SOCIO-ECONOMIC IMPORTANCE OF SOLAR ENERGY APPLICATION IN POULTRY PRODUCTION SYSTEM

ABSTRACT

Solar energy is a renewable, inexhaustible and affordable form of energy that could help mitigate climate change in poultry production systems. Its application as an emerging technology in poultry production systems is not common among the Nigerian poultry farmers. This paper presents a survey of poultry farms in Enugu State, Southeast, Nigeria. The purpose of the survey was to ascertain the status of solar energy application in Poultry production systems in the state. A survey was conducted on the methods farmers use in poultry day-old chicks brooding technology. A total of 60 poultry farms were selected at random for the survey. Data was collected using a 25 structured questionnaire items. It was observed that two types of poultry brooding methods were in use by the poultry farmers. These were conventional method (the use of fossil fuel and electric power), and non-conventional method (the use of solar energy) respectively. Survey results showed that out of 60 respondents 25% and 65% used kerosene, and combined electric/kerosene brooding methods in their brooding operations respectively. Only 10% of the respondents have used solar energy technology in their poultry brooding operations. The average mortality rates were 22.38%, 12.17% and 2.97% for kerosene, combined electric/kerosene, and solar energy respectively, while US$474.54, US$2,456.34 and US$49.1, were the respective average energy cost implications for each brooding methods eight times in a year. Solar energy was observed to have the lowest mortality rate and the least energy cost implications among the rest. Further response from the farmers showed inadequate power supply, greenhouse gas emission, fire outbreak and low profit margins characterized kerosene, and the combined electric/kerosene usage while solar energy application was observed to be environmentally and user friendly with low mortality rate and low energy cost. Solar energy utilization therefore appears the most attractive option because of the advantages it has over others. Its use in poultry brooding production will improve and enhance environmental air quality, healthy chicks' production with higher profit margins. Its wide application in poultry production in Enugu State, Nigeria however, demands sensitization and educational awareness among the stakeholders.

Key words: Socio-Economic, Solar, Importance, Poultry, Brooding.

1.0 INTRODUCTION

Poultry farming is an important unit of livestock industry that contributes significantly in animal protein production, job creation and food security in the economy of nations. Presently, poultry production is one of the most commercialized and fast-growing agricultural sectors in many developing countries due to its socio-economic importance. Poultry provides food security and protein intakes for poor countries[1] and is the largest reared livestock species worldwide[2]. Its attractiveness in the context of poverty alleviation and quality protein supply[3] is known. According to Hernandez[4], the production of food of animal origin, especially birds, constitutes an important tool in the fight against malnutrition on the planet, thanks to the fact that they provide a high-quality protein source at a low cost. The demand for poultry products is on the increase with population growth globally. In Nigeria, local poultry production only meets 30% of the demand for chicken and meat. This indicates a huge scope for expansion.

Nonetheless, despite the expected expansion, poultry production is however fraught with many challenges particularly in brooding of day-old chicks and maintaining profitable margins due to the ever-increasing energy costs which placed much financial burden on poultry farmers. Poultry farming consumes large quantities of fuel all over the world. This is due to the fact that the internal temperature, relative humidity, chemical environment, ventilation and lighting inside a chicken house would dramatically affect the growth of poultry (broilers), which should be kept within a reasonable scope[5].

In poultry industry, production is always in stages, ranging from hatchery, brooding of broilers or layers, fattening and marketing. Every stage is very important to ensure overall efficiency in the production chain. Brooding is one of the foundation stages in the production chain which needs close attention of operators in the sector and that of researchers[6]. Chicks at day-old have no father/cover and as such require optimal heat supply in proper quantities during brooding period to maintain the body mass-temperature for survival and optimal performance. Inadequate heat supply is one of the predisposing factors that leads to high bird mortality at infancy[7]. Limited energy sources and unsustainable energy utilization efficiency are major problems bedeviling brooding operations in developing countries[8]. According to Okonkwo and Akubuo[9], the quality and efficiency of energy supply and utilization in poultry brooding system has a determinant effect on the total success of poultry production at the early developmental stage. Therefore, saving energy has become more than important nowadays because of energy resource shortage, soaring energy prices as well as pressing environmental problems[10,11].

Brooders serve two major important functions in poultry production systems. It ensures a conducive physical environment that aids healthy growth of chicks and the organization and concentration of the chicks into manageable unit[12]. Provision of heat for poultry chicks is a basic necessity for their survival and optimum performance[13]. Hence, the quality of heat supply during poultry brooding operation determines the level of physical and physiological development and mortality rate of the chicks[9].

Different poultry brooding techniques are available and in use by farmers. Typically, in Nigeria, many rural poultry farmers who have no access to grid supply but have no idea of the significance of artificial brooding techniques employ the services of broody mother hen for their brooding operations. To such, the scope of their operation is limited. While some commercial poultry farmers use the fossil fuel-based systems either due to lack of electric power supply or lack knowledge of various other cheaper techniques. Majority of these farmers often use either collection of kerosene lanterns/stoves or electric bulbs or the combination of kerosene and electric power to provide the heating requirements needed to create conducive environment in poultry breeding house. The use of kerosene and electric powered techniques cause environmental pollution, fire outbreak, high mortality rate and result to high energy cost.

The opportunities to lower energy costs include many combinations of measures such as energy conservation and efficiency, and the use of renewable energy options. Among the varying options, solar energy as a renewable offers the most attractive opportunity because it is environmentally friendly with less economic burden on poultry growing more especially in the tropics where the availability of solar radiation is all the year round[14].

Recent studies showed that solar energy can be used for sustainable poultry brooding operation with high profit margins[8,9]. In a long-term frame, considering energy and carbon payback times, solar-based interventions, even for energy retrofit, proved to be profitable. Solar energy can provide at least 76% of primary energy demand of a residential building with a short payback period[15]. Thus, to increase the level of poultry production in developing countries above the present position requires concerted effort[7,8]. Okonkwo et al[13] showed 3% mortality of broiler chicks using passive solar energy brooding techniques. Passive solar techniques can reduce annual heating demand up to 25%[16].

Despite the advantages of solar energy application over other methods of brooding technologies, majority of poultry farmers are either unaware or misinformed of the socio-economic relevance of solar energy technology and its utilization in poultry production systems. This study was designed to inform and create the necessary awareness among poultry farmers and other stakeholders of the importance solar energy holds in poultry production systems.

2.0 Methodology

Survey Research Design was adopted for this study. According to Busha and Harter[17] survey research design enables specific issues to be investigated through information gathering on people's opinions and believes over a wide population. This technique is relevant to this study because it involved sampling of opinions of stake holders (poultry farmers) on the art of poultry production population in Enugu State, Nigeria.

In order to gather sufficient information on poultry brooding methods in Enugu State, Nigeria, survey instrument (Questionnaires), designed for the purpose were used. The questionnaires were administered to poultry farmers (respondents) who were involved in poultry production business in Enugu State, Nigeria. The survey was carried out with the assistance of members of a Research Group from the University of Nigeria, Nsukka – The Bioresources, Renewable Energy and Environmental Engineering (BREEE) Research Group, Department of Agricultural and Bioresources Engineering.

2.1 Administration of Questionnaire

The questionnaires were administered to sixty (60) poultry farmers spreading across Enugu State, Nigeria. Poultry farmers were selected at random for the survey and the questionnaire were administered to the respondents respectively. The questionnaire covered general information on the respondents, Social and economic, poultry brooding techniques, energy input, and information on the status of poultry production technology in use. The survey was constrained to poultry farmers both full time and part time participants. The administration of the questionnaire was conducted and administered on visits to the respective farms. The questionnaires were administered to the respondents independently to ensure that accurate information was collated and also to avoid any possible manipulation or influence by another. Oral interviews using local language were used to extract information from the farmers where possible. The BREEE members - the researchers in some cases help to explain the information content of the questionnaires to the less educated or the illiterate farmers who could not read or write. The completed copies of the questionnaire were analyzed using simple statistics such as frequency counts and percentages, and tables and graphs were provided where necessary.

2.2 Survey Instrument

The instrument used for data collection was questionnaire. A 25 items structured questionnaire was designed. The questionnaire was divided into 2 sections. Section 'A' sought for information on poultry farm (Demographic) data of the respondents. Section "B" sought for information on the poultry production methods in use.

2.3 Validation of the Instrument:

A pretest of the study was conducted using twelve (12) poultry farmers from Nsukka local Government Area, the host University of the researchers, University of Nigeria, Nsukka, Nigeria to test the validity of the questionnaire. This enabled the researchers to ascertain whether or not the questions asked would generate the required data. However, the results of the validation of the instrument revealed that all the questions contained in the questionnaire were able to generate required response. Hence, the instrument was able to measure the variables in the study.

3.0 DATA ANALYSIS

3.1 Survey data and Data Reduction Procedures

Raw data obtained from the survey questionnaire were compiled and computed in order to get reduced data presented in the Tabular forms.

Social and Occupational indicators

The social and occupational indicators were obtained by taking the statistics of the respondents on the questionnaires as administered. Information gathered from the respondents were used for the analysis. The indication by some respondents as engaged in other occupations in addition to poultry brooding operation was taken into account in the evaluation. The General formula used to estimate the percentage of each set of respondents on each question was given by

$$Y = \frac{Y_1}{X} X\ 100\%$$

Where

Y = information sort for

Y1 = number of respondents in the group

X = total number of respondents

3.0 RESULTS AND DISCUSSION

3.1: General Information

Poor record keeping of daily business activities and transactions were observed among the poultry farmers. This was prevalent more especially within the small-scale poultry farms which some were operated and owned by less educated and illiterate farmers with or without basic elementary level of education. To some, record keeping is time wasting and therefore not necessary. Time constraint and status of farmers are possible limitations to effective poultry record keeping[18]. Some farmers were unwilling to disclose the financial transactions and other information regarding their farms. Training local poultry farmers on record keeping process could help improve their perception of production capability. This could importantly enhance decision taken of the farmers necessary towards successful profitable poultry production operations. It was observed that most of the farmers owned the brooding houses and were not in any way under space renting whilst some either converted unoccupied rooms or abandoned buildings for poultry production business.

3.2: Poultry Farms by Number of Years in Operation

It was noted that brooding of day old chicks was one major delicate aspects of poultry production. The physical and physiological developments of chicks are determined at this stage of poultry development[9]. Inadequate heat supply to day-old chicks at this stage affects the overall performance of the chicks and the entire profit margin. The length of brooding differs depending on the type of birds in question and weather. For broiler chicks most farmers brood between three to five weeks while pullet chicks were between 7- 9 weeks[6]. Many poultry farms have been in the business of poultry chick brooding operation for many years. Some farms depend on already brooded chicks for their supplies because of the delicate nature of chick brooding and the danger of incurring high mortality or losing the entire birds while performing chicks' brooding operation. The experience and length in which poultry farms were in operation is shown by Fig 1.

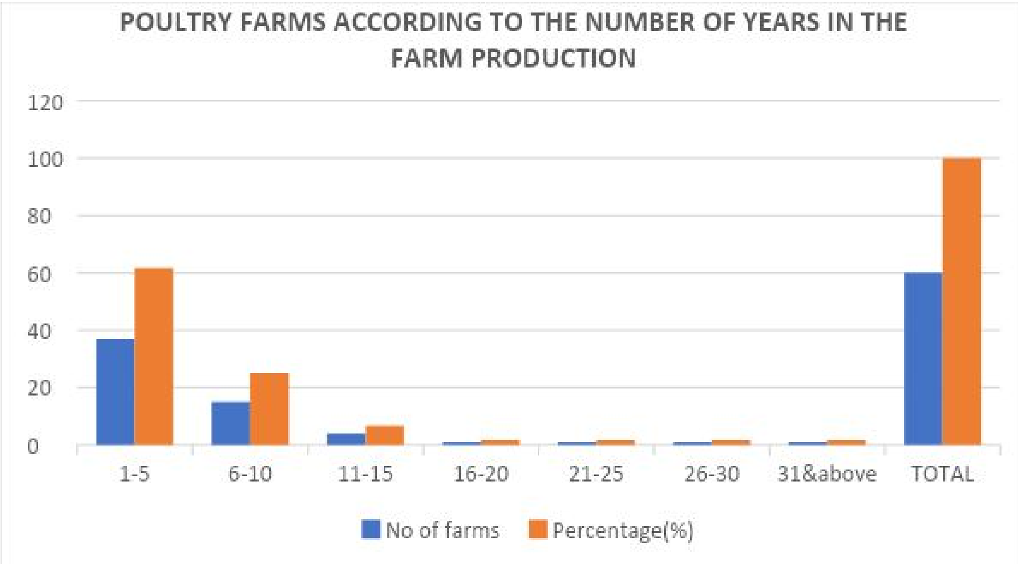

Fig 1: Poultry farms according to the number of years in the farm production

The survey revealed that 61.67 percent of the total respondent (farms) has the lowest years of operational experience in poultry brooding operation covering between 1 - 5 years. While 25 percent and 6.67 percent have been in the business between 6 - 10 and 11 - 15 years respectively. As the years increased the percentage of responding farms decreased down to 1.67% for 16 - 20 years and then to 31 years and above. The drudgery associated with poultry brooding operations may have accounted for the decline in years. Size and inputs handling in large farms in comparison with small and medium farm holdings are not the same. The least experienced were found among the small farm holdings who were new in the business. Sustainability of poultry brooding farms hinges on the nature and the available energy source and the type. According to[19], the growth of broilers mainly depended on the internal environmental condition variation which may impede the meat and eggs production, such as heat or cold stress. Fire outbreak, environmental air pollution, death of chicks and high cost of heating fuels were observed to be major challenges among the poultry farmers.

3.3: Poultry Brooding Farms by Capacity

Poultry farms were categorized into small, medium to large scale poultry day-old brooding systems based on the number of chicks per brooding session. Ranged from 1 – 100 chicks' capacity was regarded as small-scale brooding farm. This range has the highest concentration of poultry farms probably because of the less operating capital involvement required. Some farmers in this category were doing the business on part-time basis while the same time having some other thing(s) doing in conjunction with poultry business. Most of them own their farms and therefore do not pay house rent. This was followed by the medium scale brooding farms with the range between 101 – 500 birds' capacity while large scale poultry brooding farms were those between 501 and above. The higher the capacity of farm the lesser the number of such clusters or concentrations in a place. At higher levels it was observed that cost of production and heat energy requirement increased. Poultry farm is an important sector that consumes large quantities of fuel all over the world[11]. Most large poultry farms prefer already brooded chicks than doing the brooding operation on their own. Fig. 2 showed the poultry farms by brooding capacity.

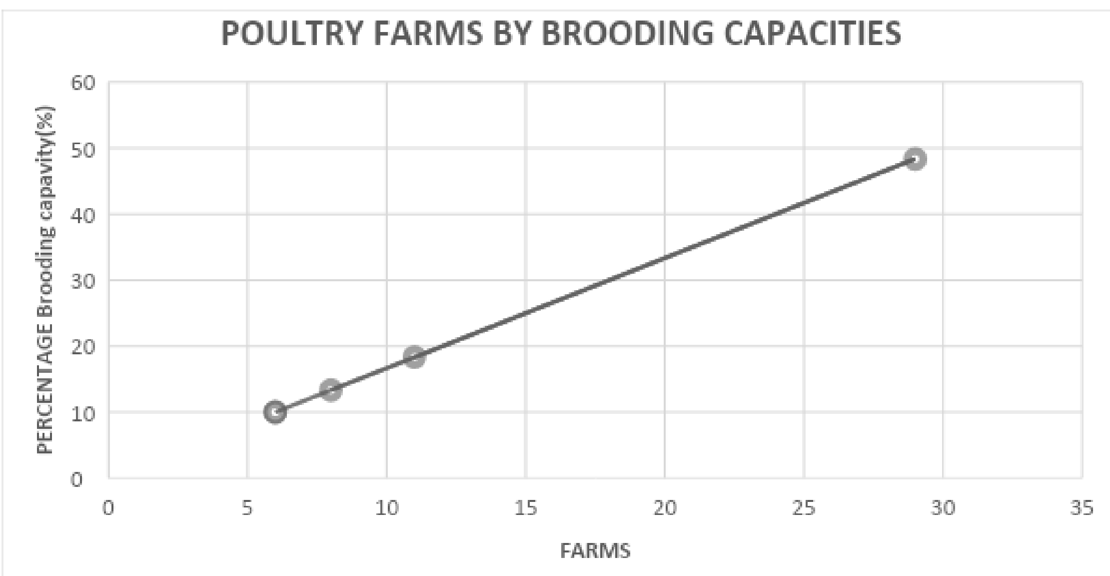

Fig 2: Poultry farms by brooding capacities

Fig. 2 showed that 48.33 percent of the total respondents were small scale farm holdings ranged from 1 - 100 birds' capacity, while 18.33 percent (101 – 300), 13.33 percent (301 – 500) capacities were classified and operated as medium scale poultry farm holdings. Only 10 percent (above 500 capacity) were large scale poultry farms. The small-scale poultry farms have the highest percentage population. This category comprised both those doing the poultry business on full time and those doing it on part-time basis.

3.4 Poultry Brooding Methods

The quality of heat supply during poultry brooding period is a major factor in determining the physical and physiological development[6], mortality rate and the success performance indices of any poultry business operation. Temperature and relative humidity regimes of a brooding environment are directly related to heat supply in a brooder. The internal temperature, relative humidity, chemical environment, ventilation and lighting inside a chicken house would dramatically affect the growth, which should be kept within a reasonable scope[5]. The growth mainly depends on the internal environmental condition variation (heat or cold stress), which may impede the meat and eggs production[19]. Poultry farmers prefer steady and sustainable heat supplying source that can maintain and keep the poultry brooding operation uninterrupted. Temperature and relative humidity ranges of between 26 – 34^{o}C and 65 – 80% are ideal for day-old chicks brooding operation. The major brooding options available to farmers were kerosene, electric, combined electric/kerosene, gas and solar energy methods. Out of these only three (3) methods were observed to be common among the farmers. These were fossil fuel (kerosene), combination of electric/kerosene, and solar energy powered methods. Fig. 3 shows the percentage share of each of the poultry brooding methods by the survey.

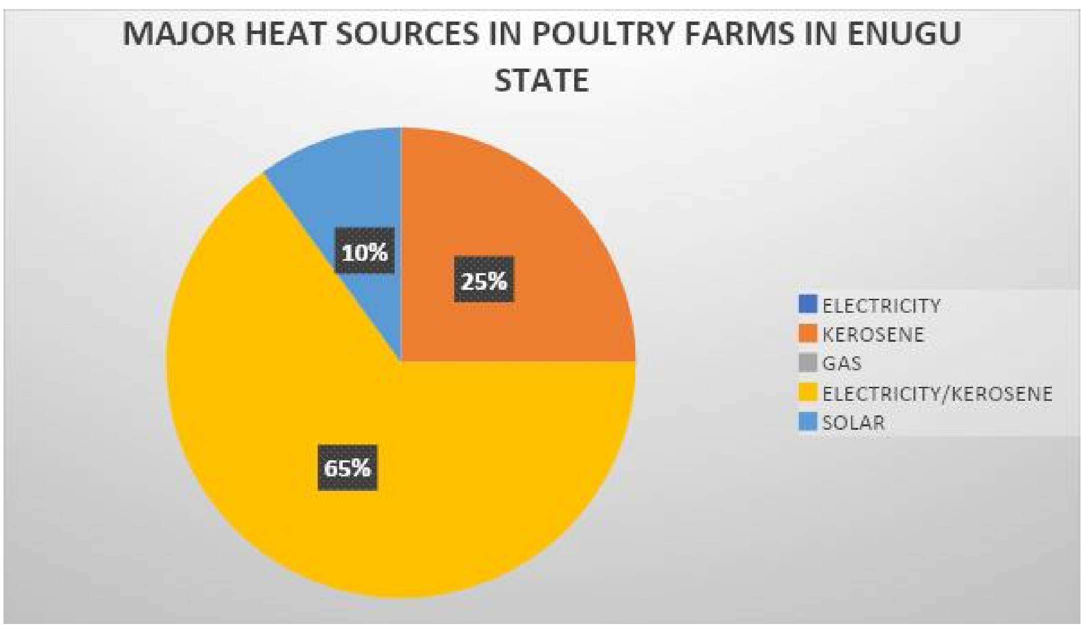

Fig. 3: Heat sources in poultry farms in Enugu State

It was observed that only 25% of the poultry farms use kerosene alone for poultry day-old chicks brooding operation and among this number, 95% were small scale poultry farm holdings, while 65% of the farms use combined electric/kerosene brooding techniques and 66.37% of this portion were the medium scale poultry farm holdings. It was discovered that no farmer employed the use of gas or electric alone in poultry brooding operation. This probably was attributed to the skill to manage gas usage and the cost of gas which was considered to be expensive. Unreliability and the unavailability of electric power makes its usage alone unattainable[8,9,13]. The famers' use of combined electric/kerosene brooding technology was to ensure that there is constant or steady heat (energy) availability during chicks brooding operation. A switch over to kerosene application occurs the moment there is outage in grid supply. Only 10% of the respondents have used solar energy in their poultry brooding operations before. Further observation from the survey showed that inadequate energy supply, environmental pollution, disease and fire outbreak, and low performance efficiency characterized the brooding technologies among the farms. It was reported by[19], that livestock production is responsible for GHG emission attaining 20–25% of global entire emission, of which approximately 70–80% stems from animal farm industries. The problems and challenges associated with different poultry brooding methods by the survey were summarized shown in Table 1.

Table 1: Problems associated with different poultry brooding methods

Problems	KEROSENE			ELECTRIC/KEROSENE			SOLAR ENERGY		
	No. of respondents	No. affected	Percentage (%)	No. of respondents	No. affected	Percentage (%)	No. of respondents	No. affected	Percentage (%)
Scarcity of fuel	15	15	100.00	39	39	100.00	--	-	-
High cost of fuel	15	13	86.67	39	32	82.05	-	-	-
Power failure	15	-	-	39	39	100	-	-	-
Air pollutio	15	14	93.33	39	35	89.74	6	-	-

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Fire outbreak	15	7	46.67	39	27	69.23	6	-	-
Disease out break	15	13	86.67	39	33	84.61	6	-	-

Kerosene brooding systems are known to result to fire outbreaks and production of greenhouse gases (GHG) such as carbon dioxide (CO_2) and carbon monoxide (CO) that constitute environmental pollutants. Carbon monoxide(CO) and carbon dioxide when inhaled by chicks reacts with hemoglobin of the red blood cell to form carboxyhemoglobin which hinders blood circulation in body system. These pollutants may have contributed to loss of huge sum of money, low productivity, high mortality rate and consequent decrease in profitability. 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[21]. Solar energy application method as a technology was observed to have none of the problems associated with kerosene, electric/kerosene and electric grid supply as indicated by the farmers that have used it. Solar energy is considered to be environmentally friendly, it does not pollute the environment by emission of greenhouse gases. The users of solar energy technology however, agreed that the initial cost of acquiring the technology is higher than the conventional brooding methods known by the majority of farmers. However, the advantages of using solar energy in poultry brooding operation outlived the conventional methods. Solar energy can provide at least 76% of the primary energy demand of a residential building, with a short payback period[20]. The use of renewable and sustainable energy technologies, including wind energy, solar energy, geothermal energy and air/water sources plays vital role on the poultry farm owing to their potential to a reduction of energy demand and welfare losses, economy and profitability, GHG reduction and conservation of resources[11].

3.5 Classification of Poultry Chicks Brooding techniques

The study revealed three major poultry brooding methods employed by the farmers to include kerosene, electric/kerosene and solar energy brooding methods. These methods were identified and categorized into two technological groups as conventional techniques and none conventional techniques. The conventional system includes the use of fossil fuel (kerosene powered systems), electric or a combination of kerosene/electric systems. The non-conventional techniques include those that use solar energy in their poultry brooding operation either as active or passive form of solar energy applications. The classification was as shown in Fig. 4.

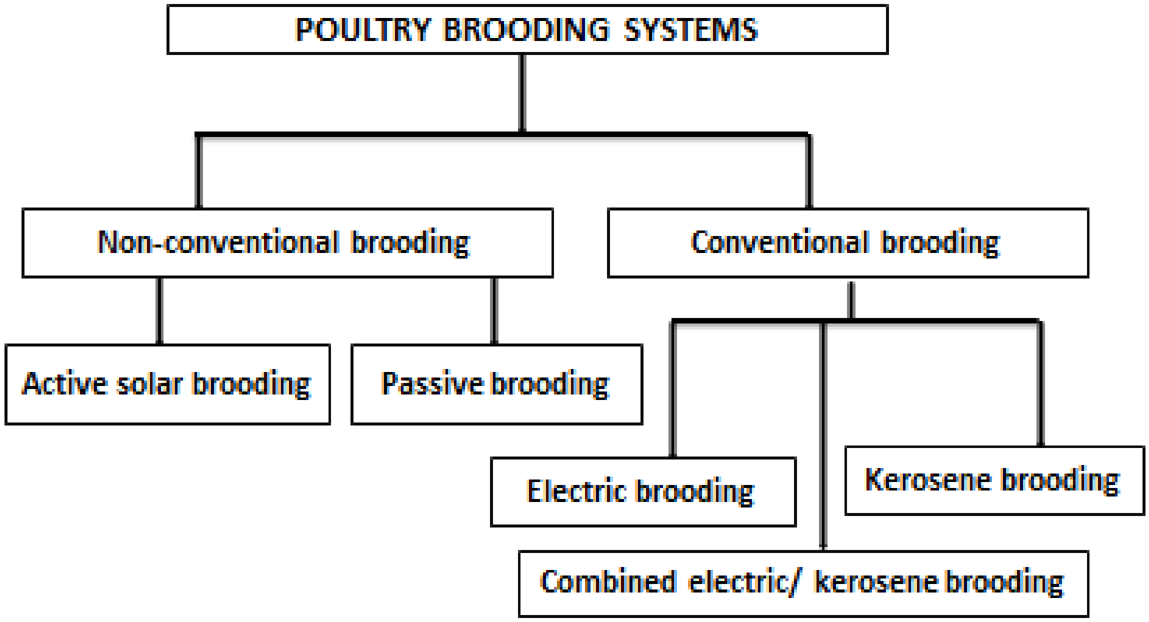

Fig. 4: Classification of poultry brooding technologies in Enugu State

3.6 Popularity of Solar Energy Poultry Brooding Technology

The technology of using solar energy in poultry brooding operation either as in active or passive forms were not popular among the poultry farmers in the State. Table 2 summarizes the level of popularity among poultry farmers. Only 10% of the respondents have used solar energy in passive form in their poultry production operations.

Table 2: Popularity of solar energy brooding technology

Brooding capacity	Total number of respondents	Number unaware of solar technology		Number aware of solar brooding technology		Number that have not used solar brooding technology		Number that have used solar technology	
		No. of respondents	%	No of respondent	%	No. of respondents	%	No. of respondents	%
1 - 100	29	20	68.97	9	31.03	7	24.14	2	6.89
101 - 300	11	4	36.36	5	45.45	3	27.27	2	18.18
301 – 500	8	5	62.50	3	37.50	3	37.50	0	0.00
501 – 1000	6	0	0	6	100.00	6	100.00	0	0.00
1000 and above	6	0	0	6	100.00	4	66.67	2	33.33

It was observed that the highest percentage of those unaware of solar energy poultry brooding technology was among the small-scale poultry farmers. This number of unaware of the technology decreased with increase in capacity of farms. The percentage awareness increased from about 31% to 100% with increasing capacity. However, only small number of the total farmers have used solar brooders either of in the small, medium to large scale poultry production systems in the order of 6.89%, 18.2% and 33% respectively. The numbers that have used solar system only acquired it as part of benefits from a workshop on solar energy brooding technology for commercialization of medium scale solar brooding systems in Enugu State, organized by the National Centre for Energy Research and Development, University of Nigeria, Nsukka, Nigeria. The workshop was sponsored by UNESCO-UNISPAR 1999. Generally, there is paucity of knowledge among poultry farmers on solar energy utilization in poultry production before this time in the state. Majority of poultry farmers were unaware that such technology does exist. Some that were aware of the technology do not know where to obtain it either. The use of solar energy in poultry production systems has many socio-economic advantages over the conventional energy systems. These include Sustainable energy supply, pollution free technology, system fire free hazard, production of healthy chicks of improved feed conversion ratios with low mortality rate. Use of solar energy technology leads to higher profit margins than the conventional methods of brooding operation[21].

3.7: Mortality Rate by Brooding Methods

The rate of Mortality of chicks during brooding operation depends on the environmental condition, type of technology or the management of the chicks. Environmental conditions and types of technology measured as temperature profile of the brooding environment is a critical issue in brooding operation. A comfortable and conducive environment breeds happy and healthy chicks. Young chicks are unable to withstand unfavorable environmental conditions because they lack the body regulatory mechanism, which helps adjust to the changing environmental conditions. Brooding takes care of provision of the heat requirement needs for survival of day old chicks during the critical period of development[9]. Fig. 5 described the mortality rates using kerosene brooding method at different levels of the farm holdings.

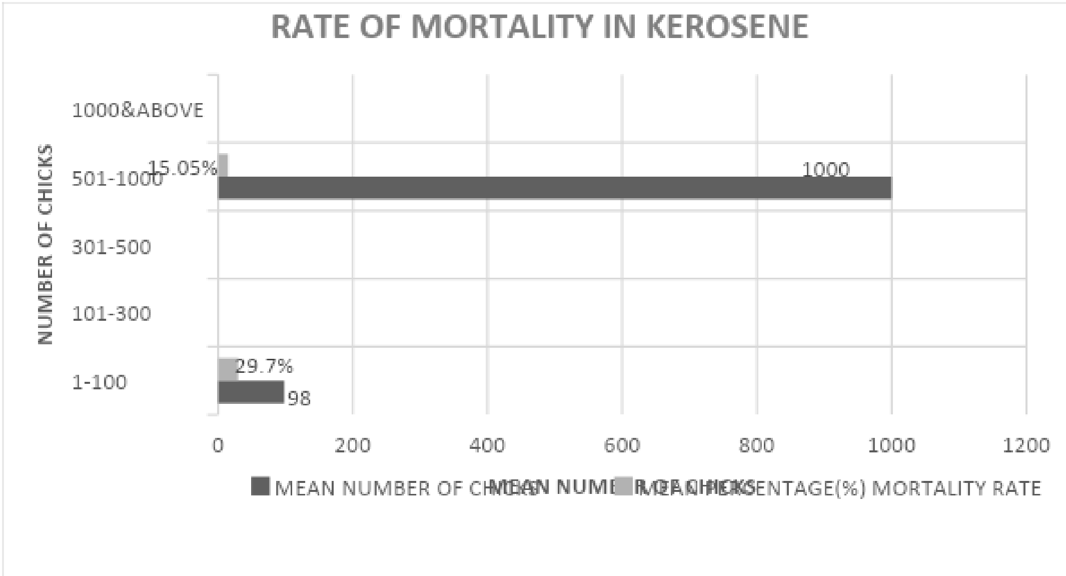

Fig. 5: Mortality rate of chicks by kerosene brooding method

Kerosene is a fossil fuel that issues out greenhouse gases like carbon monoxide (CO) and carbon dioxide (CO_2) which has negative influence on birds and their environment[23]. Inhaled unburned CO causes carboxyhaemoglobin, which hinders blood circulation in body system and death of chicks. About 29.7% of small-scale poultry farms use kerosene in brooding day-old chicks while 15% of large poultry farmers use kerosene in their brooding operations. It was observed that most farms that use kerosene were those operating and located in the rural areas where there is no grid power supply. Fig.6 shows the mortality rate as observed by poultry farms using the combined kerosene/electric energy in their poultry brooding operation.

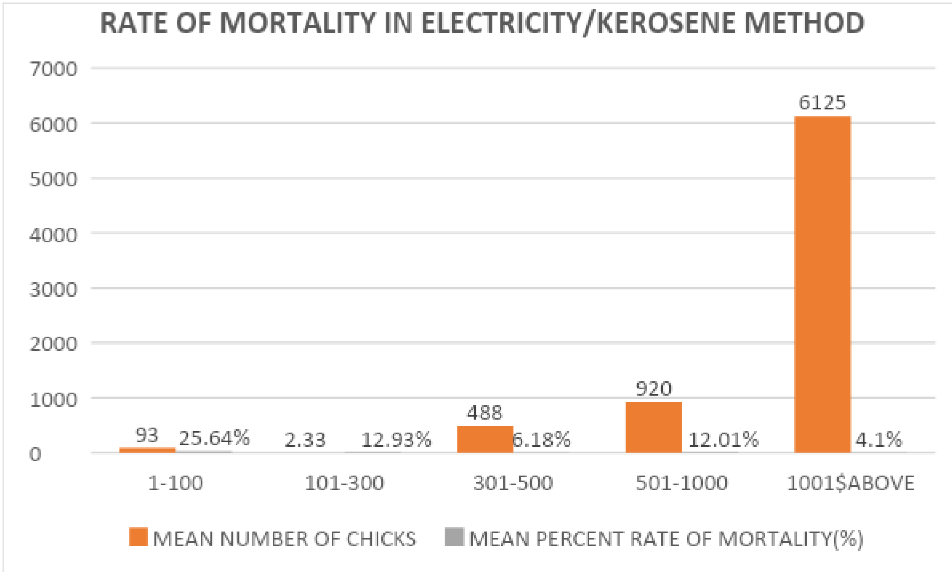

Fig. 6: Mortality rate in combine kerosene/electric method of poultry brooding method

Observation showed that among the 25% kerosene (fossil fuel system), 65% combined electric/kerosene and 10% solar energy brooding methods, the average mortality rates were 22.38%, 12.17% and 2.97% for kerosene, electric/kerosene combine and solar energy brooding methods respectively. Okonkwo and Ukachukwu[21], earlier reported 7% mortality rate for kerosene brooding system as against 3% solar energy and 10% electric power brooders respectively. It was discovered that mortality rate was lower in combined electric/kerosene brooding method than with kerosene alone was used (Figs. 5 and 6), while solar energy brooding method has the lowest mortality rate. This improvement noticed in combined method could have been influenced by electric power share of the combined which led in reduction of greenhouse gas emission in the brooding environment. 93.33% and 89.74% of the respondents indicated pollution as a problem for kerosene and electric/kerosene respectively. Electric powered poultry brooding technology is a clean technology with high environmental air quality, however, it is limited by unreliable supply and unavailability where or when needed[11]. All the respondents (100%) showed no power failure in kerosene brooding operation. It was noted that 46.67% of kerosene and 69.23% of combined electric/kerosene brooding methods reported fire outbreak as a challenge. This was attributed to the skill and management level of the operators. While 86.67% kerosene brooding respondents' showed disease outbreak by the method of brooding they use 84.6% of the combined indicated the same. Heat stress can impede or hinder poultry growth. According to[22], failure to provide adequate conducive environment during the brooding period will reduce profitability, through reduced growth and development, poorer feed conversion and increased disease incidence, condemnation and increased mortality. Further observation showed that solar energy has the lowest mortality rate of between the range 1.5 –

4.9% Fig. 7. Okonkwo and Akubuo[13], reported average of 3% mortality rate on a study of broiler chicks experiment in Nigeria using solar energy.

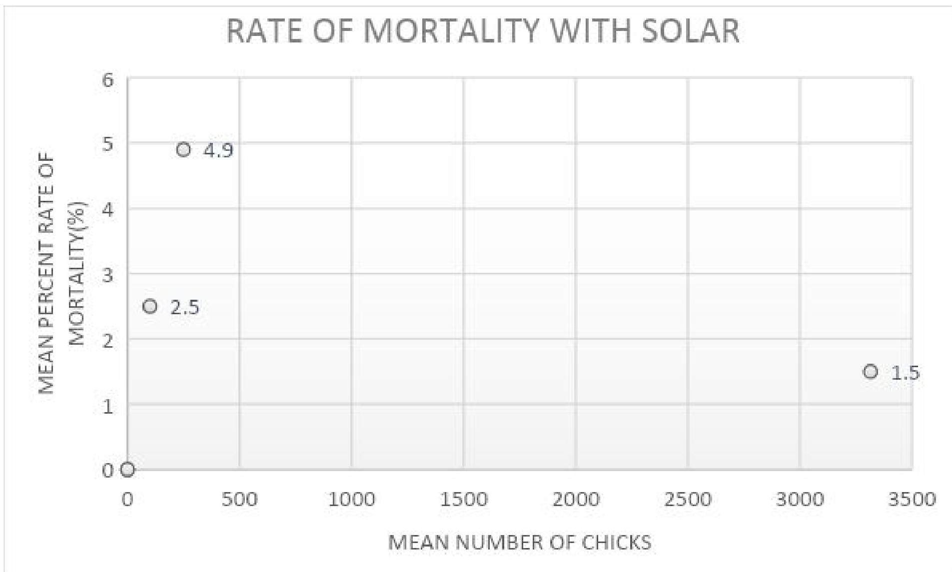

Fig 7: Rate of Mortality in solar energy poultry brooding operation

Solar energy utilization has been found appropriate technology for optimal performance, user friendly, low cost and affordable in poultry production[8]. From Fig. 7 the highest mortality rate was seen among the small-scale poultry farms (2.5% and 4.9%) while least mortality rate (1.5%) was observed among the large-scale production system. Small-scale poultry day-old chicks brooding system utilizes water in tank as a means of heat storage and dissemination while the large-scale systems use Trombe wall heat storage and heat dissemination mechanism respectively. Heat stratification in water tank heat storage system are known to result to uneven temperature distribution in a poultry brooding environment. This may have resulted to stratified and non-uniform temperature distribution in poultry brooding environments that may have affected the development of chicks. Results of Trombe wall passive solar chick brooder supported poultry brooding of day-old chicks[8].

3.8 Energy Cost in Brooding Day-Old Chicks

The economic performance of a machinery is measured in terms of money per unit output. The maximum system performance occurs when the production cost per unit is low[23]. The Survey findings, Figures 8, 9 and 10 below shows the cost of brooding with the three major brooding methods available and used by the farmers. It was observed that no farmers brood with electricity. Electric energy is clean and convenient to use, but, its usage is limited because of power outages and none availability in some cases. Where it exists, farmers combine the usage with kerosene system for optimal results[9]. However, even those farmers that have access to electricity, the frequent power outages make that source very unreliable[24].

All the respondents (100%) agreed and indicated scarcity of kerosene while 86.67% said that the cost of kerosene was high. These were in tandem with earlier observations by[9,] that conventional energy consumption in poultry production is quite enormous and expensive. About 46% of the respondents showed incidence of fire outbreak as a problem while 93% indicated environmental pollution arising from the kerosene usage. The technology of fueling poultry chick brooding system poses environmental problems and health hazards to plants, animals and man[24]. Kerosene brooding systems are known to result to fire outbreaks and production of greenhouse gases (GHG) such as carbon dioxide (CO_2) and carbon monoxide (CO) that constitute environmental pollutants[25]. In monetary terms, it costs about USD 65.11 to brood 100-day old chicks using kerosene while the same number of chicks cost USD 153.21 and USD 9.82, using combined electric/kerosene and solar energy technology per year respectively (Figs 9 and 10). According to Ezema et al[24], it has been estimated to brood 1000 day-old chicks, a farmer used 40 litres of kerosene per day, amounting to 0.04 litres/bird/day. For a 28 day (4 weeks) brooding period, a farmer would require 1.12 litres of kerosene/bird in a batch of 1,000 birds. A litre of kerosene costs about N650 Nigerian money (N415 is equivalent to US$1, present value).

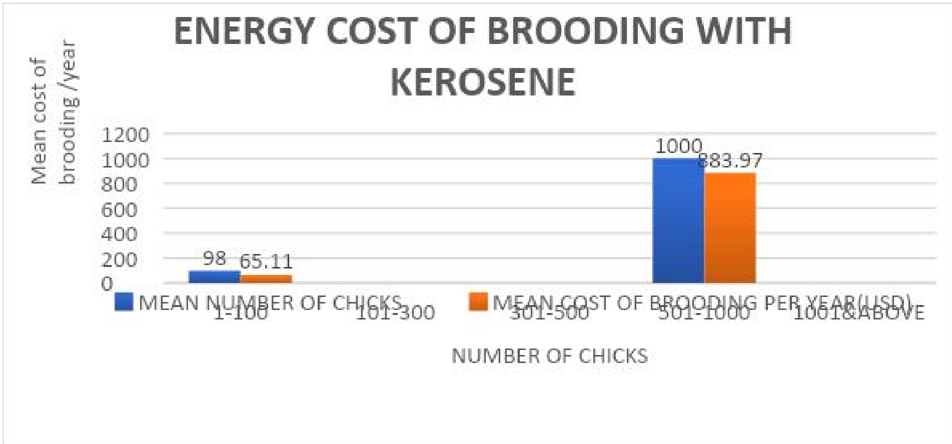

Fig. 8: Cost of brooding with kerosene

Further costing showed that to brooding 1000 day-old chicks' costs USD883.97 and USD515.81 using kerosene, and combined kerosene/electric respectively, while it costs about USD126.05 to brood the same number of chicks using solar technology. It was observed that solar energy has the least cost implication (Fig. 10). The problems associated with each brooding method were shown in Table 1. The energy cost of using solar energy may have come from getting the system cleaned off of dust to ensure optimal solar radiation collection and storage unhindered. Accordingly, Ezema et al[24], stated that solar brooding is comparatively cheaper than kerosene brooding technique. Solar brooding had relatively greater advantage over kerosene/stove brooding in terms of cost, weight gain and better haematological profile which make for improved health status in broiler during the brooding period. The study recommended solar brooding for farmers' usage against other brooding techniques for cheaper and improved broiler production.

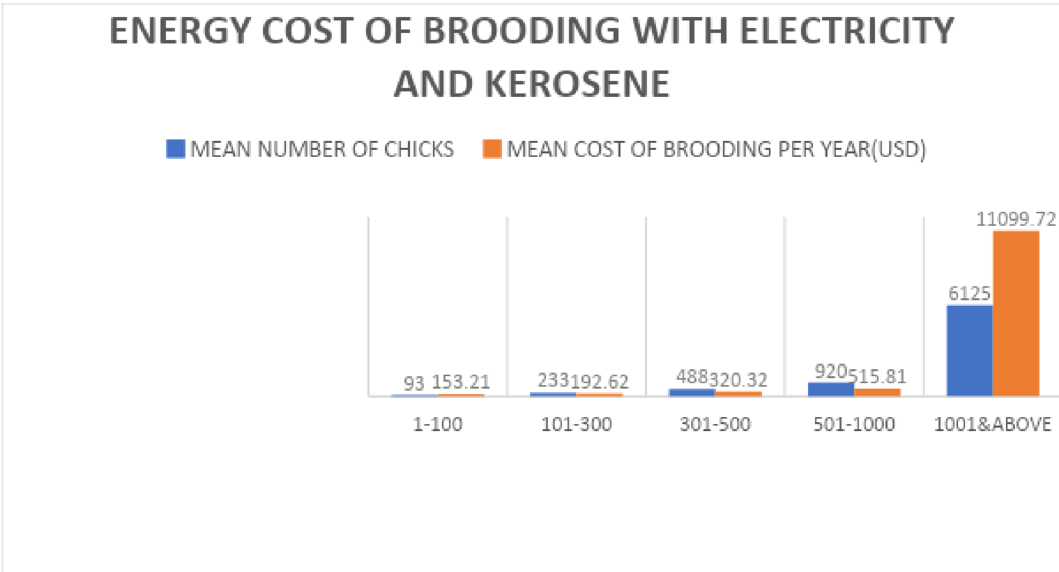

Fig.9: Energy cost of brooding with electricity and kerosene

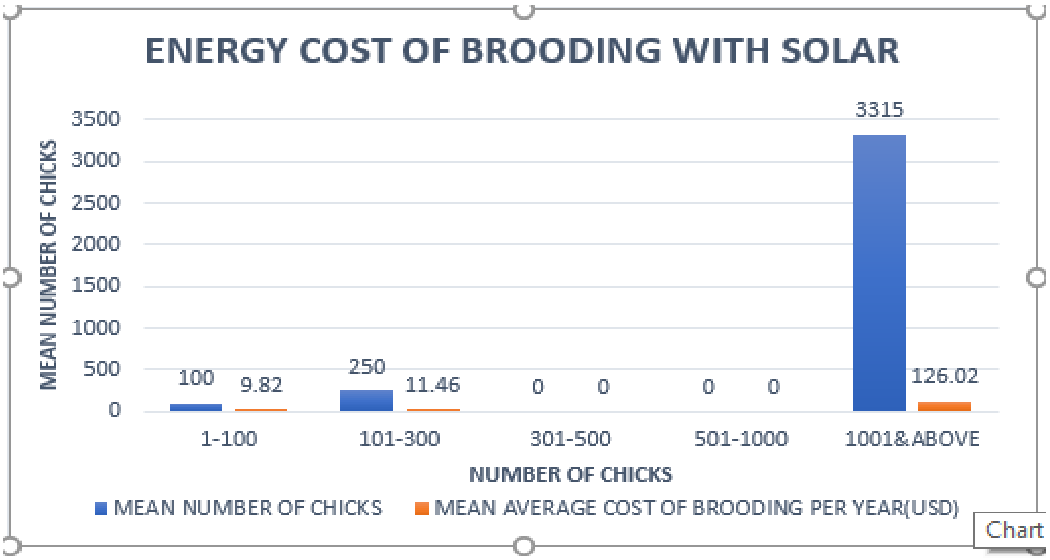

Fig. 10: Energy cost of brooding with solar energy

Conclusion

Poultry brooding of day-old chicks is an energy intensive unit operation in poultry industry that requires adequate energy supply for high performance indices and profitability. The conventional energy supply poultry brooding methods used by farmers have limitations in application, ranging from unreliability and none availability in energy supply, high energy cost, emission of greenhouse gases and high mortality rate. Therefore, a survey of techno-economic status of solar energy poultry brooding technology was conducted in Enugu State, Nigeria. Investigation revealed that out of the five brooding options of electric, gas, kerosene, combine electric/kerosene and sole energy, only three methods were in common use among the farmers. The percentage share of these were 25% of the poultry farms use kerosene (fossil fuel system) method, while 65% use combined electric/kerosene method. Only 10% use solar energy for brooding day-old chicks. The average mortality rates were 22.38%, 12.17% and 2.97% for kerosene, electric/kerosene combine, and solar energy respectively. Cost implications showed that electric/kerosene method has the highest average cost of US$2,456.34 as against US$474.54 and US$49.1 for kerosene and solar energy brooding technologies. Poor record keeping was prevalent among small scale poultry farm holdings, which have operators with low skills and poor education background. Solar energy technology was found user friendly, non-polluting tech, economical with lower mortality rate than the other two methods in use by the farmers. Solar energy innovation was found sustainable, environmentally friendly, energy saving and cost-effective. Cost-effective and energy-saving strategies are absolutely necessary in order to decrease operating costs and improve farmers' profits in production systems. Awareness and sensitization of farmers perception on the benefits of using solar energy technology are imperative towards boasting poultry production in Enugu State, Nigeria.

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