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308 Lasani Town, Sargodha Road, Faisalabad - Pakistan
Mob: +92 300 3008585, Fax: +92 41 8815544
E-mail: editorijps@gmail.com

Trombe Wall System for Poultry Brooding

W.I. Okonkwo¹ and C.O. Akubuo²

¹National Centre for Energy, Research and Development, University of Nigeria, Nsukka, Nigeria

²Department of Agricultural and Bioresources Engineering, University of Nigeria, Nsukka, Nigeria

Abstract: Performance evaluation of a Trombe wall powered poultry house for brooding day-old chicks was undertaken. The poultry house consists of a Trombe wall for solar energy collection and storage, a brooding room having a floor area measuring 6.6m². The house was tested experimentally with poultry day-old chicks under University of Nigeria, Nsukka, weather, over the ambient environmental temperature range of 18-37°C and daily global irradiance of 5.7-904W/m² for a period of 5 years. The measured Trombe outer wall temperature was within the range of 22-60°C. The brooding house maintained a temperature range of 28-35°C during the period of the experimental investigation. The indication is that Trombe wall system could be a good temperature moderating device in poultry brooding houses. Test using broiler day-old chicks showed average body weight of 586 grams, feed conversion ratio of 1.87 and 3% mortality rate at the end of session of five weeks per batch for the five year experimental study. The system can also find useful application in other animal rearing operations where heat is needed to keep the young animals warm at the early stage of development. One of such applications could be in pig production.

Key words: Trombe wall system, poultry brooding, poultry house

Introduction

Provision of heat for poultry production is a basic necessity for the survival and optimum performance of day old chicks during the brooding period. The sustainability of poultry production at this stage is highly dependent on the energy availability. In Nigeria majority of poultry farmers often use a collection of kerosene bush lamps/stoves or the combination of both to supply the heating requirements of hatcheries and box nurseries for brooding day-old chicks. Though the farmers are in the majority, they have their scope of operation seriously limited by the high cost of heating power or the total absence of it (Achi, 1987; Okonkwo *et al.*, 1992). At present, it takes a poultry farm of 1000 birds capacity about 40 litres of kerosene to brood day-old chicks per day. This when translated to monetary value amounts to US\$ 4,320 per annum. Few farmers who have access to the national grid system use electricity for raising day old chicks. But, frequent power outages render electric based brooding systems ineffective and therefore unreliable. To the rural poultry farmers, the above value is a huge amount and the unavailability of the national grid supply makes electricity brooding systems prohibitive. Studies (Okonkwo *et al.*, 1993; Okonkwo and Agunwamba, 1997, Rockby *et al.*, 1983) showed that conventional energy consumption in poultry production is quite enormous and therefore expensive. The technology of fossil fuel poultry chick brooding systems poses environmental problems and health hazards to both plants and animals (Reece, 1981; Okonkwo, 1998). Kerosene brooding systems are known to result to fire outbreak and production of green house gases (GHG) such as carbon dioxide (CO₂) and

carbon monoxide (CO) which constitute environmental pollution. This may have accounted for loss of huge sums of money, low production level and high mortality rate ranging between 60-70% in poultry enterprises in Nigeria (Okonkwo, 2000). These have led to poultry production intensification in order to meet up with increasing daily demands. Poultry production intensification as an aversion to the limitations associated with conventional energy utilization in poultry production is known to give rise to serious socio-economic and environmental problems.

For successful poultry production in developing countries such as Nigeria alternative methods of meeting the energy needs in the poultry industry have to be evolved. Such alternative energy resources should be reliable, in abundance supply, environmentally friendly, pollution free and fire incident free, and moreover should be inexpensive. Solar energy looks the best alternative energy option at least for now. This is because solar energy is a clean cheap energy to harness, and is widely available all the year round in the tropics.

A good solar system should be able to convert solar radiation into useful energy and stores the same for utilization when needed. Several methods of solar energy storage are available in literature (Duffie and Beckman, 1980). These include storing as sensible and latent heats. The advantage of sensible heat storage is that materials for energy storage are locally available and inexpensive. Such materials include water, stones, and Trombe wall (masonry) system.

The technology of Trombe wall system as solar energy collector and storage device in buildings has been reported (Wray *et al.*, 1978; Nayak *et al.*, 1983). However,

its application in poultry production for raising day old chicks has not been documented in Nigeria. The Nigerian poultry production sector has remained insulated from the modern technology practices prior to the utilization of Trombe wall technology in raising day-old chicks. Earlier studies (Echiegu, 1986; Okonkwo *et al.*, 1993) utilized water in tank as sensible heat storage and dissemination system. The limitation of water in tank is that large overhead water storage tanks impose structural problems on poultry house. Such problems result to poor efficiency of the brooding house.

The sustain ability and the potentials of Trombe wall application in poultry production systems are high in Nigeria. Indication is that the nation's fossil fuel reserve is exhaustive and is estimated to last for the next 30 years while solar radiation is available all the year round in the country. The country receives about 4.85×10^{12} kWh of energy from the sun daily. This is equivalent to about 1,082 million tones of oil equivalent (mtoe) per day.

The advantages of Trombe wall system are that it is simple in design and has the ability of moderating the temperature of a poultry house for thermal comfort of day old chicks without much temperature fluctuation. Trombe wall poultry brooding house has high reliability in terms of energy supply with low maintenance cost and great economic benefit to both rural and urban poultry production. Birds brooded under solar energy indicate better performance values (Okonkwo and Ukachukwu 2004). According to Oladipo (1999), the application of renewable energy in particular solar energy as a source of heat in chick brooding is environmentally acceptable and promotes sustainable development. Impact assessment of the practice, indicates that the pay back period of the innovation technology is two years with a net economic gain of 23% per annum (UNDP, 2003).

In this paper the experimental study of a Trombe wall poultry chick brooding house using poultry day old chicks is reported. The major objective of the paper is to show that Trombe wall system could be a good heating device that can moderate the temperature requirements for the sustain ability of brooding of day old chicks in a poultry house.

Description of Trombe wall poultry chick brooding house: A photograph of the Trombe wall poultry chick brooder house is shown in Fig. 1. The cross sectional view is displayed in Fig. 2. The poultry chick brooding house measures 3.44 m x 2.64 m x 3 m external dimension. Three major components of the solar brooding house are

1. Trombe wall system (g)
2. poultry brooding room (n)
3. air chimney (c)

The Trombe wall formed an integrated part of the house duly orientated southward for maximum solar energy collection all the year round. This is made of 0.22 m thick solid block (masonry) to form the thermal storage

system for the poultry house. The external surface of the wall, which is exposed to the environment is treated with black paint for the absorption of radiant energy from the sun. Six vents measuring 0.05 x .1 m were made, three each at the upper and lower parts of the wall respectively. The wall is covered with a single glass distanced at an air space of 0.25 m. The glazing reduces excess heat losses by long wave radiation and convection to the ambient environment. During the day, the wall (solar collector) receives radiant energy transmitted across the glass cover. The radiant rays striking the wall are absorbed thereby and converted into heat energy. The absorbed heat is transmitted and stored in the massive wall for dissemination into the house.

The vents provide good facilities for air circulation between the wall and the glass into the chick brooding house. Air sweeping across the wall surface carries hot air during the day from the wall into the brooding room while the absorbed radiant energy is conducted across the wall into the poultry brooding room.

To supplement and augment heat storage capacity of the Trombe wall a thermal pebble storage bin measuring 2m x 1.5m, filled with black pebbles is strategically located outside the wall but connected with pipes through the floor into the brooding room. This contributes to the thermal increment of the room. The choice of Trombe wall and pebbles for the study was based on their availability locally and less expensive compared to other energy storage materials such as salt and water. Structurally, Trombe wall has an advantage over water tank placed on top of a building. Water tank on building imposes load on the building. Trombe wall forms major support to the building loads – the roof and adds no additional load to the building. Trombe wall and pebbles have good thermal conductivity enough to reduce high temperature fluctuations experienced with direct gain solar buildings.

The brooding house has an internal dimension of 3m x 2.2m x 3m giving a floor area of 6.6m² for 150 poultry day-old chicks for four weeks brooding period at a recommended brooding space of 0.04m² per chick plus 10% of the brooding space for drinkers and feed troughs (Oluyemi and Roberts, 1979). The east, west and north walls of the brooder were constructed with hollow blocks however not painted black. The roof of the brooder is made of conventional roofing sheet (zinc) and sealed with asbestos ceiling board. To enhance even temperature distribution within the brooder, an air chimney is centrally located and positioned within the brooder to allow exhaust air from the brooding room to the ambient environment. The chimney (c) measures 0.4m x 0.3m x 3.3m and extends well above the roof of the brooder. This creates draught for natural air circulation.

Two openings for ventilation control are located at the east and west ends of the brooder house.

Materials and Methods

Physical and biological performance evaluations were conducted. The physical performance evaluation involved the testing of the long-term thermal effect measured as temperature of the brooding house and the Trombe wall using Copper-constant thermocouple wires manufactured by Cole-Palmer Inc located at strategic positions. The thermocouple wires were connected to a common switch point for digital thermometer reader, and mercury in bulb thermometers all positioned at locations within and outside the house. The temperatures were obtained in degree centigrade at one hour intervals through the day. Solar radiation and wind data for the period were obtained from the meteorology Department of the National Centre for Energy Research and Development, University of Nigeria, Nsukka, Nigeria, measured using Eppley radiometer, model PSP, serial number 17361F3.

The biological performance evaluation involved the use of 150 broiler day-old chicks per batch for the brooding operation to test the efficiency of the brooder house. The chicks were all supplied by Alpha Poultry Farm, Enugu, a commercial vendor. Each batch lasted for five weeks-brooding period. The chicks were fed continuously (*ad libitum*) with commercially made broiler starter feed for the four (4) weeks period. Good drinking water was given to the chicks throughout the period while disease preventive measures were taken as prescribed by a veterinary personnel. The chicks were weighed at every four-day intervals. Also measured were the average body weight, rate of feed consumption and feed conversion ratio of the chicks.

Results and Discussion

Physical performance evaluation: The experimental performance data was gathered for a five year performance evaluation of the poultry brooder house, covering the period 2000 – 2004. The evaluation covered the two prevailing seasons namely dry and rainy seasons commonly found in Nigeria. The data were obtained on different days of the months for each year. Table 1 summaries the mean climatic data and the daily solar irradiation measured for different months. Table 2 shows the mean monthly temperature of the brooder house and ambient conditions.

While the brooder temperature profiles ranged between 35-28°C the ambient condition was between 18-37°C when solar radiation was 3.7-923 W/m². The mean measured hourly temperature profiles are shown in Fig. 3 and 4 for typical cloudy and clear sky weather conditions for the period. The minimum and maximum mean Trombe wall outer surface temperatures were 25°C and 60°C, and 22-48.3°C for a typical clear sky and cloudy weathers of the year respectively. The inner surface Trombe wall temperatures were maintained between 29.73°C-39.1°C. During the period an average

Table 1: Average Solar Radiation and Mean Temperature Values

Month	Solar radiation (Wm ⁻²)°C		Ambient temperature °C	
	Max.	Min.	Max.	Min.
January	833.5	4.8	35.3	24
February	865	3.75	33	22
March	910.8	7.3	34	24
April	923	5.2	34.7	20
May	658	4.3	33.9	21
June	784.4	4.7	35	19.7
July	675	3.8	33.7	20.6
August	645.5	5.3	30.3	18
September	769	4.2	30.4	23
October	886.7	5.8	34	21.3
November	854	3.7	37	19.7
December	904	4.6	36.3	22

Table 2: monthly measured Temperature values from 2000 -2004

Year	Brooder temperature °C		Trombe outer wall temperature °C	
	Max	min.	max	min
Jul-00	34.7	29	48.28	23.6
Jan-00	34	30	53.3	24
Sep-01	33.5	29	51.4	25
Mar-01	33.8	29.7	50.7	24
Dec-02	35	29.3	49.7	25.3
Aug-02	34.4	28	48.3	22.7
Nov-03	33.6	28.5	55	24.8
May-03	33	29.3	48.6	22
Feb-04	34.4	29	51	23.8
Jun-04	34.2	29	49.8	24.7

Table 3: Seasonal mortality rates (%)

Year	Month(s)	Dry season	Rainy season
2000	Jan/Feb	3	
	May/June		3
	Aug./Sept.		5
	Nov./Dec.	3	
2001	Feb/March	3	
	July		6
	Sept.		3
	Oct/Nov	5	
2002	April/May	3	
	July		0
	Sept.		3
	Dec.	3	
2003	Feb.	0	
	April/May	3	
	July		0
	Aug./Sept		5
2004	Jan.	3	
	April	3	
	June/July		3
	Sept/Oct.		3
Average mortality rate		2.9%	3.10%

measured brooding room temperature range of 28°C-35.3°C were maintained within the brooding room. Fig. 3 indicates typical rainy season weather (cloudy period) with intermittent sunshine. The temperature range was between 28-33 °C. While Fig. 4 shows a typical clear sky weather (dry season) temperature in which outside



Fig. 1: Trombe wall poultry chick brooding house

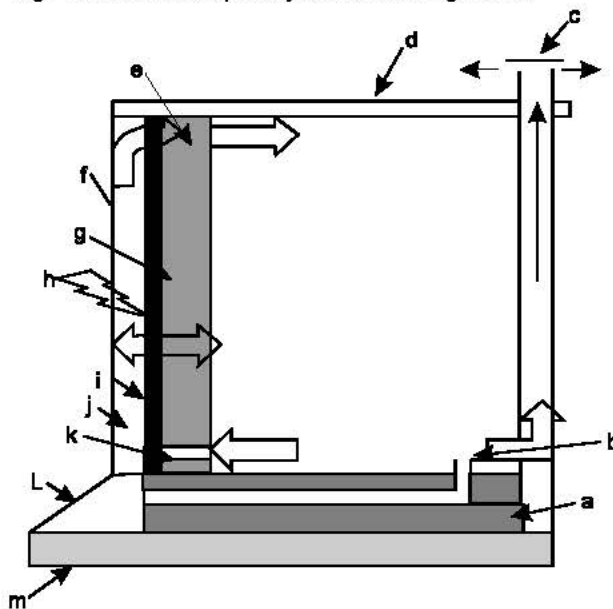


Fig. 2: Cross sectional view of Trombe wall poultry chick brooding house

(a) pebble bed storage bin (b) heat exchanger (c) air chimney (d) roof (e) upper air vent (f) glass cover (g) Trombe wall heat storage system (h) solar radiation (i) solar collector (j) sun space (k) lower air vent (l) pebble bin glass cover (m) basement

temperature was 37°C at 1 pm and hovers 25-33°C. The brooder temperature remained reasonably stable, rising slowly during the day to around 35°C and falling quite gradually around 29°C during the morning hours. The solar radiation was between 9-516W/m² and 11-865W/m² respectively. The results showed that the brooder house could maintain acceptable temperature level for poultry brooding operation irrespective of the season. The overall rate of change in the brooder temperature against the outdoor temperature suggests the moderating effects of Trombe wall massive for the poultry brooding house. The temperature spread in the

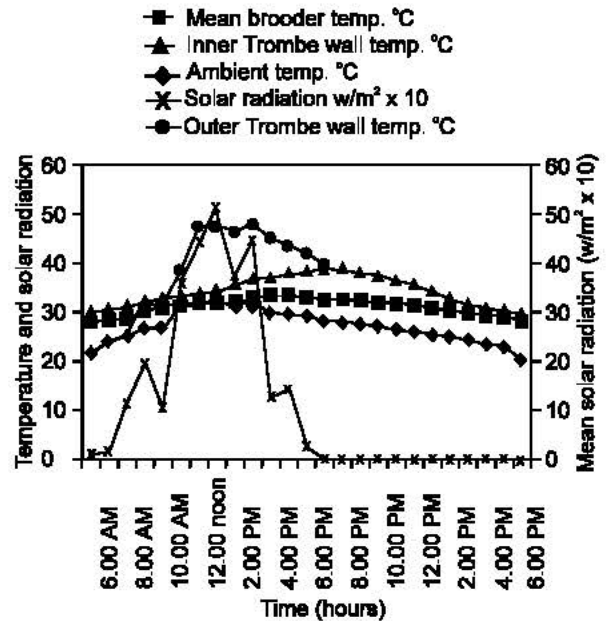


Fig. 3: Hourly mean temperature profile of Trombe wall brooder house and ambient condition on a typical cloudy weather

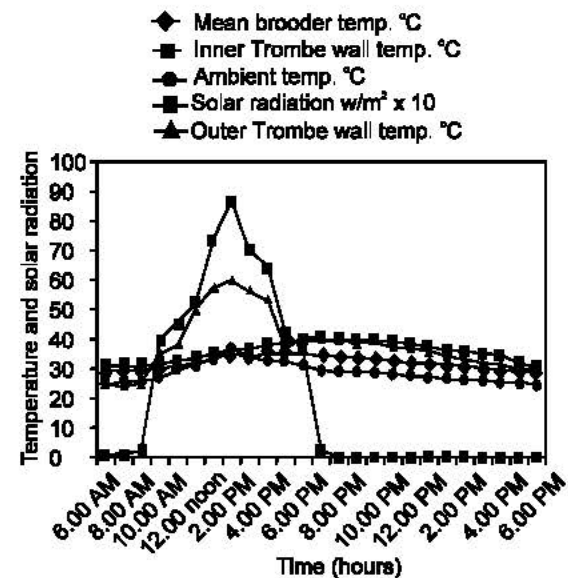


Fig. 4: Hourly mean temperature profile of Trombe wall brooder house and ambient conditions on a typical clear sky weather

brooding room was good enough for day old chicks' brooding at least for the first four weeks. Average wind speed for the period was between 0.04-4.27 m/s.

Biological performance evaluation: Four brooding operations were conducted in each year of experiment, two brooding operations to cover each of the prevailing seasons common in Nigeria. Fig. 5 showed a batch of



Fig. 5: Broiler day old chicks inside the brooder house



Fig. 6: Broiler chicks after four weeks of brooding

150 day old chicks used for the brooding operation while Fig. 6 shows the chicks at the end of brooding operation at eighth weeks of operation. The experimental investigation results indicated that at the end of five weeks brooding operation an average live body weight of 586 grams were attained by the chicks from an initial body weight of 29 grams.

The cumulative feed consumption per chick for the period was 1253 grams. While the average weight gain and the rate of feed consumption by chicks per period are given as in Fig. 7 and feed conversion ratio (Fig. 8). At the end of the experimental study an average weight gain of 184.3 grams and feed consumption rate of 318.3 grams were recorded. These indicated better performance when compared with 96.3 and 298.7 grams, and 140.7 and 374.7 grams earlier studies (Echiegu, 1986; Okonkwo *et al.*, 1993) which utilized water in tank for solar energy storage and heat dissemination in poultry brooding house. The average percentage mortality rates was 3%. The summary of the yearly and seasonal mortality rates are given in Table 3. These results showed brooder house efficiency of 97%. Earlier study Okonkwo and Ukachukwu, (2004) showed 3%, 7% and 10% mortality rate for solar, kerosene and electric brooding systems. In poultry chick brooding a 5% mortality rate is permissible. The above results compared favourably to earlier studies by Echiegu (1986) and Okonkwo *et al.* (1993) which utilized water as

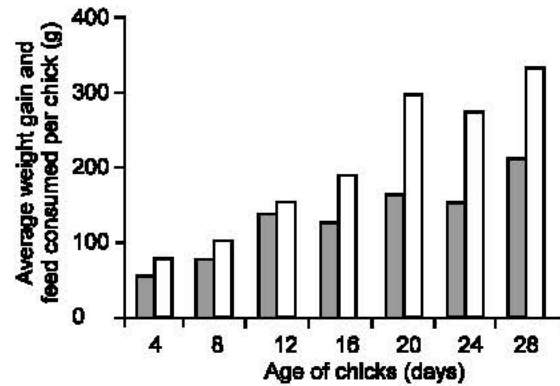


Fig. 7: Average weight gain and feed consumed per chick vs age of chicks

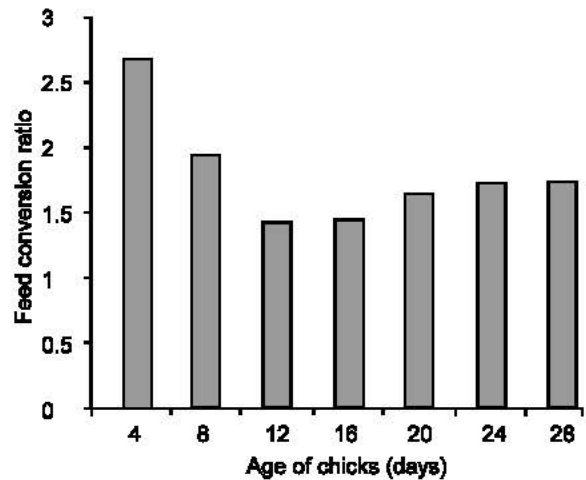


Fig. 8: Feed conversion ratio vs age of chicks

the major heat storage medium in solar brooding systems. It could be observed that the 5% and 6% mortality rate recorded in few months of the experimental investigation could be attributed partly to disease outbreak which broke out while the brooding operation was in session. That the temperature spread within the brooder house sustained the day old chicks till the brooding sessions were over without supplemental heat system is evident that Trombe wall system is a good heat storage and a temperature moderating device for poultry brooder house operations.

Conclusion: The experimental study of a Trombe wall poultry chick brooding house has been presented. Results of experimental work showed that brooding temperature range between 28-35°C temperature could be maintained in the brooder house under ambient temperature range of 18-37°C while the temperature of the Trombe wall heat storage device ranged between 22-60°C. Biological evaluation using day-old chicks as test samples showed 3% mortality rate, indicating 97% efficiency. The above results indicate the ability of

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Trombe wall system in moderating the temperature fluctuations within poultry house. It further suggests that Trombe wall could collect/store enough heat for day old chick brooding purposes in the tropics. Trombe wall heating system could be useful in such other area as in piggery for brooding piglets.

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