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Characterization of a Photovoltaic Powered Poultry Egg Incubator

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Abstract. Poultry egg incubation plays an important role in the overall poultry production system especially during the day old chick development. In Nigeria, poultry production is a lucrative business but lack of commercially owned hatchery machines hinder the expansion and make poultry products for instance day old chicks costly more especially in the south eastern part of Nigeria. Presently, few commercially owned poultry hatcheries in Nigeria are located distance far away in the western and northern parts of the country. Majority of these hatcheries have little or no access to the national grid system but operate at about 60 per cent below the installation capacity. Generally, environmental pollution, unreliability and lack of access to grid power supply and low performance efficiency characterize the condition of the poultry hatchery business powered by conventional energy supply in Nigeria. These hamper and adversely affect the establishment of medium to large scale poultry production outfits in the rural areas of the country. But with the introduction of solar energy powered technology in poultry production, poultry farmers in Nigeria is likely to incubate and hatch poultry eggs and breed day-old chicks under a sustained power supply in a clean environment. This paper presents the characterization of a photovoltaic (PV) powered poultry egg incubator. The system consists of three basic compartments: a power supply unit, an energy storage unit and the egg incubation chamber. The incubator is capable of handling up to 375 eggs per batch of incubation. Physical test performance evaluation of the incubator indicates temperature and relative humidity range of between 36 – 39oC and 77 – 67% respectively. Further biological test using fertilized poultry eggs showed 74% efficiency of the incubator. The successful development and the characterization of the PV powered poultry egg incubator made significant innovation contribution in the Nigerian poultry production industry. Solar PV powered incubator is location free so long solar radiation is available. This study proffers solution to a major constraint of power inadequacy for commercial poultry egg incubation in Nigeria.

Keywords: Design, Construction, Characterization, Photovoltaic, Incubator

1. Introduction

Poultry egg incubation is an activity that requires sustainable energy supply for efficient performance, operation and profitability. This involves the management of fertilized poultry eggs to a satisfactory development level that leads to normal chicks [1]. It includes the control of the extrinsic environmental factors of the surrounding.

Naturally, a mother hen performs this function but at low efficiency [2]. And artificially, an incubator, a special system that simulates the environmental conditions required for such operation is usually employed by poultry farmers to do the same operation within specified temperature and relative humidity range. The ranges are usually between temperature and relative humidity of between 36 – 39^{o}C and 50 – 70% respectively. To maintain this temperature range sustained heat supply is paramount. In the most developing countries, the vast majority of poultry farmers in the rural communities operate their farms on small scale and/or even subsistence level. They often use a collection of bush lamps and kerosene stoves to achieve the heating requirements of the small hatcheries and brooders for day-old chicks [3]. The problems with these

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systems are enormous ranging from environmental pollution and fire outbreak. Use of fossil fuel is known to produce toxic gases which are harmful to eggs and poultry attendants. Electricity based egg incubators are known to produce clean energy without harmful effects on the environs but they are however limited in operation due to the initial cost of procuring such equipment coupled with the high cost of electric bill, frequent power outages where grid electric exists and the unavailability especially in the rural areas.

For sustainability in poultry chick production, the need for sustainable and environmentally friendly energy supply resource can never be over estimated. Such energy resource measure should be attractive and easy to come by or renewed by nature for example the use of solar energy. A special feature of solar powered incubator is that it could harnesse solar energy by using available materials. and is adaptable to both rural and urban poultry production. Major advantages of solar powered poultry egg incubator is that it could lead to a pollution-free environment, systems that are free from fire hazards and the development of small, medium to large-scale commercial incubators.

Survey [4] revealed that at the present there is no commercially functioning poultry egg incubator in the southeastern part of Nigeria. The day old chicks' supplied to the zone come either from the southwest or northern parts of Nigeria. The poultry farmers in the zone has no option order than to purchase the day chicks at very exorbitant rates at about three hundred naira (N300) about two US dollars ($2) per chick due to high cost of logistics and transportation.

Few individuals that own low capacity incubators ranging from 100 – 300 eggs which are powered by fossil fuel kerosene systems, generators or the combination in the process. They often collect and hatch eggs for individuals at non refundable charge of about one dollar ($1) per egg. To an average Nigerian poultry farmer this amount is considered very costly. The direct effect is high cost of day old chicks. Majority of the incubators operate at very low capacity at about 20% efficient.

The National Centre for Energy Research and Development (NCERD), University of Nigeria, Nsukka, Nigeria, pioneered research into the use of solar energy in poultry production in Nigeria. This is in order to alleviate the problems and challenges poultry farmers are going through in the poultry industry. The study is also a furtherance of earlier study on solar chicken brooding and solar powered dryer earlier developed by NCERD. The overall objectives are to imrpove production and provid sustainable energy supply under beign environment for successful poultry production in Nigeria.

2. Materials and Methods

Engineering equations involving heat and mass balances were used to estimate the components elements of the incubator. The physical and biological elements of the egg incubator were conducted. The physical measurements involved the use of thermometers to measure the ambient and incubator temperature while temperature-relative humidity sensor was used to monitor the ambient and incubator chamber conditions. A sliding device as a provision for regulating the degree of ventilation rate through openings ensured that proper ventilation was maintained within the incubation chamber. While egg positioning and turning were done manually at 45o rotation, using a lever handle at six hourly intervals. This prevents the sticking of egg yolks on the shell. Daily solar radiation data for the period of the test run was obtained from the meteorological unit of the National Centre for Energy Research and Development, University of Nigeria, Nsukka, Nigeria.

3. Description of the PV Powered Poultry Egg Incubator

Figures 1 and 2 show the units of the photovoltaic (PV) solar powered poultry egg incubator. While Figure 1is the incubator chamber made up of egg trays Fig. 2 shows the PV panels that powers to the incubator. The egg incubator is made of three compartments namely the egg incubation chamber, energy storage and the power supply units. The egg incubation chamber consists of five egg trays with dimensions 0.4m x 0.53m and a relative humidity pan. The chamber is capable of handling about 375 poultry eggs with each tray housing 75 eggs per batch. The entire body of the incubator is constructed with 2cm thickness wood. The whole system is wrapped with galvanized metal sheet to protect it against the adverse effect of weather while the inside is aligned with tarpaulin sheet for easy cleaning and to avoid moisture absorption by the wooden material. The egg trays were connected to an externally extended manually operated lever system that could turn the trays at 45^o. The turning mechanism is to avoid egg yolk sticking on the egg shell. The power supply unit consists of eight arrayed PV modules of 45Watts and 12Volts per module. The energy storage unit is made up of 6 lead batteries of 100Ah each, a charge controller and a 100Watts, 24 Volts solar powered inverter to convert direct current to alternative current from the PV panels. Heat supply in the incubation chamber is by 200 watts electric heater powered by the photovoltaic modules. An automatic temperature device regulates and controls the temperature of the incubation Chamber. This regulates and maintains the proper incubation temperature within the chamber between 36.5^oC to 29.5^oC. An air vent allows air circulation within the egg chamber. A transperant window located at the door helps to monitor and inspect the incubator chamber from outside without opening the incubator door.

Fig. 1: Solar PV powered poultry incubator.

Fig. 2: Incubator pvstand-alone power supply system.

3.1. Design Calculations

3.1.1. Heat Load of the Poultry Egg Incubator

In determining the heat load of the PV poultry egg incubator, the following assumptions were made:

- steady state condition exists
- one dimensional heat flow prevails
- incubator materials have constant thermal conductivity
- the incubator is a closed system at constant temperature.

The heat balance equation of the incubator chamber was estimated by

$$Q_{load} = Q_{pv} + Q_{egg} - Q_{cond} - Q_{conv} \tag{1}$$

Q_{load} = heat load of the incubator, W

Q_{pv} = heat supply by PV panels, W

Q_{eg} = heat supply due to metabolic activities of eggs, W

Q_{cond} = heat loss by conduction through the incubator walls to the ambient, W

Q_{conv} = heat loss through air convention, W

Conduction heat loss is expressed using Fourier heat conduction equation as

$$Q_{cond} = \frac{KA\Delta T}{\Delta x} \tag{2}$$

where

ΔT = change in temperature, C

A = total area of incubation walls, W/m^2

K = thermal conductivity of incubator wall, $W/m^2\ ^oC$

ΔX = thickness of incubator wall, m

Heat loss by air convention through the incubator air vents was expressed using

$$Q_{conv} = v\ell C\Delta T \quad (3)$$

where

v = rate of ventilation, m^3/sec

ρ = density of outlet air, kg/ m^3

C = specific heat capacity of air, kJ/kgK

3.1.2. Heat Production by Eggs

Heat production due to the metabolic activities of the eggs was estimated using the average of Lourens et al [5] heat production rate of 137mW for small egg and 155mW for big egg. A heat production rate of 146mW was used for the design.

3.1.2.1. Estimation of Battery Storage Size

An operating voltage of 220V was choosen for the design. From this, the design current of the battery was therefore calculated by

$$I_d = \frac{Q_{load}}{V_{op}} \quad (4)$$

I_d = design current, A

An off-sunshine period of 16 hours duty cycle of 7 days was condered. The ampere-hour discharge rate of the battery was obtained from

$$\text{Current load x duty cycle} = I_d \text{ x 16hr} \quad (5)$$

The corrected ampere hour/day considering derating for losses through wire and battery efficiency factor was calculated using

$$Correctedamprehour/day = \frac{I_d x 16hr}{0.98x0.9} \quad (6)$$

In sizing the battery to store enough energy to sustain the incubator the following factors were considered. These include the number of storage days, maximum depth of charge and the effect of temperature. The capacity of the energy storage battery was then determined by

$$\text{Required battery capacity} = \frac{\text{corrected Amp-hour load/day x storage days}}{\text{Max depth of discharge x temperature derate factor}} \quad (7)$$

Max depth of discharge (DoD) for automobile batteries is 0.15 and this figure was used in the design. A temperature derate factor of 1 was used. The capacity of a typical automobile battery is 60 Ah. 8 batteries were used to store enough energy that will sustain the egg incubator for at least 24hr of no sunshine.

3.2. PV Sizing

To determine the number of panels to be used, consideration was given to the heat load of the incubator, hour of usage and the inverter output voltage. This was estimated as

$$\textit{Number}\text{ of Panels} = \frac{\text{Heat Load x Hours of Usage}}{\text{Inverter Output Voltrage}} \text{ x Interter wr} \quad (8)$$

4. Results and Discussion

The performance evaluation of the photovoltaic (PV) powered incubator was conducted at the National Centre for Energy Research and Development, University of Nigeria, Nsukka, Nigeria. The photovoltaic incubator was initially run empty without eggs. This was done to ensure that the level of the operating micro elements- temperature and relative humidity of the incubation chamber were right. The incubator was then loaded with fertilised poultry eggs for a period of twenty one days and replicated three times. The eggs were turned periodically and manually six times each day. This was to no sticking of the egg yorks on the shell. Before loading the eggs candling was conducted to ascertian the condition of the eggs. This was repeated on the seventh, fourtenth and eighteenth days of the incubation period. At two days towards the end of the twenty one days incubation period the eggs started hatching. The hatched day old chicks are Fig 3 as shown the incubator chamber.

The incubator chamber and the ambient temperatures were monitored with circuit meter and mercury in glass thermometer, while the relative humidity was measured with relative humidity sensor, while solar radiation measurment was collected from Meterology unit of the National Centre for Energy Research and Development, University of Nigeria, Nsukka, Nigeria. The measurements were measured at every hour intervals. Figures 4 and 5 show the temperature and relative humidity profiles of ambient and incubator chamber respectively.

Fig. 3: solar hatched day old chicks inside incubator

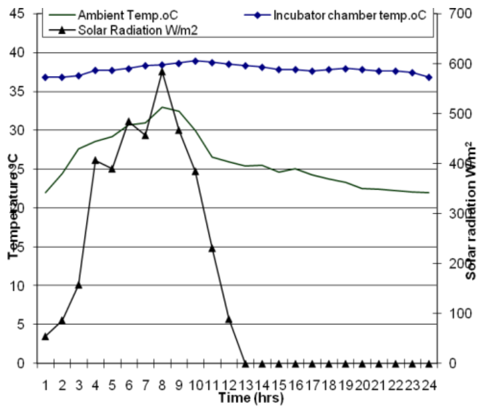

Fig. 4: Ambient and incubator temperature profiles with time.

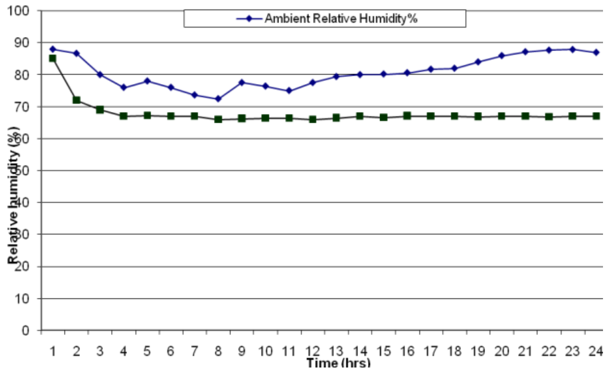

Fig. 5: Ambient and incubator relative humidity with time.

Observation showed that the micro elements- temperature and relative humidity of the incubator chamber were maintained between 36 – 39^{o}C and 77 – 67%, while ambient conditions were between 22 – 34^{o}C and 87 –74% relative humidity respectively when the minnmum and maximum solar radiation were 55W/m^2 and 584W/m^2 respectively. The rsults showed that steady incubation operating conditions could be achieved and maintained using solar energy for sustained egg incubation. Futher test run of the incubator using fertilised poultry eggs recoded about 74% efficiency. The incubator was loaded with 300 fertilised eggs 222 of the number hatched while the remaing number could not hatch. While 30 of the unhatched eggs showed evidence of fetus development 48 ggs showed no sign of fertility.

5. Conclusion

Many egg incubators have failed to perform optimally as a result of unsteady power supply and inappropriate temperature regulatory systems within the incubation operation. The unavailability of power supply greatly affects the operation of egg incubators. This paper has shown that solar energy could supply and sustain power needs in poultry egg incubation. It revealed that stable temperature and relative humidity range of 36 – 39^{o}C and 77 – 67% could be maintained within the incubator using a circuitry temperature control system. Test run using fertilized poultry eggs showed an efficiency of 74%. The utilization of this innovation in poultry production systems is therefore advanced for small to large scale poultry production system. PV powered poultry incubator is environmentally friendly and could save huge sums of money whem compared to other systems powered by fossil and grid connections.

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