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GLOBAL JOURNAL OF ENVIRONMENTAL SCIENCE & SUSTAINABILITY

Economics of Solar Energy Usage among Poultry Farmers in Nigeria

Kehinde K. Osasona[1*], Mercy F. Salami[1], Adeola O. Fayemi[1], Abibat A. Opakunle[2], Peace E. Owolabi[1]

[1]Department of Agricultural Economics and Farm Management, P.M.B. 1515, University of Ilorin, Ilorin, Nigeria
[2]Rural Development and Gender Issues (RUDEG), Agricultural and Rural Management Training Institute, Kwara State, Nigeria

[*]Corresponding Author:
Email: okennieegreat@gmail.com

Article Information

https://doi.org/10.69798/65594395

ISSN (Online): 3066-3660

Published by: Koozakar LLC. Norcross GA 30071, United States.

Edited by: Oluseye Oludoye PhD

Abstract

Nigeria poultry farmers face high energy costs and unreliable electricity supply which hinders their productivity. This increasing energy demand and rising energy prices have led to a growing interest in renewable energy sources. Hence, we assessed the cost and returns to poultry production using solar energy, resource use efficiency of production, factors that affect resource use efficiency and constraints faced by poultry farmers using solar energy. A total of 53 poultry farmers that have adopted this innovation were selected through a snowballing sampling technique from 6 different states in Nigeria. Primary data was used, and the objectives were analysed using profitability ratio, gross margin analysis, stochastic frontier analysis, OLS regression and a 4 -point Likert scale respectively. The results revealed that poultry farmers kept about 67% of the total revenue generated from the sales of their output and a Return on Investment of 78 kobo on every ₦1 invested was realized, a technical efficiency rating of 93% was recorded on average for the poultry farmers and this implies that the poultry farmers were highly resource use efficient dropping only 7% due to inefficiencies. This study also revealed that cost of feeds, cost of birds, cost of labour and the solar energy technology were very significant in determining the resource use efficiency. Finally, the high cost of input was identified as the most significant challenge faced by the poultry farmers assessed. It can be concluded that adopting solar energy on poultry farms presents a highly profitable solution. Furthermore, this shift offers potential benefits for policymakers by reducing the sector's dependency on conventional energy sources, promoting sustainable agricultural practices, and supporting the formulation of policies that incentivize renewable energy adoption to enhance food security and economic resilience.

Keywords: Renewable energy, Sustainability, Poultry farmers, Nigeria

INTRODUCTION

The poultry production sector in Nigeria is a significant contributor to the animal production industry and the country's economy. The production of animal proteins, the creation of jobs, and food security all significantly add to the importance of poultry farming as a sector of the livestock industry. Due to its socio-economic significance, poultry production is currently one of the most commercialized and quickly expanding agricultural industries in many developing nations (Okonkwo *et al.*, 2022). Poor health conditions were mostly linked to a diet that was deficient or insufficient in animal protein in emerging nations. The fact that poultry have many advantages over other livestock and that poultry birds are excellent at converting feed into usable protein in meat and eggs can be used to explain why poultry production has become so popular.

Nevertheless, the production of poultry is still fraught with challenges, particularly when it comes to raising day-old chicks and maintaining profitable margins because of the steadily rising cost of energy, which has placed a significant financial burden on poultry farmers. Energy scarcity and inefficient energy use are two significant issues that plague breeding operations in developing nations (Okonkwo *et al.*, 2022). The effectiveness and quality of energy provision and utilization in poultry brooding systems, according to (Okonkwo *et al.*, 2021), have a significant impact on the overall success of poultry production at the early developmental stage. Due to the scarcity of energy resources, rising energy costs, and urgent environmental issues, saving energy has therefore become more crucial than ever. Okonkwo *et al.* (2022), emphasized that one renewable, endless, and cost-effective energy source that may be able to lessen the effects of climate change in poultry farming systems is solar energy. Solar energy technology has the potential to reduce electrical costs for chicken production by 30 to 85%. Furthermore, solar energy technologies have a service lifetime of roughly 25 years and require little or no maintenance which makes them ideal for poultry houses (Qui *et al*., 2021).

One most attractive possibility among the various importance of solar energy as a renewable energy is that it is less expensive for poultry farms to utilize and more environmentally friendly. This is especially true in tropical regions where sun radiation is year-round (Okonkwo, 2018).
Gad *et al*. (2020), opined that utilizing solar energy and advanced climate control systems in poultry housing can significantly maximize productivity and efficiency compared to conventional methods.

There is a knowledge gap in the economics of solar energy usage among poultry farmers. Previous studies have focused on the adoption of solar energy in the agricultural sector in general, without specific focus on the poultry industry. This study provides new insights into the adoption of solar energy in the poultry industry, which contributes to the existing literature on renewable energy adoption in agriculture. This study will also help the government by providing valuable insights into the economic viability of solar energy adoption in the farming sector. The government can use these insights to formulate targeted policies and incentives that encourage farmers to transition to solar energy aligning with broader renewable energy and sustainability goals. Therefore, this study provides insights into the adoption of solar energy in the poultry industry, which can contribute to achieving the government's renewable energy targets. Specifically, we

i. examined the costs and returns to poultry production using solar energy in the study area;
ii. analysed the resource-use efficiency of solar energy technology in poultry production in the study area;
iii. determined the factors that affect the resource-use efficiency of solar energy in poultry production in the study area;
iv. identified the constraints faced by poultry farmers using solar energy in the study area.

METHODOLODY

Study Area

This study was conducted in six states in Nigeria namely; Oyo, Kwara, Osun, Edo, Lagos and Niger Osun State is south-western state in Nigeria bordered to the east by the states of Ekiti and Ondo, to the north by the state of Kwara, to the south by the state of Ogun, and to the west by the state of Oyo. The state was created on August 27, 1991, from the south-east of Oyo State, and is named after the River Osun, an important river that flows through the state. Osogbo serves as the state's capital (Onyeakagbu, 2021).

Kwara state and eleven other states of the union were established on May 27, 1967. It is situated in Nigeria's north-central geographic region (KWADP, 2014). The state has sixteen Local Government Areas (LGAs), with Ilorin serving as its capital. Each LGA is further split into districts, which are then further divided into villages.

Edo state, southern Nigeria was formed in 1991 from the northern portion of Bendel state, the southern portion becoming Delta State. It is bounded by the states of Kogi to the northeast and east, Anambra to the east, Delta to the southeast and south, and Ondo to the west and northwest; the Niger River flows along the state's eastern boundary. Benin City is the state capital and largest urban centre (Mckenna, 2023).
Niger state is located in the west-central Nigeria. It is bounded to the south by the Niger River along with Kebbi and Zamfara to the north. It is also bordered by Kaduna to the north and northeast, Kogi to the southeast, and Kwara to the south (Mckenna, 2023).

Lagos state is located on the Bight of Benin coast in southwest Nigeria. Its borders are the Republic of Benin to the west, the Bight of Benin to the south, and the State of Ogun to the north and east. The state's territory was governed by the British as part of the colony of Nigeria from 1914 to 1954 (Adam, 2023).
Oyo State is located in the western part of Nigeria. Oyo was reduced in size when Osun state was created out of its eastern portion in 1991. Oyo is bordered on the north by Kwara, the east by Osun, the south by Ogun, and the west by the Republic of Benin. The Yoruba Hills run through Oyo State in the north. The state is mostly covered by a derived savanna, which is largely the result of clearing and burning the former forest cover to provide land for cultivation (Michele, 2023).

Sampling Technique
A snowballing sampling technique was employed in the selection of 53 poultry farmers using solar energy. Snowballing sampling technique was preferred because it avails the opportunity to connect with Poultry farmers using solar energy who may be difficult to connect with through conventional sampling procedures. The initial step involved identifying a small number of poultry farmers that use the solar energy technology on their poultry farms. These poultry farmers known as the seeds of the snowball sample then referred other poultry farmers they know belong to the target population. The new poultry farmers were contacted and asked to participate in the study. This process was repeated until the desired sampling size of 53 respondents was achieved of which 29 was selected in Kwara State, 13 in Osun State, 4 in Edo State, 4 in Oyo State, 2 in Lagos and 1 in Niger State. Achieved sampling size was small due to the fact that poultry farmers that make use of solar energy technology is relatively next to none. The use of mixed method research was adopted with questions such as inputs used during production, output level realized, constraints faced during production process among others.

Analytical Technique
Profitability Ratio and Gross Margin Analysis: It was used to estimate the cost and return to poultry production using solar energy. The tools that were used include the Gross profit, Net Farm Income and the Return on Investment.
The equation is as follows;

GP= TR-TVC_____ i

The gross margin was calculated as
GM=Gross Profit (GP)/Total Revenue (TR) × 100% _____ ii

Net Farm Income was calculated as:
NFI = TR-TC _____ iii

Return on Investment was calculated as:
ROI = Net Farm Income (NFI) / Total Cost (TC) iv

GP = the Gross profit
TR = the Total Revenue
TVC = the Total Variable Cost
P = the price per unit of output
Q = the total quantity of output.
NFI = Net Farm Income
TR = the total revenue generated from the sale of outputs
TC = Total cost of production

Stochastic Frontier Analysis: It was used to estimate the resource use efficiency. The formulae for the SFA model was written as:

$$ln(Y) = \beta_0 + \beta_1 ln(X_1) + \beta_2 ln(X_2) + \beta_3 ln(X_3) + \beta_4 ln(X_4) + \beta_5 ln(X_5) + (V_i\text{-}Z_i)$$ _____ v

Where;

Y = Total cost of output of the poultry farm (₦)
In = The natural algorithm
B_0 = Constant term
B_1-β_5 = Regression coefficients
X_1 = Cost of birds (₦);
X_2 = Cost of feeds (₦);
X_3 = Cost of labour (₦);
X_4 = cost of drugs and vaccines (₦);
X_5= Cost of solar energy for one production cycle (₦);
Z_i= Deviation from maximum potential output attributable to technical inefficiency (Age, Household size, farming experience, poultry size);
V_i= Random variability in the production that cannot be influenced by the farmer

Ordinary Least Square Regression: It was used to determine the factors that affect the resource-use efficiency. The ordinary least square regression model assumes that the relationship between the dependent variable and the independent variables is linear, and the goal is to find the best-fitting line or plane that describes this relationship.
The equation for the Ordinary Least square Regression model is written as:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \varepsilon \quad \text{vi}$$

Where;

Y = Resource use efficiency
β_0 = Intercept
β_1 - β_6 = the coefficients for each predictor variable
X_1 = Age of the farmer (Years)
X_2 = Educational level of the farmer (Years)
X_3 = Household size (Number)
X_4 = Access to credit (Amount of credit accessed)
X_5 = Experience of the farmer (Years)
X_6 = Farm Size (No. of Birds)

Likert Scale: A 4-point Likert scale of strongly agree, agree, disagree, strongly disagree was used with a list of items that might be serving as constraints encountered by the poultry farmers and it was grouped into:

Strongly agree = 4
Agree = 3
Disagree = 2
Strongly Disagree = 1

RESULTS AND DISCUSSIONS

Costs and Returns to Poultry Production using Solar Energy

The feasibility of an enterprise is indicated by the amount of profit realized at the end of a production cycle. Profit is calculated as the difference between the monetary value of the revenue realized and the total cost incurred during production. The gross profit margin measures the percentage of revenue retained by the company after deducting the total variable cost. Total variable cost is the cost of resources use up in the production process.

Table 1 shows the gross margin is estimated as 67.8%. This implies that on average, poultry businesses using solar energy in the study area keep on average 67.8% which is more than half of the total revenue realized after sale of outputs, and this means that the business is quite profitable. The net farm income indicates the total income generated from revenue after deducting all expenses. It provides an overall measure of the company's profitability and considers all costs and expenses. Table 1 shows that the estimated mean value of the net farm income of poultry businesses in the study area was ₦1,288,895.91 ($1,678). This is about 44% of the total revenue realized after sales of output.

Table 1: Cost, Gross Profit, Net Farm Income and Return on Investment

Items	Mean Value	% of the Total Cost
Revenue	₦2,932,628.49	
Variable Cost	₦943,588.95	57.41
Depreciation Cost	₦700,143.63	42.59
Total Cost	₦1,643,732.58	100
Gross Profit	₦1,989,039.54	
Gross margin	67.8%	
Net Farm Income	₦1,288,895.91	
Return per Naira Outlay	1.78	

Source: Field Survey, 2023.

The average rate of returns on investment (Return per naira outlay) was 1.78, indicating that for every ₦1 invested in poultry production using solar energy in the study area, a profit of 78 kobo was made. Thus, it can be concluded that poultry production in the study area substituting fossil fuel or generated electricity with solar energy or using solar energy in combination with generated electricity is highly profitable as it returns an average of 78 kobo on every naira invested in production. This agrees with the discoveries of (Okonkwo *et al*., 2022) that the use of kerosene and combined electric/kerosene fuel was characterised by insufficient power supply, greenhouse gas emissions, fire outbreaks, and low profit margins, while solar energy use was found to be user and

environmentally friendly with low mortality rates and low energy costs.

Resource-Use Efficiency of Solar Energy Technology in Poultry Production

The frequency distribution for the estimated resource use efficiency of poultry farmers using solar energy in the study area as obtained from the stochastic production function model is presented in Table 2. The result below shows that 90.57% of poultry farmers had resource use efficiency ≥ 0.81 while 9.43% operated between 0.60-0.80 resource use efficiency levels. The farmer with the best practice had resource use efficiency level of 0.987 while the farmer with the least practice had resource use efficiency level of 0.624.

The average resource use efficiency level is 0.93 indicating that the poultry farmers obtained 93% optimal output from the given set of inputs selected for the study. This implies that on the average output fell by 7% from the maximum level possible due to inefficiency. Although, the poultry farmers were highly technically efficient with average efficiency level of 93%. This result agrees with the findings of (Ilori *et al*., 2019) that solar-powered brooding is cleaner and safer and the best in reducing the mortality rate of the chicks thereby increasing resource use efficiency as there was no case of mortality during the brooding period unlike in the conventional brooding method where there are cases of mortality.

Table 2: Technical Efficiency Estimates

Technical efficiency	Frequency	Percentage
0.60-0.70	1	1.89
0.71-080	4	7.55
0.81-0.90	3	5.66
0.91-1.00	45	84.91
Total	**53**	**100**
Mean 0.930		
Minimum 0.624		
Maximum 0.987		

Source: Field Survey, 2023.

Factors affecting the Resource-Use Efficiency of Solar Energy in Poultry Production

Table 3 shows the maximum likelihood estimates of poultry production using solar technology. It was also revealed that cost of birds, cost of feeds, labour cost and the solar energy for the production cycle were all significant in determining the output of poultry farms using solar energy. The coefficient estimate of cost of birds is 2.438, with a standard error of 0.458. The t-ratio is 5.317, indicating that the number of birds has a significant positive effect on efficiency effects, this reveals that an increase in the quantity of day-old chicks purchased for production will increase the resource use efficiency of the poultry farm. This agrees to the report made by (Torki and Ali, 2013) who reported that an increase in number of birds on the farm would lead to an increase in the quantity of broiler meat produced.

Table 3: Factors affecting Resource Use Efficiency

Variables	Coefficients	Std. error	t-ratio
Constant	-39.910	1.000	-31.780
Cost of birds	2.438*	0.458	5.317
Cost of feeds	1.350*	0.193	6.959
Cost of labour	12.619*	4.311	2.927
Cost of drug and vaccines	-0.141	3.137	-0.045
Cost of Solar energy for one production cycle	2.018*	0.234	8.596
Age	-0.483	1.840	-0.262
Household size	-0.159	1.124	-0.141
Farming experience	0.686	2.456	0.279
Poultry size	-46.418	148.417	-0.312
sigma-squared	610.000	1.000	600.000
gamma	0.053	0.157	0.341

Source: Field Survey, 2023 * $p < 0.05$

Maximum Likelihood Estimates of the SPF estimates are: log likelihood function = -732.44

Total number of observations = 53

Cost of feed coefficient estimate is 1.350, with a standard error of 0.194. The t-ratio is 6.959, indicating that the cost of feed has a significant positive effect on resource-use efficiency. This suggests that as the quantity of feeds consumed by the poultry birds increases the output of the farm will increase. This observation conforms to similar study by (Kanu and Nwaru, 2020) who reported that as the quantity of consumed feeds increases, output of broilers is likely to increase. This is true because broiler birds have a high feed intake to be able to justify their genetically endowed fast growing ability.

The coefficient estimate for cost of labour is 12.620, with a standard error of 4.311. The t-ratio is 2.927, suggesting that the cost of labour has a significant positive effect on resource-use efficiency. This implies that an increase in the labour force on the farm will result in a substantial increase in the output of the farm. This agrees with findings made by (Mian and Malik, 2021) who reported that the cost of day-old chicks, feed, flushing, labour, rent and miscellaneous cost had positive and significant effect on poultry production. Solar energy for product cycle coefficient estimate is 2.018, with a standard error of 0.235. The t-ratio is 8.596, indicating that solar energy for the product cycle has a significant positive effect on resource-use efficiency.

Barriers Faced by Poultry Farmers in Adopting Solar Energy Usage

The result in Table 4 showed that high cost of initial set up was ranked 1st as the most serious challenge facing poultry farmers using solar energy. This is due to the fact that solar energy has high initial cost though it lasts longer and provides benefits worthwhile in the long-run. Inadequate marketing facilities ranked 2nd as less serious than high cost of input. Lack of access to credit facilities was ranked 3rd as it suggests that most backyard poultry producer cannot access enough funds that they need in the purchase of solar systems which in turn can limit their scale of operation due to inadequate credit facilities.

Table 4: Barriers Facing Poultry Farmers in Adopting Solar Energy

Constraints	Strongly Agree	Agree	Strongly Disagree	Disagree	Mean	Rank
High cost of Initial Setup	34(64.15)	17 (32.08)	2 (3.77)	0 (0.00)	3.60	1st
Lack of access to credit facilities	8 (15.09)	18 (33.96)	20 (37.74)	7 (13.21)	2.50	3rd
High infiltration of Pest and diseases	7 (13.21)	15 (28.30)	15 (28.30)	16 (30.19)	2.24	5th
Poor quality of day old chicks	12(22.64)	10 (18.87)	19 (35.85)	12 (22.64)	2.41	4th
Inadequate marketing facilities	5 (9.43)	30 (56.60)	12 (22.64)	6 (11.32)	2.64	2nd
Inadequate energy storage facilities	2 (3.77)	6 (11.32)	19 (35.85)	26 (49.06)	1.69	7th
Adverse weather conditions	2 (3.77)	9 (16.98)	13 (24.53)	29 (54.72)	1.68	8th
High cost of maintaining solar technology	1 (1.89)	8 (15.09)	19 (35.85)	25 (47.17)	1.72	6th

Values in parenthesis represents percentage score (%)**; Source:** Field Survey, 2023.

Poor quality of day old chicks was ranked 4th followed by high infiltration of pest and diseases ranked 5th. High cost of maintaining the solar energy technology was ranked 6th, this can be in form of changing the batteries as well as purchasing of additional energy storage devices. However, this operation is not a regular operation as a change can last years before another change is needed. Inadequate energy storage facilities was ranked 7th and the least serious challenge facing poultry farmers using solar energy is Adverse weather condition ranked 8th, this implies that external conditions such as low sunlight intensity may affect the level of lightning as well as the duration.

CONCLUSION

Based on the findings made in the study area, It can be concluded that using solar energy as the major source of energy in poultry production in the study area is highly profitable as it returns 78 Kobo on every ₦1 investment made with a gross margin of 67.8% which shows the percentage of the profit made from the total revenue. The result of the study also showed that tertiary education is key for the

adoption of solar energy technology among poultry farmers as it shows that about 89% of the poultry farmers assessed furthered their education to the tertiary level. Thus, adoption of solar energy technology should be encouraged not only in residential homes and established organisations but also among farmers engaged in poultry production. This could be attributed to the fact that solar energy as a clean renewable resources can reduce carbon emissions which will significantly contribute to climate change mitigation. Also, the use of solar power reduces reliance on conventional energy sources and ensures long-term sustainable poultry farming operations.

Recommendation

- Awareness campaign and sensitization on the usage of solar energy need to be more actively embarked on among solar energy service providers.
- To further improve poultry production in Nigeria, efforts need to be made to increase the adoption of solar energy technology among poultry farmers in Nigeria particularly among large-scale brooding poultry farmers. It is observed that producing with solar energy will not only be profitable but also reduce environmental conditions which may cause high mortality rate during brooding.
- For optimization, the Government in partnership with Poultry Association of Nigeria need to embark on Cost-effective and energy-saving strategies campaigns which are absolutely necessary in order to decrease operating costs and improve farmers' profits while making provision for solar energy installation components available to farmers at subsidized rate.
- The use of feeds, birds, labour and the solar energy need to be more intensified as they contribute to the resource efficiency of production. Also, in order to boost variable resources and maximize profit, it is advised that loan facilities be made available to broiler producers.
- It is also recommended that farmers pay adequate commitment to the depreciation cost of the solar energy technology because at the long run, the batteries might require changes and the depreciation costs which has been gathered can cater for these changes.

Data Availability Statement

The data for this study is available upon request from the authors.

Ethics Statement

This study was approved by the Institutional Review Board of University of Ilorin, approval number [FERC/AEFM/2023/170]. Written informed consent was obtained from all participants.

Author Contributions

Author A designed the study, Authors B and C conducted the data analysis and interpretation, Author D did the draft manuscript preparation, while Author E conducted data collection, and. All authors reviewed and approved the final manuscript.

Funding Statement

The author(s) received no financial support for the research, authorship, and/or publication of this article.

Acknowledgments

We thank every member of staff of the department of Agricultural Economics and Farm Management, University of Ilorin for their invaluable assistance and support during this research.

Conflict of Interest Statement

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Supplementary Material

No supplementary material is available for this study

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