IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 2 Issue 12, December 2015.
www.ijiset.com
ISSN 2348 – 7968

Performance evaluation of a passive solar Poultry egg incubator

Ahiaba, V.U[1]; Nwakonobi[2] T.U. and Obetta S.E.[3]

[1]Ahiaba Ugbede Victor, Lecturer II, ahiaba.victor@uam.edu.ng ; [2]Nwakonobi Theresa Ukaamaka, Associate Professor, napeth66@yahoo.com ; [3]Obetta Samuel Echi, Professor, sam.obetta@gmail.com

[1,2,3]Department of Agricultural and Environmental Engineering, University of Agriculture, PMB 2373, Makurdi, Benue State –Nigeria.,

Correspondent: ahiaba.victor@uam.edu.ng ; +2348036521370, +2348028990817

ABSTRACT

Evaluation of a Solar Poultry Egg Incubator designed and developed under Makurdi's weather condition on latitude $7^o7'$**N** was undertaken. The incubator had a floor area of 1 m^2 and a height of 2 m from the floor. The average solar irradiance per square metre of the earth surface around Makurdi, Benue Valley, on latitude $7^o7'$**N** and 111 m above sea level has been determined to be 224.17 W/m^2 over an average sunshine hour of approximately 7 all year round. This available solar power translates to 5.7 MJ of heat energy per day, the energy value on which this design was based. The design had a means of collecting the solar energy (using plane window glass), a means of storing the collected energy (using an 80 mm concrete slab serving as the thermal mass) and a means of transferring the stored energy (using a heat exchanger and direct dissipation from the thermal mass) into the incubating chamber where the fertile eggs are to be kept for the purpose of incubation. There was also a means of supplementing the main heat storage chamber, especially during cold night hours (using granite stones). The materials were pre-treated by painting them black for better heat collection. Maximum temperature of 95 ^oC was obtained in the heat collection chamber (surface of the thermal mass). The required temperature range for incubation of poultry egg is between 37 and 39 ^oC. The incubator was tested with 125 broiler eggs obtained from a reliable commercial hatchery for fertility and hatchability. Thirty Two (32) were found to be unfertile after candling on the 7^{th}, 14^{th} and 18^{th} day of incubation; 93 were fertile, giving a fertility rate of 74.4 %. Out of the 93 fertile eggs loaded into the incubator, 68 of them successfully hatched, giving a hatchability efficiency of 73.1%. The incubation took 21.5 days. The solar incubator can be used to hatch all poultry eggs.

1. INTRODUCTION

According to Lunde, (1980), solar systems in the past and present all relied on glass, mirrors or other transparent covers to trap heat as in a green house. The craving for alternative energy source, outside fossil fuel, has become a global trend. To this effect, countries around the world are investing massively in solar energy power plants. One of such major investment in the recent times is by the USA Department of Energy which has been charged with the development and sponsoring programmes that will transform the way energy is provided in the United States. Researchers from University of Arkansas have developed a high performance concrete to store thermal energy for concentrating solar power plants.

Incubation requires energy; energy that can raise the temperature of the air and the eggs to be incubated, from ambient to the required incubation temperature of about 37 to 39^oC. Such energy should be environmentally friendly and should be inexpensive and readily available to local farmers at no much cost. Solar energy looks one of such energy sources, because it is a clean, cheap energy to exploit, and is widely available all the year round in the tropics and in North Central Nigeria, along Benue River Valley, Makurdi-Nigeria. A good solar system should be able to convert solar radiation into useful heat or electrical energy, store it and releases it for utilization when needed.

Duffie and Beckman (1980), said that several methods of solar energy storage are available in literature. These include storing as sensible and latent or concealed heats. The advantage of sensible heat storage is that materials for energy storage are locally available and inexpensive. Such materials include water, stones, masonry wall systems, gravels and local bricks walls. The technology of masonry wall system as solar energy collector and storage device in buildings has been reported (Wray *et al.*, 1978; Nayak *et al.*, 1983). In Nigeria, solar heating system was reported in 1992 by Okonkwo *et al.* The results of the analysis showed an absorber plate temperature of up to 83 ^oC measured and 122 ^oC predicted while storage medium temperature was 45.56 ^oC.

Though the solar incubating system and heating system is not generally common in Nigeria, but the built-in thermal storage solar water space conditioning system could serve as a good example of utilizing solar energy in Nigeria as illustrated by some researchers (Okonkwo *et al*, 1992 and Okonkwo *et al*, 1993).

Several other researchers have worked on solar energy systems. Notable among them are Adeyemo (1988), Fagbenle (1990), Pelemo *et al* (2002) who worked on estimation of daily radiation in Nigeria using meteorological data, Yohanna *et al* (2011), Itodo *et al* (2007), Okonkwo *et al* (2007), among others. Owokoya (1992) designed and constructed solar air heater. Adaramola *et al* (2004)

ISSN 2348 – 7968

worked on solar cooker and was able to generate and maintain temperature up to *170* °C. Also, Odia (2006) effectively designed a solar assisted refrigeration system.

2. MATERIALS AND METHODS

The materials used for this evaluation are fertile eggs, obtained from a reliable source and a fabricated egg tray for carrying the eggs in the incubating chamber. The fabricated tray is shown in Figure 1. The average weight of the eggs was 56.4 g, about the weight of a normal egg.

The egg tray's size was selected base on the average area of each egg multiplied by the number of eggs to be stocked. A chicken's egg is, on the average 57 mm long and 44.5 mm in diameter through its widest part, and weighs averagely 59 g (Sainbury, 1980). However, the average weight of the eggs in this study was found to be 56.4 g – which is still very close to what Sainbury obtained. Base on this information, each egg is about 0.07 m x 0.05 m length and breadth respectively. This is about 0.0035 m^2 per egg.

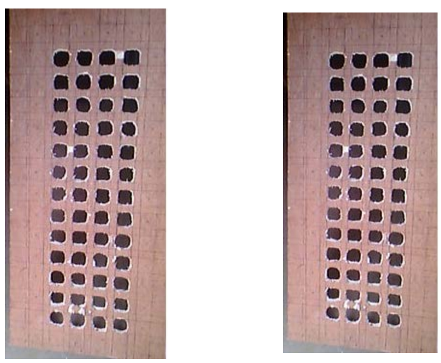

Plate 1: The Fabricated Egg Tray

3. MATERIAL TREATMENT

For the purpose of dehumidification, the material used was Powdered Activated Carbon (PAC), otherwise known as grinded charcoal of diameter of about 0.15 and 0.25 mm. Thus they present a large surface to volume ratio with a small diffusion distance. When humidification was needed, a pan of water with surface area of more than half the floor area of the incubator was used.

4. METHODS

The average solar power available per square area of earth surface at the region of this research was 224.17 W (Yohanna *et al*, 2011). The solar incubator under consideration has a solar glass surface (collector surface) of 1 m^2. By implication, this collector receives 224.17 J/s over sunshine hours of 7 hour per day. When this energy strikes the glass cover of the collector, the properties of the glass allows free and smooth passage of short wave solar radiation owing to its high transmittance. It was assumed that all the solar energy that successfully passed the glass was absorbed by the thermal mass, since the entire collector chamber was maximally insulated. Plane glass does not allow passage of longwave energy to pass across it. This collected energy gets into the incubation chamber in two ways; by direct dissipation from the thermal mass and through the heat exchanger that connects the collector chamber to the incubating chamber.

Table 2 shows the temperature behaviour of the incubating chamber. Note that at different hours of the day, temperature differs from the inner surface of the thermal mass down to the floor of the incubator. The turning of the eggs was manually done three times a day and the eggs are moved accordingly, to the portion of the incubating chamber where the temperature was found to be favourable. Plate 2 is the picture of the evaluated incubator.

On a typical day, between the hours of 12 am to 9 am, the required incubation temperature was found at a maximum distance of 20 cm from the thermal mass. In this time range, the closer the egg tray to the thermal mass, the better. Also, between the hours of 12 noon to 9 pm, the incubation temperature was found at a minimum distance of 100cm away from the thermal mass. Similarly, from 9 pm to 12 am, the temperature was ideal at around 60 cm and less, away from the thermal mass.

Turning—the entire eggs were turned three times a day, alternating between the broad side and the slim side. Turning the eggs was done such that the side that sleeps downward the previous night must stay up the next night. No turning was done in the night hours. The turning process was done manually.

Candling: Candling is required to know the stage of development of the embryo. A Candler was fabricated to achieve this. Candling process was carried out on 7th and 14th day of incubation. It was this process that helped fish out the infertile eggs.

Table 2: Temperature and Relative Humidity Variation between ambient and the incubating chamber and temperature variations at 20, 60 and 100 cm away from the thermal mass, as determined for 6am, 9am, 12 noon, 3pm, 6pm, 9pm, 12 am and 3 am.

Time of the day	T_{am} ^oC	Amb. R-H %	T_{tm} ^oC	T_{tmds} ^oC	R-H of incubating room,%	Incubating chamber temperature at various distances from thermal mass		
						20 cm	60 cm	100 cm
6am	28.4	84.3	37.1	36.9	56.1	36.9	33.4	30.5
9am	31.9	76.0	60.4	37.9	59.7	37.7	37.1	36.6

12 noon	36.5	78.1	84.1	43.5	64.2	42.9	41.5	38.9
3pm	36.6	69.2	91.5	56.6	64.0	46.6	40.8	38.5
6pm	33.1	60.5	68.6	48.9	62.7	46.1	42.7	38.5
9pm	31.1	61.6	59.4	55.4	62.6	43.8	40.6	38.9
12 am	29.0	62.9	50.6	47.5	62.5	39.2	38.3	36.6
3am	28.3	61.3	39.4	38.1	61.3	38.5	35.9	34.3

Keys: T_{am} =Ambient Temperature, Amb.R-H = Ambient Relative Humidity, T_{tm} = temperature of the thermal mass, T_{tmds} = temperature of the thermal mass at discharged point inside the incubating chamber, R-H = Relative Humidity.

Plate 2: Picture of the developed Solar Incubator

5. RESULTS AND DISCUSSION

Out of the 125 eggs obtained and stocked in the incubator, 32 were found to be infertile using candling process. The remaining 93 were fertile and were allowed to remain in the incubator to the end of the incubation process. Out of the 93 fertile eggs, 68 successfully hatched while 25 died in their shells as they were not able to break out successfully. So many factors may be responsible for the death of these 25. However, infection seems to be culprit as the dead chicks where not particularly found in a particular part of the incubator – which means, high or too low temperature or humidity in some parts of the incubator could not have caused their deaths.

Performance Evaluation of the Solar Incubator

The fertility and hatchability percentages of the eggs were determined from the following relationships;

$$\% \boldsymbol{Fertility} = \frac{Number\ of\ fertile\ eggs}{Number\ of\ eggs\ loaded}\ x\ 100\%$$

$$= \frac{93}{125}\ x\ 100\% = 74.4\%$$

$$\% \boldsymbol{Hactchability} = \frac{Number\ of\ eggs\ hatched}{Number\ of\ fertile\ eggs}\ x\ 100\%$$

$$= \frac{68}{93}\ x\ 100\% = 73.1\%$$

DISCUSSION OF RESULT

Hatching success of 100% is not common due to a number of factors: temperature fluctuations, unstable humidity, infections, and shocks on the eggs as a result of turning. Other factors could be accidental, inefficient systems, power failure from the sun such as on prolonged raining and cloudiness. Hatchability rate above 70 percent is not considered a colossal failure or loss in incubation analysis. Hence, the hatchability rate of 73.1 % shows that the system can be utilised in poultry enterprise. The difference of 1.3 % between the percentage fertility and percentage hatchability means that 98.7 % of all the fertile eggs were successfully hatched. The 1.3 % could represent those that failed to hatched as a result of infections, wrong handling or unnoticeable cracks on the eggs.

CONCLUSIONS AND RECOMMENDATIONS

Conclusion

The incubating system designed and developed was evaluated with fertile eggs, to ascertain its ability to incubate and hatch fertile eggs. The system was a passive solar incubator developed using materials such as plywood as the insulating part, plane window as the solar collector and concrete slab and granite stones as the thermal masses.

At the end of the experimentation, hatchability was found to be 73.1% at egg fertility of 74.4%. Observe that the difference between hatchability rate and fertility rate is not much at all. It means that under normal circumstances, the system under evaluation is highly suitable for incubation process in Makurdi, North Central Nigeria.

Recommendation

It is recommended that the incubator be remodelled and improved upon, especially in the area of insulation, thermal storage materials and finishing. This way, a perfect and easy to use solar incubator may become the darling of poultry farmers around the world.

6. REFERENCES

Adaramola, M. S. Amaduoboga, and Allen, K. O. (2004). Design, Construction and Testing of Box-Type Solar Oven, Nigerian Journal of Engineering Management, Issue vol. 5, No.2 pp 38 - 46.

Adeyemo, S. B. (1988). Estimation of The Average Daily Radiation on Horiwntal Surface, NSE Transactions, vol.33 No.1 pp 53 - 65.

Duffie, J.A. and Beckman, W.A. 1980. Solar Engineering of Thermal Processing, John Willey, New York.

Fagbenle, R. L. (1990). Estimation of Total Solar Radiation in Nigeria using Meteorological Data, Nigerian Journal of Renewable Energy, Vol.l, No.1, pp.l-l0.

Itodo, N.I., 2007. Solar energy technology, 1st edition. North Central Nigeria, along Benue River Valley, Makurdi-Benue State, Nigeria. Aboki Publishers

Lunde, P.J., 1980. Solar Thermal Space Heating and Hot water system.USA. John Willey and Sons, Inc.

Nayak, J.K., N.K. Bansal and M.S. Sodha, 1983. Analysis of Passive Heating Concepts, Solar Energy.

Odia, O. O. (2006). Solar Energy Application to Steam Jet Refrigeration. Nigerian Journal of Industrial and Systems Studies, Vol. 5, No.1 pp 10-15.

Okonkwo, W.I and C.O. Akubuo, 2007. Masonry Wall System for Poultry Brooding. International Journal of Poultry Science 6 (2): 125-130, 2007. Asian Network for Scientific Information.

Okonkwo, W.I., 1998. Solar Energy Brooding System, in Rural Renewable Energy Needs and Five Supply Technologies, Publication of Energy Commission of Nigeria.

Okonkwo, W.I., G.U.N. Anazodo, O.C. Akubuo, E.A.,Echiegu and O.C. Iloeje, 1992. The UNN Passive Solar Heated Poultry Chick Brooder- Further Improvement and Preliminary Testing, Nigeria Journal Solar Energy.

Owokoya, S. I. (1992). Design and Construction of Solar Air Heater, First Degree Project, Federal University of Technology, Minna.

Pelemo, D. A., Fasasi, M. K., Owolabi, S. A. And Shaniyi, Z. A. (2002). Effective Utilization of Solar Energy for Cooking, Nigeria Journal of Engineering management, vol. 3 No. 1 pp 13-18

Wray, W.O., J.D. Balcomb and R.D. McFarland, 1978. A semi empirical method for estimating the performance of direct gain passive solar heated buildings. LA UR-78-1176. Los Alamos Scientific Laboratory, University of California, Los Alamos, New Mexico.

Yohanna, J.K., Itodo, I.N. and Umogbai, V.I. (2011). A model for determining the global solar radiation for Makurdi, Nigeria. *Renewable energy, 36(3), 1989-1992.*