Solar Energy as an Alternative for Poultry Brooding in Nigeria and Chick Brooding Requirements: A Review

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ABSTRACT

The energy consumption in poultry brooding has been on the increase recently. This is due to the rising cost of fossil fuels. Research has suggested that alternative energy sources in poultry brooding should be utilized effectively. However, it is expedient that such alternative energy sources should be dependable, in abundant supply, and environmentally friendly. It should also be inexpensive and readily available to local farmers. Solar energy looks to be the best alternative energy option for this, because it is clean and is readily available all 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 release it for utilization when needed. This work reviewed solar energy sources as an alternative in poultry brooding to reduce cost of energy utilization. Other energy sources already being used were also highlighted in this work. The requirements for good poultry brooding such as temperature and humidity were well discussed.

(Keywords: brooding, alternative energy, temperature, humidity, chicks, poultry rearing)

INTRODUCTION

Poultry is an essential component of the agricultural sector in that it is a major source of protein of high biological value needed for optimum health of the citizenry [1]. It also provides raw materials for some industries and promotes crop agriculture through provision of manure (Olaniyan, 2004; Agbo, 2004) [2, 3]. But, there is a widening gap between demand and supply of poultry products. This is attributed to such factors as high-energy consumption cost as well as inefficient and inappropriate production technology employed the farmers [1]. The technology includes the use of conventional sources of energy for the brooding of chicks. Common sources of electricity and fossil fuels used are not only non-renewable but also pollute the environment in which the birds are brooded (Okonkwo, 1993a; Okonkwo and Aguwamba, 1997) [4, 5].

The solution to this problem is to use a source of energy that is renewable, affordable, and environmentally friendly for poultry chick brooding, which is the most delicate period in poultry production. The energy from the Sun meets these requirements. Okpani (2002) found that if the irradiance on only 1 percent of the Earth's surface could be converted into useful energy with 10 percent efficiency, solar energy could provide the energy needs of all the people on Earth [6].

Chick Brooding Requirements

There are strict environmental conditions that need to be kept in commercial chick brooding. Temperatures must be within 20°C and 35°C [7]. According to van Eekeren [7,8] recommended brooding temperatures are 30°C to 34°C in the first week, 25°C to 30°C in the second week, 25°C to 28°C in the third week, and 20°C to 25°C in the fourth week.

According to Wageningen et.al [7, 9] brooding temperatures should be 30°C to 32°C in the first week, 28°C to 30°C in the second week, 25°C to 28°C in the third week and 22°C to 25°C in the fourth week.

STOAS human resources development worldwide [7, 10] proposed brooding temperatures of 30ºC to 34ºC in the first week, 25ºC to 30ºC in the second week, 25ºC to 28ºC in the third week, and 20ºC to 25ºC in the fourth week.

B. Fairchild [7, 11] recommended brooding temperatures of 31ºC on the first day, 30ºC on the third day, 29ºC on the seventh day, 28ºC on the 14th day, and 25ºC on the 21st day for radiant brooders. These conditions may easily be met using air conditioners. However, in the absence of electricity and capital to maintain the air conditioners other methods are likely to be applied which may not attain the temperatures; rendering the brooder to be either too hot, too cold or fluctuating [7].

High brooder temperatures cause heat stress in birds. Unlike mammals, birds have no sweat glands and can only resort to panting to reduce the effects of heat stress. This is more so with chicks which cannot regulate their body temperature, in fact a chick’s thermoregulatory system does not fully develop until about two weeks of age [12]. High brooder temperatures also cause chicks to increase water intake at the expense of food consumption. This has a negative effect on their growth.

Chicks subjected to low temperatures have impaired immune and digestive systems. Low temperatures can result in death due to opportunistic infection and overcrowding. In low temperatures the young chicks tend to crowd together, this may result in the smaller chicks getting smothered by the larger chicks [10]. Provision of adequate heat is essential during the brooding whereas a chick can go without food for the first three days of its life, it cannot survive without adequate heat [13].

In cold countries, wood shavings are spread on the floor to assist in insulating the ground to maintain the brooder temperature [14]. Wood shavings are also necessary for absorbing excess moisture from chick droppings and spilled drinking water. They also dilute fecal material thus reducing contact between the chicks and manure [7]. Wood shavings also cushion the birds from the hard floor.

Another important brooding condition is the relative humidity. According to Fairchild [11] relative humidity should be maintained at 50 to 70 percent throughout the growing period. Relative humidity below 50 percent causes dusty conditions which results in respiratory diseases [7]. Relative humidity above 70 percent encourages microbial growth in the litter. Ammonia is generated from the chick droppings due to microbial growth in wet environments. High ammonia levels result in poor growth and increased respiratory disease [12].

Ventilation is very important to the health of chicks during the brooding. Proper ventilation reduces the build-up of ammonia, moisture and other gases such as hydrogen sulfide. Poor ventilation resulting in high relative humidity promotes production and build-up of ammonia. High ammonia levels cause impairment of the immune system and respiratory diseases.

According to Czarick [7,12] ammonia levels above 60ppm cause a decline in performance of layers. Broilers are more sensitive to ammonia and can be harmed by less than 25ppm of ammonia. Broilers affected by ammonia never reach physical maturity. Short periods of high ammonia levels lead to decreased weight, increased feed conversion and increased respiratory disease. Ammonia levels should be kept below 30 ppm at all times and preferably below 20 ppm. A minimum ventilation rate of 0.1cfm per bird is recommended [7].

As the birds grow the ventilation rate should be increased by the age of the birds in weeks multiplied by 0.1cfm per bird. High ventilation rates result in removal of heat from the brooder. As fresh air is added at a lower temperature more energy is required to heat the air in the brooder. Poor ventilation allows build-up of hydrogen sulfide (H_2S) [7]. Hydrogen sulfide is formed when the protein in the birds manure is broken down. It is a very dangerous gas with a very offensive smell. It is fatal to both chicks and human beings even in low concentrations. It is recommended to eliminate it completely using proper ventilation [15]. Carbon dioxide is exhaled by the birds. It should not exceed 2500 ppm [15] Carbon monoxide is formed as a result of incomplete combustion from charcoal stoves. This occurs when charcoal is used for brooding. It is an odorless and very dangerous gas. It should be eliminated through proper ventilation [7].

Space requirement for brooding chicks from one day old to 4 weeks old is 0.044m^2/bird [7,16]. Space required varies depending on the type of floor. The recommended spacing varies from 0.04 to 0.065m^2/bird for litter and wire systems and 0.036 to 0.065m^2/bird for all litter systems [10].

Lighting is also important during brooding. Chick activity is greater in brighter light. The light should be bright enough to enable the chick to locate feed and water [7]. The light intensity should be at maximum on the first day. This should be reduced gradually after 7 to 10 days

Solar Energy in Brooding house

Many fields of research have been explored for utilizing different states of renewable energy including, geothermal, wind, solar and biomass energy [17]. Solar energy is considered one of the most promising sources of renewable energy. The total annual solar radiation received on earth is approximately 3,400,000 EJ, which is tremendously greater than all other discovered and undiscovered non-renewable energy resources worldwide and is thousands of multiples of the world's total annual primary energy consumption of 450 EJ [17, 18].

Egypt is privileged to be in one of the best locations to receive huge amount of solar radiations as shown in Figure 1. Being the most abundant source of energy, there is a great opportunity to utilize solar energy for space heating of poultry houses in Egypt [17]. Solar energy is extensively investigated worldwide to be used in different thermal applications such as solar water heaters, driers (air heaters), cookers, ponds, architecture, air-conditioning, chimneys and power plants [18]. Space heating of poultry houses can be achieved using the developed solar air or water heating techniques.

However, it has to be noted that one of the main challenges of using solar energy is the energy storage method. Generally, for thermal energy storage, energy is stored by the change in the internal energy of a material by sensible heat, latent heat or thermo-chemical heat [17, 20].

Sensible heat storage depends on raising the temperature of a certain material, whether solid or liquid, to utilize the heat capacity of this material. It depends on the change in temperature, specific heat of the material and the amount of the storage material as the amount of heat stored is: $Q= \int mCpdT$ where, *Ti* and *Tf* are the initial and final temperatures; m is the mass of the material and *Cp* is its specific heat [21]. As for the latent heat storage (LHS), it depends on the heat absorption or release of a material when it changes from solid to liquid or liquid to gas or vice versa. That material used for latent energy storage is called phase change material (PCM). When the temperature rises, the chemical bonds within the PCM break up as the change of phase occurs; this can be described as an endothermic process absorbing heat. When the phase change temperature of the PCM is reached, the material starts to melt and the temperature is kept constant until the melting process is completed. The heat stored during the melting process is called the latent heat [21].

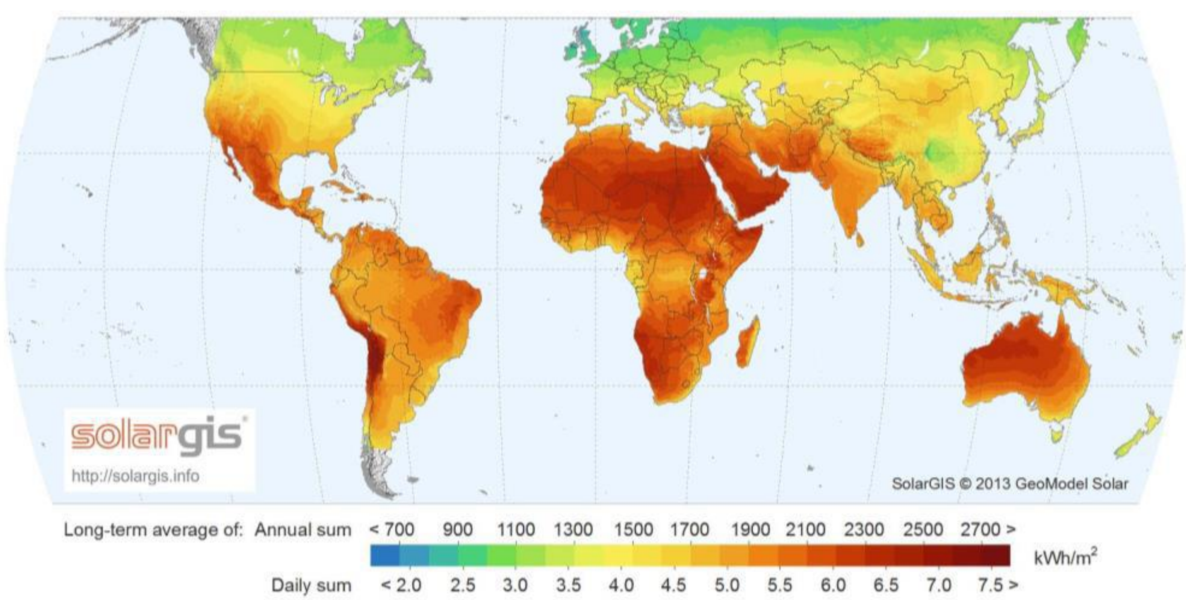

Figure 1: World Map of Global Horizontal Irradiation [17, 19]
Source: SolarGIS © 2015 GeoModel Solar.

Heating of Solar House Using Solar Energy

In 1976, Benard et al. carried out an interesting experiment of using solar-roof to solve the problem of heating traditional chicken brooders in a Peruvian village [22]. The installation is 4.9×2.8m and divided into a patio with asbestos roof and a heated enclosure of lower height than the patio [22]. Two semi-circular tanks with transparent glass covers containing 42kg of paraffin wax each were installed below the glass roof of the heated enclosure. Mobile mirrors were used to direct the sun rays to increase the radiation on the paraffin.

During the night, a polyurethane insulator of 10cm thickness was used to isolate the paraffin tanks from the glass roof. The paraffin wax had a melting temperature of 58-60°C. It was used to collect and store the radiation at daytime [17]. Then, the heat stored was exchanged during night time through radiation of the blackened tanks to the walls and floors of the enclosure. The aim of the system is to regulate the enclosure temperature between 22-30°C. The first version of the installation yielded daily mean variation of temperatures from 16-33°C. The following enhancements were carried out:

- The glass roof was changed to avoid air leakage
- The mirrors were remade to avoid direct radiation into the enclosure in order to lower the maximum enclosure temperature
- The patio was covered with the asbestos roof (it was not roofed during the 1st experiment)
- The ventilation of the installation was enhanced by adding four ventilators; two Trombe walls and two wind ventilators. This was done to bring fresh air into the installation and push hot air from above the tanks into the lower region of the enclosure (i.e.: better circulation of air).

The modifications resulted in the following:

- A higher minimum temperature of around 22^{o}C
- A lower maximum temperature of around 30^{o}C
- Greater stability during bad weather sequences
- Better ventilation

Then, the experiment was carried out at four different periods of the year and was repeated at two periods with the chickens housed. According to the local climate, the solar daily total irradiation (I) varies from 2.1x10^{4} kJ/m^{2}/day to 2.7x10^{4} kJ/m^{2}/day [17]. The result of the experiment at Period I show that Tm is not correlated to the outside temperature TeM but to the daily variations of I with a 1-day delay. However, the variations in Tm are much smoother than that of I [19].

The storage gives back a total average of 14,500 kJ. The expected loss of heat from the upper glass surface was calculated over the 15 hours to be around 2,000 kJ. Thus, the useful heat QU was 12,500 kJ. The radiative night losses QR that take place between the storage and the enclosure was calculated assuming black body radiation and was found to be around 7,300 kJ. This proved that the natural ventilation created a non-negligible, even significant, heat transfer by convection [17].

Heating Poultry Houses with Other Energy Source

Heidari et al. [23] studied the energy inputs and outputs in broiler farms in Yazd province, Iran. Their main objective was to determine the energy use efficiency (EUE) per 1,000 birds. Data was collected from farmers through face-to-face interviews across 44 farms over the period between January and February 2010. The average capacity of the surveyed farms was 18,142 birds per farm, while the average meat production was 2,601 kg per 1,000 birds [17, 23]. According to their study, the “input energy sources included human labor, machinery, diesel fuel, electricity, chicken (chick) and feed; while output energy sources were broiler and manure”. Table 1shows the tabulated result of their study by stating the total energy equivalent for each input and output per 1,000 birds. It also shows the constituting percentage of each item from the total input and output energy.

It was found that diesel fuel was the highest energy consumption with 59.2% of the total input energy. According to the results of the study, an average of 2,314.49 liter of diesel fuel was consumed for the heating of 1,000 birds during one production cycle [23]. The share of each input energy in percentages is shown in Figure 2.

Table 1: Energy Equivalents of Inputs and Outputs in Broiler Production in Yazd, Iran [23].

Energy equivalents of inputs and output in broiler production.

Inputs/Outputs	Unit	Quantity per unit (1000 bird)	Total energy equivalent MJ $(1000\ \text{bird})^{-1}$	Percentage
A. Inputs				
1. Chick	kg	51.50	531.96	0.28
2. Human labor	h	65.27	127.93	0.07
3. Machinery	kg	3.54	196.06	0.10
4. Diesel fuel	L	2314.49	11,0632.79	59.20
5. Feed	kg	5501.49	59,311.40	31.74
6. Electricity	kW h	4468.26	16,085.73	8.61
B. Outputs				
1. Broiler	kg	2601.82	26,876.78	97.87
2. Manure	kg	1948.11	584.43	2.13

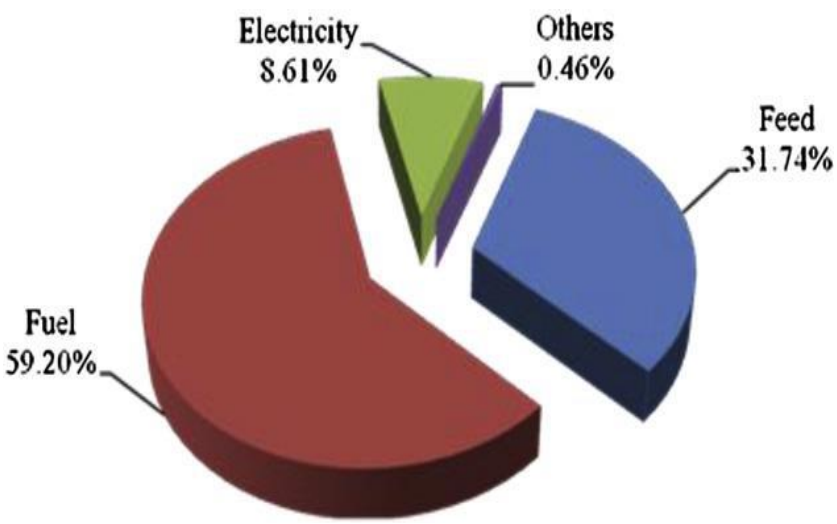

Figure 2: The Share of Energy Inputs in Broiler Production in Yazd, Iran [17, 23].

In another research, "Sustainable heating and cooling systems for agriculture", Kharseh and Nordell investigated the heating demand for poultry houses in Syria [24]. They mentioned that for the production of 172,000 tons of meat, 13,000 chicken farms in Syria consume 1,196 GW.hr as an estimated annual heating demand [24].

In an attempt to use renewable energy for space heating systems, Choi et al. used a geothermal heat pump (GHP) for the economic heating of a broiler house in Korea [18]. They carried out an investigation to evaluate the effect of using the GHP on the performance and housing environment of a broiler house in comparison with that of a conventional diesel fuel heated house. The comparative analysis was performed on two environmental-controlled commercial broiler houses each of capacity 17,000 birds divided on 5 replicates [17]. The experiment was carried out on a production cycle of 35 days long during winter time, where the outside temperature reached -10.8°C.

The conventional house was equipped with 3 oil heaters (Power Heater, Samsung, Seoul, Korea) each with a capacity of 116.3 kW [17]. The other broiler house was equipped with a GHP with a capacity of 210.9 kW (Ten Co., Seoul, Korea) in addition to 3 oil heaters with the same capacity that were used only when the GHP couldn't maintain a suitable brooding temperature for chicks at the first stage of the production cycle. The birds' weight (BW) gain was observed in both houses.

The O_2, CO_2, and NH_3 gas concentrations were measured inside the two houses. Also, the electricity and fuel consumption of both houses were recorded.

The results showed that replacing the diesel fuel heating system with the GHP, enhanced the air quality inside the house as fresh air was supplied, which caused the average BW to increase by 6.8% in the GHP house more than the conventional house. The record of the gas emissions showed that the O_2 content was not affected by the heating system but the CO_2 and NH_3 contents significantly decreased in the GHP house relative to the conventional house as shown in Table 2 [17].

The consumption of fuel was reduced from 2,813 Liter per 35d cycle per 3,400 birds in a conventional house to 160 liter in the GHP house. From the results of the fuel and electricity consumption and the total energy cost calculated for each house (shown in Table 3), it was found that the GHP house was more economical than the conventional house. According to Choi et al., "GHP house saved about 92% of the energy cost compared with the conventional house" [18].

Table 2: The O_2, CO_2, and NH_3 Contents Comparison [17, 25].

	O_2 content (%)		CO_2 content (ppm)		NH_3 content (ppm)	
Wk	**GHP System**	**Conventional System**	**GHP System**	**Conventional System**	**GHP System**	**Conventional System**
1	20.6	20	4500	6500	1	3
2	20.7	20.4	3281	4304	4	14
3	20.6	20.8	2803	3967	10	25
4	20.5	20.6	3299	4945	11	20
5	20.4	20.6	3967	3866	15	21

Table 3: Energy Consumption and Costs of Heating using GHP vs. Conventional System [17, 25].

Item	GHP system	Conventional System
Fuel consumption (L)	160	2,813
Electricity consumption (kWh)	1,905	292
Total energy cost for heating (won)[2]	222,363	2,711,217

1GHP = geothermal heat pump. [2]One US dollar = 1,159.87 won (as of January 2010); diesel price = 960 won/L; and electricity price = 36.1won/kWh (as of January 2010).

CONCLUSION

The poultry industry is one of the energy intensive industries that consume large quantities of fuel, especially for the Broilers sector. Broiler poultry houses, producing chicken meat, heavily consume diesel fuel, gasoline or gas for their heating systems in order to maintain the temperatures required for the breeding of the chicks. The required temperature of any broiler house ranges from 22°C to 32°C depending on the birds' age.

This work reviewed solar energy source as an alternative for poultry brooding. The work also examined other energy source that farmers have been using in poultry brooding such as gasoline, electricity, kerosene and other renewable energy source. The basic requirement at early stage in chicks brooding such as temperature and humidity are highlighted in detail in this work.

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SUGGESTED CITATION

Ugwuoke, E.C., A.I. Ali, I.E. Alhaji, C.P. Ezeigwe, and N.P. Oputa. 2019. "Solar Energy as an Alternative for Poultry Brooding in Nigeria and Chick Brooding Requirements: A Review". *Pacific Journal of Science and Technology*. 20(1):5-12.

Pacific Journal of Science and Technology