DESIGN, CONSTRUCTION AND PERFORMANCE EVALUATION OF A PASSIVE SOLAR ENERGY HEATED POULTRY CHICK BROODER FOR EDUCATION, POWER AND EMPLOYMENT FOR CHANGING COMMUNITIES

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Abstract

A passive solar energy heated poultry chick brooder house (the Trombe wall system) of internal dimensions 6.096mx3.118mx1.83m and external dimensions 6.450mx3.40mx2.44m was designed and constructed using locally available materials comprising of sand, gravel, cement, rods, wood, nails, ceiling boards, black paint, acrylic glazing, chips of laterite (pebble stones painted black) covered with thick acrylic glass. The south facing wall was painted black and covered with acrylic glazing of dimension 1.83mx1.83m. The brooding space was divided into two equal compartments of internal dimensions 3.05 x 3.35m. Performance evaluation was undertaken by monitoring the temperatures and relative humidity for one month before introducing day old chicks. The physical and biological performance of the room and the chicks were respectively monitored over the period of brooding of four weeks. The measurements were conducted under Eha- Amufu weather over the ambient environmental temperature range of 25^{o}c -38^{o}c and daily global irradiance of 5.7 -9^{o}4w/m2 for a period of one year. The physical performance indicated that brooding temperature range of 25^{o}c -38^{o}c and relative humidity range of 30% to 82% were attained. Testing with day old chicks showed that an average live weight of 1023.04 gram was achieved after four weeks with 4% mortality. The device from all indications is a good temperature moderating device for poultry brooding in FCE Eha- Amufu and Nigeria by extension. This will provide the alternative power and provide employment for youths to develop our rural communities.

Key words: Trombe Wall System, Poultry Brooding, Poultry House Power, Rural Community.

Nigeria no doubt is presently faced with the challenges of epileptic power supply from the national grid, economic meltdown and a down-ward trend in the price of her crude oil resulting in mass unemployment, youth restiveness, armed robbery, kidnapping and other numerous vices. Experts from various fronts have made valuable suggestions on various for a on the way out of the woods. The most popular of these ideas and suggestions tend towards massive and aggressive agricultural development. The sustainability of any agricultural development effort is highly dependent on power and energy.

The earth receives enormous amounts of radiant energy from the sun, which directly or indirectly sustains all living things (New science encyclopedia, 1989). The sun can potentially provide the equivalent of about 25,000 times the total amount of energy presently used from all other sources. However, only a very small fraction of this freely available energy is exploited through direct means for human use (UNESCO Report, 1979).

Provision of heat energy for poultry production is a basic necessity for the survival and optimum performance of day old chicks during the brooding period.

Brooding is the act of caring for young chicks after hatching. The period from hatching until the chickens no longer require supplemental heat is called the 'brooding period' and usually lasts for 3-6 weeks, depending on seasonal temperatures and the type of housing (New south Wales government portal, 2004). Since young chicks are yet to develop the heat insulating feather covering, supplemental heat must be provided to enable the chicks to develop without much stress and mortality. This is done with the aid of a brooder. Brooders may be as simple as a brooding mother hen, a brooding chamber or specially designed brooding house (Odo, 2008)

Methods of Brooding

In Nigeria most 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 (Okonkwo, and Akubuo, 2007). 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 about ₦630 million per annum at stock market price of ₦350.00 per dollar. To the rural farmers, the above value is so huge and the unavailability of the national grid supply makes electricity brooding so expensive. Apart from the expensive nature of fossil fuel poultry chick brooding, environmental problems caused by emission of green house gases such as carbon dioxide (CO_2) and carbon monoxide (CO) result to environmental pollution. There is also the problem of fire outbreaks in kerosene brooding systems. These result to low production and high mortality rate ranging between 60-70% in poultry enterprises in Nigeria (Okonkwo, 2000).

Solar Energy in Brooding

For successful poultry production in developing countries such as Nigeria, alternative methods of meeting the energy needs in the poultry industry have to evolve to create employment towards changing our communities. Solar energy in brooding systems makes use of solar radiation which is converted into thermal energy to provide required warmth to the chicks. The heat obtained during the day is stored for use in the night period when there is no sunlight to supply heat to the brooding chamber or house. Solar energy would be an excellent source of sustainable power for poultry farmers in Nigeria because solar radiation is available all year round in the country which receives about 4.85×10^{12} kilowatt of energy from the sun everyday, equivalent to about 1.082 million tons of oil per day.

Assessments have proved that the initial cost of installing a photo thermal system from poultry brooding can be recuperated within two years of energy savings.

The technology is environmentally sound because it does not pollute the atmosphere and it also drastically reduces the risk of fires. Solar powered poultry brooders have the following characteristics:-

- They are economically viable.
- They use equipment that are relatively easy to construct and operate.
- They produce cost free energy.
- They improve the quality of chicks produced.
- They are relatively inexpensive to maintain.

Table 1: Performance of Broiler Chicks under Three Brooding Systems

Chick Parameters	Kero-sene	Grid Electri-city	Solar Energy
Initial body weight (g)	49.84	49.91	49.91
Final weight (g)	452.16	400.01	562.74
Feed intake (g)	39.30	37.20	38.37
Weight conversion ratio	2.73	2.89	1.90
Mortality rate %	7	10	3

National Centre for Energy Research and development (NCERD) UNN, 1999

Scope of the Research

The scope of the work includes; design, construction, characterization and testing of the equipment in relation to temperature and relative humidity changes. The biological process of raising the birds to maturity will equally be discussed.

Description of Trombe Wall Poultry Chick Brooding House

Design Consideration:

The following factors were considered in designing the Trombe wall poultry chick brooding house; temperature, air quality, climatic condition in the location of FCE Eha- Amufu, water and feed management, duration of materials, solar collector slope, size of brooder house and number of birds in the brooding space and finally the design equations. The cross sectional view is shown in fig 1. The photograph of the completed brooder house is shown in fig 2 and fig. 3.

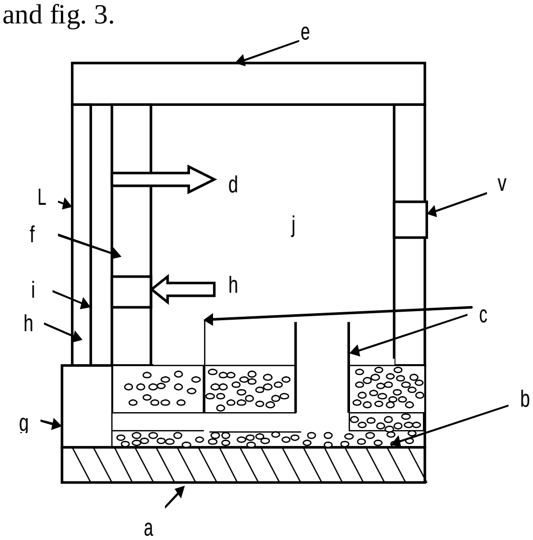


Fig. 1: Sketch of Solar Brooder

2. Photographs of completed brooder house

Fig 3. Photograph of Completed Brooder House (Front View)

Fig 3. Photograph of Completed Brooder House (Rear View)

The poultry chick brooding house measures 6.450m x 3.40m x 2.44m external dimension. The three major components of the solar brooding house are

1. Trombe wall system (f)
2. Poultry brooding room (j)
3. Collector base (h)

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 0.22m 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. Vents measuring 10cm x 10cm were made, five at the upper part of the wall and five at the lower part. The wall was covered with a single glass distanced at 0.25m. 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. To supplement and augment heat storage capacity of the trombe wall, two thermal pebble storage bins measuring 2.5mx1.5m are filled with black pebbles and attached to adjacent sides of the trombe wall and connected with pipes through the foundation into the brooding spaces. Each pebble bed carries two pipes into the room.

The brooding room has internal dimensions of 3.048m x 3.048 x 1.524m and is divided into two equal apartments giving a floor space of $2.323m^2$ for 150 poultry day old chicks making a total of 300 chicks in a brooding period. The recommended brooding space is $0.04m^2$ per chick plus 20% of the brooding space for drinkers and feed troughs (Oluyemi and Roberts) in (Okonkwo and Akubuo, 2007). The East, West and North walls of the brooder house were constructed with hollow blocks, however not painted black. The roof of the brooder is made of conventional roofing (zinc) sheets and sealed with paper ceiling board. Two openings (windows) for ventilation were located at the east and west ends of the brooder house.

Materials and Methods

Physical and biological performance evaluations were conducted. The physical evaluation involves testing the long- term temperature readings of the brooding house and the trombe wall using copper-constantan thermocouple wires connected to digital and analogue multimeters located at strategic locations. Mercury in glass thermometers were also positioned within and outside the brooder house for comparative readings. Readings of brooder temperature Tb, solar storage temperature Ts, and ambient temperature Ta were recorded in degrees centigrade determined at two hour intervals from 6am to 6pm. The physical performance of the house was tested one month before introduction of day-old chicks. Solar radiation and wind data from the period were obtained from the meteorological department of the space centre at Nsukka, Nigeria.

The biological performance evaluation of the house involved testing with 300 broiler day-old-chicks for the brooding period (September 24th – October 22nd 2013) and testing the efficiency of the brooding equipment. The second batch testing involved 200 broiler day-old-chicks introduction. The chicks were fed day and night using top starter broiler feed interchanged with vita starter feed. Good water fit for human consumption was given to the chicks. Disease prevention measures were taken as prescribed by a veterinarian from the Veterinary Department of University of Nigeria, Nsukka.

Table (a) Stage Reports on Building and Research Activities on Solar Energy Trombe Wall Chick Brooder at Agricultural Education Department of FCE Eha- Amufu July 22nd – December 22nd, 2013

1st Stage July 22nd Aug 24th	2nd Stage Aug 25th – Sept 23rd	3rd Stage Sept 24th – Oct 22nd	4th Stage Oct 23rd – Nov 20th	5th Stage Nov 21st – Dec 22nd
Founda-tion and walling completed	Roofing ceiling solar-collector fittings door and window fittings completed	Testing of physical perfor mance of the brooder house	Broodi ng of the first set of 300 birds. Experi-ments	Moving the 4 week old birds to poultry house for rearing to maturity

		was done	and records being taken on the brooder	and introduce-tion of additional 200 day old chicks in the brooder. Continued observation was in 2014 .

Results and Discussion

Physical Performance Evaluation: The experimental performance data was gathered for one year period 2013. The evaluation covered the two prevailing most difficult season of the year in terms of solar radiation- the rainy season. The data were obtained for different days of the months for the year, the results of the performance evaluation of the passive solar energy heated house showed that poultry brooding can be effectively done using solar energy. The physical performance indicated that brooding temperature range of 25^oc to 38^oc and relative humidity range of 30**.**00% to 82% can be attained. Testing with day old chicks showed that an average live weight of 1024.04 gram was achieved after four weeks with 4% mortality.

Daily temperature measures of ambient Ta, brooding Tb and pebble bed Ts were recorded. Relative humidity measures for some days were also recorded.

Also plots of Ta, Tb and Ts on some selected days are shown. The brooder temperature for all the test days rose above the pebble and the ambient for the reason that the trombe wall as well as the pebble pipe kept feeding the brooding space with heat energy. It remained stable between 25^oc and 38^oc. The results showed that the brooder house could maintain acceptable temperature level for poultry brooding operation irrespective of the season.

Conclusions

The following conclusions were reached based on the results of this study.

1. A relatively cheap passive solar energy heated chick brooder**-** the trombe wall system, using locally available materials comprising of sand, gravel, cement, rods, wood, nails, ceiling boards, black paint acrylic glazing, chips of laterite, and improved feeding/ watering systems was successfully designed and constructed
2. Preliminary test without chicks showed that a brooding temperature range of 25^oc to 38^oc and relative humidity range of 30% to 82% can be attained.
3. Testing with day old chicks showed that an average live weight of 1023.04 gram was achieved after four weeks with 4% mortality as against those tested in brooding systems heated with kerosene stove and electric lamp.

Therefore, it can possibly be concluded that;

a. Successful brooding is achievable under acceptable conditions of temperature and relative humidity using solar energy heating systems.
b. Brooding chicks with solar energy enhances the production performance of chicks in terms of live weight and feed conversion.
c. Establishment and management of large and medium scale poultry farms are feasible in rural and semi urban areas where electricity and other conventional sources of heat supplies are epileptic.

Recommendations:

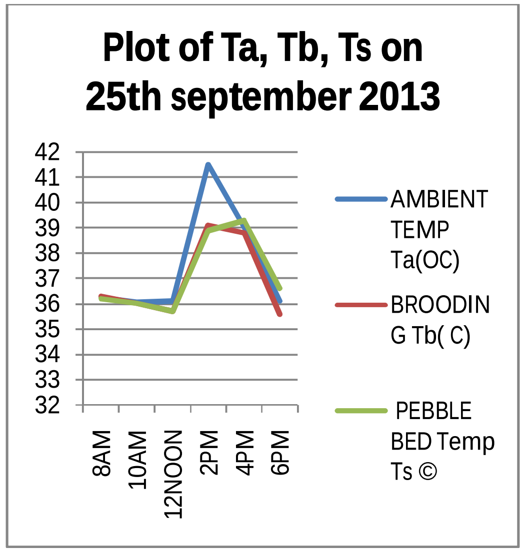
(a) Nigeria stands to gain in changing our communities and solving her unemployment problems partly by investing massively in solar energy brooding systems in poultry farming especially in rural areas.

(b) The passive solar energy heated chicken brooder can be designed in a large scale so that the roof of the building of the poultry house will entirely be a pebble bed solar collector with concrete adobe walls.
(c) The poultry droppings removal can be automated instead of a manual approach used in this work to prevent pollution and diseases.
(d) Lighting the brooding space is a challenge of the present work. Effort should be made to install a solar powered lighting device in the brooding space so that the birds can feed at nights and on cloudy days with brighter light than the rechargeable lamps used in the present work.
(e) There is need to have a complete passive solar heated poultry unit integrating the solar incubator, solar drier, solar manure and the solar heated brooder. The challenge is in integrating all the systems into one unit.

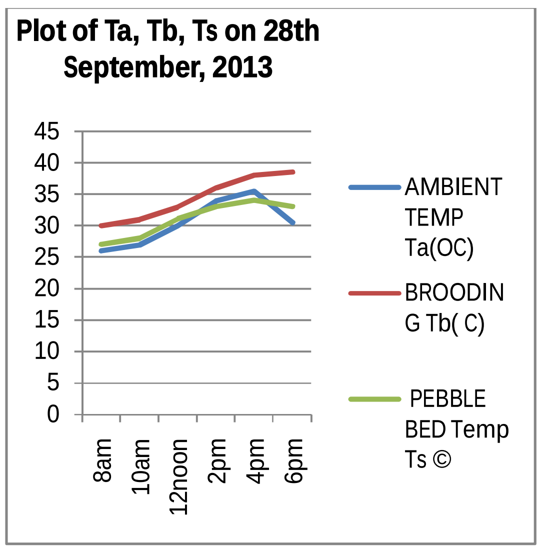
Table (b) Cumulative Weight of the Chicks

Days	Weight (Gram)	Average weight gain in 7 days
1.0 6.0 7.0	50.0 70.3 85.5	35.5
9.0 11.0 14.0	112.2 160.3 220.4	134.9
16.0 18.0 21.0	240.3 260.8 391.4	171.0
23.0 25.0 27.0 28.0	460.3 630.5 710.4 820.3	428.9

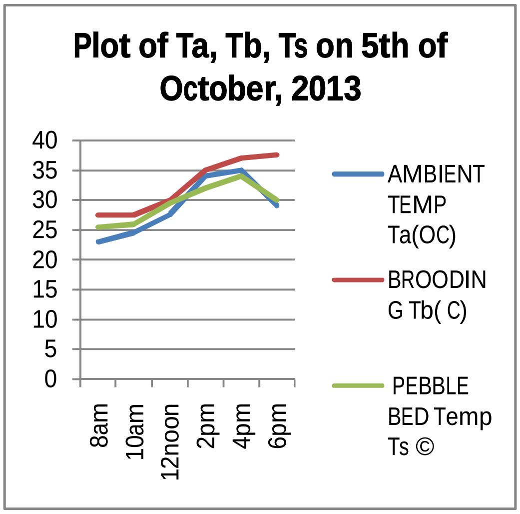
Appendix A



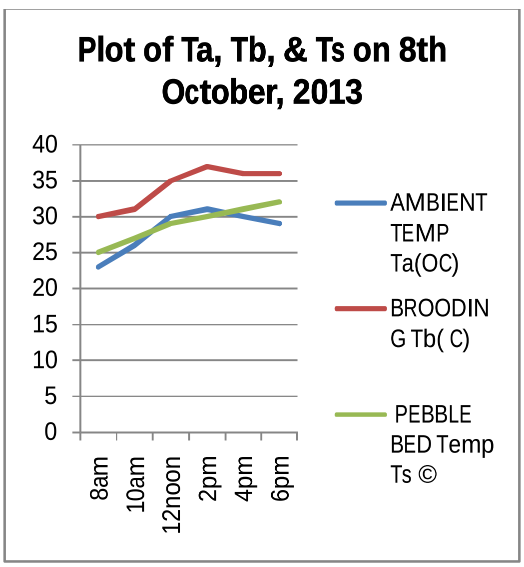
Appendix (a) Graphs of Ambienet temp, Ta, Brooder temp Tb and pebble bed temp, Ts on different times of the day on 25th Sept. 2013



Appendix (b) Graphs of Ambienet temp, Ta, Brooder temp Tb and pebble bed temp Ts on different times of the day on 28th Sept. 2013

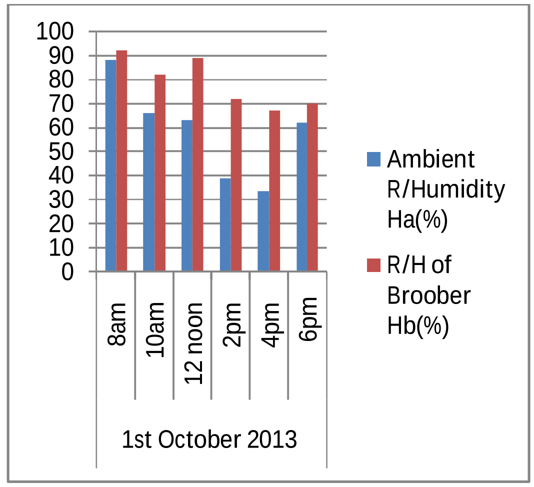


Appendix (c) Graphs of Ambienet temp, Ta, Brooder temp Tb and pebble bed temp Ts on 5th Oct. 2013 at different times of the day

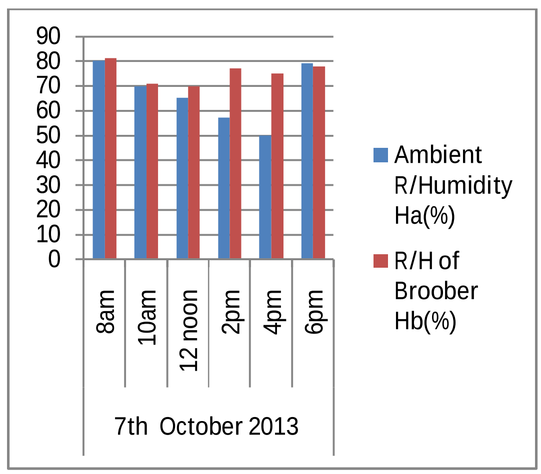


Appendix (d) Graphs of Ambienet temp, Ta, Brooder temp Tb and pebble bed temp Ts on 8th Oct. 2013 at different times of the day.

Appendix B



Appendix (e) Plot of relative humidity of the Ambient Ha and relative humidity of the brooder on 1st Oct 2013 at different times of the day.



Appendix (f) Plot of relative humidity of the Ambient Ha and relative humidity of the brooder on 7th Oct 2013 at different times of the day.

APPENDIX C

Hourly Solar Radiation on the test days (W/m^2)

Time in Hours	Oct 13th W/m^2	14th W/m^2	15th W/m^2	16th W/m^2	17th W/m^2	18th W/m^2	22nd W/m^2	23rd W/m^2	Nov 25th W/m^2	26th W/m^2	27th W/m^2
600am	0	0	0	0	0	0	0	0	0	0	0
7.00.	-	16.92	30.29	16.31	11.27	25.54	22.67	16.41	0	37.68	43.08
8.00	-	197.60	184.90	81.40	74.80	213.90	226.00	144.20	0	244.50	249.20
9.00	-	300.60	446.80	256.10	143.60	217.00	462.20	320.80	866.00	482.50	470.10
10.00	-	325.20	765.00	228.20	410.10	287.40	256.00	538.00	824.00	693.30	667.30
11.00	590.80	763.00	504.70	423.20	476.40	867.00	477.20	635.00	696.00	808.00	814.00
12noon	443.80	735.00	736.00	736.00	878.00	763.00	950.00	608.10	511.20	883.00	879.00
13.00pm	894.00	729.00	616.00	506.90	972.00	790.00	767.00	696.70	293.40	850.00	854.00
14.00pm	634.40	599.90	799.00	364.00	885.00	632.70	501.10	622.70	99.4	743.00	754.00
15.00pm	457.50	290.80	590.30	62.98	709.00	363.30	458.10	276.20	7.75	574.90	591.40
16.00pm	47.57	158.80	225,80	235.70	296.10	100.60	177.90	150.40	-	360.10	372.30
17.00pm	24.49	122.20	142.10	239.40	216.40	82.90	63.81	170.40	-	149.40	146.40
18.00pm	17.26	31.77	34.49	189.00	67.46	26.74	12.17	-	-	22.78	24.72

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