Trombe wall system can meet the heating demand of a typical poultry brooding operation. Trombe wall system can reduce energy consumption in poultry houses and is environmentally friendly as well.

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