African Journal of
Agricultural and Resource Economics
Volume 18, Number 2 (2023), pp 171–189

Willingness to pay for the production of biogas from poultry waste recycling: Evidence from farmers in Nigeria

Chukwuemeka Onyia
Department of Agricultural Economics, University of Nigeria, Nsukka. E-mail: chukwuemeka.onyia@unn.edu.ng

Benjamin Okpukpara*
Department of Agricultural Economics, University of Nigeria, Nsukka. E-mail: benjamin.okpukpara@unn.edu.ng

NwaJesus Anthony Onyekuru
Department of Agricultural Economics, University of Nigeria, Nsukka. E-mail: anthony.onyekuru@unn.edu.ng

Victoria Okpukpara
Centre for Entrepreneurship and Development Research, University of Nigeria, Nsukka. E-mail: Victoria.okpukpara@unn.edu.ng

* Corresponding author

Received: January 2023
Accepted: November 2023

DOI: https://doi.org/10.53936/afjare.2023.18(2).11

Abstract

Poultry waste management and the energy demand have generated environmental and climate change concerns. Experts have suggested converting poultry waste to biogas energy through recycling to reduce these concerns. Biogas, a poultry waste-recycling product, has yet to gain popularity in Nigeria. However, there is only limited research that has examined awareness of biogas, along with farmers' willingness to pay (WTP) for it and their payment capacity (PC). Data generated through focus group discussions with and questionnaires completed by 225 poultry farmers selected through multistage sampling were analysed using descriptive and contingency valuation methods. The study established differentials in the magnitude of determinants of households' WTP and PC. Farmers' willingness to pay was mostly responsive to variables tied to the type of farm product and household endowment, while the capacity to pay was tied to income and environmental conditions. The study proposes that policy on farmers' willingness to pay for biogas from poultry production should take into account differences in the type of poultry product, household endowment, and environmental conditions.

Key words: biogas production, eco-friendly, Nigeria, poultry waste, willingness to pay

1. Introduction

Climate change and environmental issues have become prominent problems facing poultry industries in developing countries, including Nigeria. Poultry pollution is considered humanity's most significant environmental concern in the 21st century (Kamran *et al*. 2023). It is common to see piles of poultry excrement on farms in Nigeria, or waste discharged into water from poultry farms (He *et al*. 2016). The methods employed by poultry producers in Nigeria for waste disposal are, in most cases, not environmentally friendly (Onyia *et al*. 2022). As a result, large amounts of poultry waste are improperly disposed of, including excessive waste application to the land and improper timing of application on farms. This has led to soil, water and air pollution through burying, burning and flushing waste into pits, toilets and streams, which has encouraged the emission of greenhouse gases that contribute to climate change (Bakhtiyari *et al*. 2017; He *et al*. 2020). There has been an increase in poultry waste in Nigeria in the last decade as a result of the ban on the importation of poultry products (Onyia *et al*. 2022). This has also increased the mismanagement of poultry waste disposal (Abioye *et al*. 2022).

Animal waste management, especially poultry waste, has continued to be a primary concern for government and private organisations (Situmeang *et al*. 2022). Compared to other domestic animals, poultry provides humans with meat, eggs, industrial raw materials, economic benefits and employment opportunities (Yilmaz & Şahan 2020). As reported in the literature, global climate change brings more health risks and increases concerns about greenhouse gas emissions (He *et al*. 2020). Although fossil fuels dominate any conversation regarding climate change, the supply chain of household animals, including poultry, has been neglected as a major source of greenhouse gases (GHG) (Aryal *et al*. 2020). For instance, by 2050, biomass energy will account for 50% of the world's energy (Wang & Tao 2020). Fossil fuels now supply about 30% of the world's energy demands in poultry farming (Atinkut *et al*. 2020). Similarly, natural gas, fuel, electricity and coal constitute 10.6%, 37.2%, 42.7% and 3% of the energy supply to poultry farming in Nigeria respectively (Zhang *et al*. 2020). The most regularly available and utilised energy sources among poultry producers in Nigeria are fossil fuels such as gasoline, electricity and kerosene, which contribute to global warming (He *et al*. 2016; Onyia *et al*. 2022).

The lack of knowledge and availability, and the high cost, of installation of renewable energy sources has popularised the use of non-fossil energy. This has intensified the problems of climate change. Several measures have been developed to mitigate the problems associated with climate change in Nigeria, include adopting a green economy policy (GE), which focuses on building resilience. The production of biogas through eco-friendly poultry waste recycling has been acknowledged as an important sustainable mitigation strategy for climate change (Onyia *et al*. 2022). Biogas production from poultry waste has also been acknowledged as the pathway to reducing climate change problems and energy costs in poultry farming (Da Silva Lima *et al*. 2019). In spite of the importance of these measures, the use of biogas has received only low acceptance and usage. The low use of biogas is associated with its high cost, a lack of availability, a lack of technological knowledge, a lack of government support and a lack of confidence, among others (Situmeang *et al*. 2022). More importantly, the sustainability of the green economy policy can only be guaranteed when the farmers willingly pay for biogas production produced through modern poultry waste management on their farms. The generation of biogas by farmers on their farms has helped minimise costs and increased the ecofriendly behaviour of farmers and farms. In addition, studies have reiterated that eco-friendly poultry waste management could generate the renewable energy needed in poultry production through a modern poultry waste management strategy, namely recycling (Situmeang *et al*. 2022). Aryal *et al*. (2020) reported the potential of using renewable energy to augment existing energy systems. In support of this, the government of Nigeria proposed using subsidies to encourage biogas production through poultry waste recycling, but its use by poultry farmers will only succeed if farmers accept and continue to use the biogas produced on their farms. The cost associated with the use of biogas may be enough hindrance to the sustained use of biogas on poultry farms. This has made the study of willingness to pay for biogas production on poultry farms a compelling necessity.

Recent studies on developing countries have stressed the importance of utilising alternative bioenergy in the poultry industry (Štreimikienė & Baležentis 2015), but only a few studies have examined knowledge of and willingness to pay for biogas, which is a highly rated renewable energy in the poultry industries in other African and Asian countries (Wang & Tao 2020; Wang *et al*. 2020). A study by Wairimu *et al*. (2020) focuses more on characterising energy sources. Therefore, more studies are needed that emphasise the acceptance of and willingness to pay for energy production from poultry waste recycling and utilisation in Nigeria's existing poultry industry.

Biogas utilisation by poultry farmers in Nigeria has not gained popularity, probably because of low levels of awareness, expensive component and installation costs, a lack of confidence, as well as the absence of strong government regulation (Ogunleye & Awobeyi 2010; Zhang *et al*. 2020; Ashish & Saraswat 2022). As far as we know, studies on the level of awareness of biogas, farmers' willingness to pay for it, and the determinants of the amount they are willing to pay in the Nigerian poultry industry are limited. We used the contingent valuation method (CVM) to estimate public goods based on stated preferences as part of the survey process.

2. Research methodology

The study was conducted in South East Nigeria, which consists of five states: Abia, Anambra, Ebonyi, Enugu and Imo. The state is located at latitudes 5° and 7° 75′ North and longitudes 6° 85′ and 8° 46′ East (Federal Ministry of Lands, Housing and Urban Development [FMLUD] 2018). According to Onyia *et al*. (2022), the area has a high concentration of poultry farming. Using a multistage sampling technique, 250 poultry farmers were selected for the study. In the first stage, three states, viz. Anambra, Enugu and Imo, were purposively selected because of the high concentration of poultry farmers in them. In the second stage, three local government areas (LGAs) were purposively selected because of the high concentration of poultry farmers in them, giving a total of nine LGAs selected for the study. These LGAs were Anambra West, Awka North and Ekwusigo in Anambra State; Enugu South, Udi and Nsukka LGAs in Enugu State; and Ideato North, Oru West and Okigwe local government areas in Imo State. A stratified random sampling technique was used to select 28 poultry farmers with a production capacity of fewer than 1 000 birds from the list provided by the Poultry Association of Nigeria. This gave a total of 252 poultry farmers for the study. Twelve questionnaires were not completed adequately, thus only 240 farmers were used in the study. A structured, pre-tested and validated questionnaire was used to collect data. The data was analysed using descriptive statistics and the contingent valuation model. The study used descriptive statistics, such as a four-point Likert rating scale and frequency distribution tables, to evaluate the respondents' opinions on poultry waste management practices and their perceptions of biogas production as an alternative energy source for the poultry industry. A single-bound CV method was used to analyse the determinants of willingness to pay for biogas production from poultry waste from the farm.

3. Empirical framework

The farmer's willingness to pay for biogas produced from poultry waste was estimated using a contingent valuation method (CVM). The dichotomous choice contingent valuation method can be used either in the single- or double-bound formulation. The former is easier to implement, while the latter is known to be more efficient (Calia & Strazzera 2000). The greater efficiency of the double bound is confirmed, although differences tend to be reduced by increasing the sample size. Provided that a reliable pre-test is conducted and the sample size is large, the use of the single- rather than the double-bound model is essential (Kimenju & De Groote 2008; Zobeidi *et al*. 2022). In addition, the discrepancy between the estimates produced by the single- and the double-bound method has been discussed extensively in the literature (Kling 1997; Hanemann 2000; Sillano & Ortuzar 2004), but, as far as we know, no precise and unbiased simulation study has been conducted to assess gains or losses from using either model for contingent valuation.

In economic theory, some economists have expressed concerns about how questionnaires are designed to elicit respondents' 'valid' preferences and how data are collected and interpreted (Hanemann 2000). In the most common contingent valuation question format, respondents are offered a binary choice (yes/no response) between two options: conventional energy (diesel, gasoline, kerosene and electricity), which are current practices, and alternative energy (biogas), which is produced from modern recycled poultry waste.

The insufficiency of data on biogas characteristics and benefits could result in considerable scepticism among farmers regarding these benefits. Despite the market potential, this uncertainty could have detrimental effects on the usage of biogas as a source of renewable energy and, subsequently, on the willingness to pay (WTP) for biogas. Therefore, if the information on biogas is limited or unknown, educating farmers about its benefits is important and will affect their WTP. This also informed the use of the single-bound approach in the current study. First, respondents were asked whether they would be willing to pay for poultry waste recycling (PWR) (the same as biogas generation) under a hypothetical scenario. Second, the interviewer inquired how much the farmer would pay to generate biogas from poultry waste if the first answer was affirmative. In this case, the respondents were provided with bids in a progressive manner from lower to higher bids. It is important to note that average prices of related products are sufficiently known to help set the bids. First, ten hens = 0.4 kg/day of dung, and biogas production from poultry manure is 440 litres/kg. A cubic metric is equivalent to 1 000 litres; therefore it will take 2.27 kg of poultry manure to feed 1 m^3 of biogas. One cubic metre of biogas is equivalent to 3.474 kg of firewood, 1.458 kg of charcoal, and 4.698 kWh of electricity (Adeoye *et al*. 2014; International Renewable Energy Agency 2012).

From the reconnaissance survey, it was found that installing one cubic metre of biogas will cost 90 000 Nigerian naira (N90 000 or $211). Based on this, there were seven possible bid values: 1) N90 000 ($211); 2) N90 000 ($211) ≤ N180 000 ($422); 3) N180 000 ($422) ≤ N270 000 ($632); 4) N270 000 ($632) ≤ N360 000 ($843); 5) N360 000 ($843) ≤ N450 000 ($1 045); 6) N450 000 ($1 045) ≤ N540 000 ($1 265); 7) ≥ N540 000 ($1 265). It is assumed that the decisions of the two groups of farmers (those willing to adopt and those not) are independent. A logit model was initially employed to investigate the variables influencing farmers' WTP decisions about eco-friendly biogas production. In the second stage, we utilised the tobit model to determine the amount of WTP (censored at zero). Like other non-market valuation techniques, the contingent valuation method is subject to strategic, hypothetical and zero-bidding biases. We therefore applied the biased treatment of oaths and cheap talk (Halder *et al*. 2016). Ex-ante bias-controlling strategies were applied, includes providing participants with a pre-survey explanation of the study's objectives, outlining environmental concerns, explaining the gains of using biogas, increasing the sample size to lower sample variability, and conducting face-to-face interviews to avoid non-response.

3.1 Model specification

The data had to be corrected for sample selection bias; as Greene (2011) has indicated, farmers' characteristics generally influence their willingness to pay in a survey. This study used the Heckman estimation to prevent sample selection bias in parametric estimation. All respondents with more than zero on the scale are considered farmers who are willing to pay in our study. Therefore, the willingness to pay and the amount they are willing to pay were achieved using the double-hurdle model suggested by Wairimu *et al*. (2016). The expected utility framework was the primary anchor for this study. The framework has been used to model farmers' decisions under risk and uncertainty.

The model assumes that the sample of farmers obtained utility from using biogas technology and the two possible levels of environmental quality involved in the status quo, namely the indiscriminate disposal of poultry waste and specific level of improvement, which is eco-friendly poultry waste recycling towards the production of biogas. Utility at status quo is then given by

$$V_0 = v_i(y_i z_i, q^0, \varepsilon_{0i}), \quad (1)$$

and each farmer's utility function with a specific level of improvement is

$$V_1 = v_j\left(y_{j,} z_j, q^1 \varepsilon_{1j}\right) \quad (2)$$

Thus, we can re-write equations (1) and 2) for a change in farmer's utility, as follows:

$$V_{ji} = v_j\left(y_{i,}, z_i, q^1, \varepsilon_{1ji}\right) \quad (3)$$

$$WTP = V_j\left(y_{i,} z_i, q^0, \varepsilon_{0i}\right) - m(y_i z_i, q^1, \varepsilon_{1i}), \quad (4)$$

where $i = 0$ (1) and i refers to the different states of poultry waste management; $j = 1{,}2 \ldots n$ denotes the farmers; and v_i and v_o are the indirect utilities at status quo and in the improved hypothetical scenario, respectively. The logit model for farmer j's 'Yes' and 'No' responses is formulated as follows:

$$\text{Pro}\left(\text{yes}_j\right) = 1 - F_i\left[-\left(v_1\left(y_{j-}q_j, z_j\right) + \varepsilon_{1j} - v_0\left(y_j, z_j\right) + \varepsilon_{0j}\right)\right] \quad (5)$$

The general formulation of the tobit model is usually given in terms of an index function. This can be re-written as follows:

$$y_i = X'\beta + \varepsilon_i, \quad (6)$$

where y_i is the dependent variable; in this example, the amount farmers are ready to pay for eco-friendly poultry waste disposal via biogas production. As indicated by the respondents' WTP, X' is a set of independent variables, and ε_i is considered to be an independent and normally distributed stochastic term with an $\text{N}(0, \sigma)$ distribution. We assume that there is a perceived utility, U(1), for paying for eco-friendly biogas, and a utility, U(0), for paying for conventional gas, with (0) otherwise. In addition, imagine that there is a population cluster regarding the decision to be taken at the limit. Then

$$y_i = \begin{cases} y_i = 1 \text{ if } y_i^* > 0 \text{ for paying for eco-friendly biogas} \\ 0 \text{ if } y_i \leq 0 \text{ for not paying for eco-friendly biogas} \end{cases}, \quad (7)$$

where y_i^* is the latent variable or the threshold, which is observed only when y_i, or the amount of money for which farmers exhibit WTP, is positive. The expected value, Ey, if farmers exhibit the WTP amount necessary for the eco-friendly biogas, is given as follows:

$$E(WIP) = X_j \beta F(z) + \text{ of}(z), \quad (8)$$

where X is the vector of explanatory variables; $F(z)$ is the cumulative distribution of z, $f(z)$ is the value of the derivatives of the normal curve at a given point (i.e. the unit normal distribution); z is given as $X\beta/\sigma$; β is the vector of the tobit maximum likelihood estimates, and σ is the standard error of the model.

The relationship between the expected value of all observations, Ey, and the expected conditional value above the limit Ey*, is given by:

$$Ey = F(z)Ey. \tag{9}$$

We prioritise analysing the policy implication of changes in the relevant explanatory variables. To this end, the effect of the change in the ith variable of X on Y leads to the following decomposition:

$$\frac{\delta Ey}{\delta xi} = F(z)\left(\frac{\delta Ey^*}{\delta X_i}\right) + Ey^*\left(\frac{F(z)y}{\delta X_i}\right) \tag{10}$$

According to equation (8), the change in y_I for eco-friendly biogas can be categorised into two parts: the change in probability of intensity and the change in elasticity of WTP. The following formula is used to calculate the marginal effect of an observed variable:

$$\frac{\partial \mathrm{E}(y/x_i)}{\partial x_i}\beta''\text{prob }(0 < y^* < 1) \tag{11}$$

The maximum likelihood of the Tobit model can be specified as follows:

$$\begin{aligned}\ln L \quad &= \textstyle\sum_{yi=0} -\frac{1}{2}\left[\log(2\pi)\ln\ \sigma^2 + \left(\frac{yi - Xii^j}{\sigma^2}\right)^2\right] \\ &+ \textstyle\sum_{y=0}\ \ln\ \left[\frac{1-\sigma(X\grave{\rho}\rho)}{\sigma}\right]\end{aligned} \tag{12}$$

The likelihood function is maximised with respect to P and σ to determine the most accurate estimate of the parameters. In other words, with respect to the dependent variables, WTP is partially unobserved, and this must be taken into account. For this reason, we estimated the observed variable maximum WTP (MWTP) using the tobit model:

$$\text{MWIP }_1^* = \alpha + \beta X_i + \varepsilon_i > 0, \tag{13}$$

where MWIP $_1^*$ is the householders' MWTP for eco-friendly biogas; MWIP is the farmers' actual WTP for eco-friendly biogas; Xs' denotes the explanatory variables; α is the intercept; β is a vector of coefficients; and ε is the error term, which is assumed to be normally and independently distributed, that is, $\text{NID}(0, \sigma^2)$ and independent of x_i. Assuming that the censoring point is zero, we have the following:

$$\begin{aligned}&\text{MWTP }_i^* = \alpha + \beta_1 X_1 \ldots\ldots + \beta_{13} X_{13} + \epsilon \text{ if MWTP; } > 0, \\ &0 = \text{otherwise (if MWTP}_1^* \leq 0)\end{aligned} \tag{14}$$

Studies have reported various factors affecting the willingness to pay in similar study subjects (Mijinyawa & Dlamini 2006; Muriithi *et al*. 2021). These informed the use of 13 independent variables and the associated *a priori* expectations in Table 1.

Further, an inverse Mills ratio was used as a control variable in the first stage. With the regression of the control variable and other regressors, this study addressed possible factors affecting farmers' WTP value in the second stage. Specifically, 'farmers' WTP value' is defined as a bid, which is presented in the following way:

$$Bid^*i = Xi\,\beta + \mu i \quad (15)$$

Covariate X influences farmers' WTP value. There is a disjointed relationship between ω and X. Independent errors followed a Gaussian distribution; their mean was zero, but their variance was ð2u. In the case of Z = 1, the conditional expectation of the bid determined by vector X is given by:

$$(E(bid \backslash Z = 1, X_i) = X_i^1\,\beta + ð_{2u} + ƛ_i, \quad (16)$$

where $ƛ_i$ represents the inverse Mills ratio obtained in the first stage with the logit model to estimate the samples if Z = 1.

X_i ranges from one to 13 independent variables, which are defined as follows:

X_1 = age (years)
X_2 = management system (battery cage = 1, 0 otherwise)
X_3 = years spent in formal education
X_4 = gender of farmer (male = 1, 0 otherwise)
X_5 = distance between farm and the farmer's residence
X_6 = household size
X_7 = primary occupation of the farmer (farming = 1, 0 otherwise)
X_8 = where the farm is located (rural = 1, 0 otherwise)
X_9 = type of farm product (layer producers = 1, 0 otherwise)
X_{10} = amount paid for waste management fees (naira)
X_{11} = experience vandalism on your farm (yes = 1, 0 otherwise)
X_{12} = environmental assessment (good = 1, 0 otherwise)
X_{13} = annual income
μ/ϵ = error term

3.2 A priori expectation of the signs of the variables used in regression

The expected signs of all the variables used in the regression model are presented in Table 1. As presented, the expected signs show that five, six and two variables were expected to be positive, negative and inconclusive respectively in relation to the dependent variable.

Table 1: Definition of explanatory variables used in the model and the expected signs of the coefficients

Variables	Measurement and definitions	Expected signs
Gender of poultry farmer	This is a dummy variable. The value is 1 if male; 0 if female	+/-
Education level of farmer	Measured as total number of years spent in school by the respondent	+
Household size	Number of persons in a household	-
Member of an association	The value is 1 if a respondent is a member of a community or voluntary association; 0 otherwise.	+
Management system	The value is 1 if the farmer uses a battery cage; 0 otherwise.	+/-
Distance between farm and residential areas	This is the distance between the farm and the residential building, measured in kilometres	-
Primary occupation of the farmer	The primary occupation is the occupation that generates about 80% of the income. The value is 1 if farming is the main occupation; 0 otherwise	-
Annual income	The total income from farm and non-farm sources in Nigeria naira	+
Location of the farm	The value is 1 if the farm is located in a rural area; 0 otherwise	-
Type of farm product (egg producers = 1, 0 otherwise)	The value is 1 if the main product is layers; 0 otherwise	+
Amount paid as waste management fees	This is an amount measured in Nigerian naira and charged to poultry farmers for the monthly collection and disposal of poultry waste	-
Assessment of environmental conditions	When the environmental assessment is good, the farmer is coded 1; 0 otherwise	+
Experience vandalism on the farm	The value is 1 if the farmer has experienced vandalism; 0 otherwise	-
Dependent variables		
Willingness to pay	The value is 1 if the respondent is willing to pay for eco-friendly poultry waste management by recycling to produce biogas; 0 otherwise	
Amount willing to pay	Amount willing to pay for eco-friendly poultry waste management to produce biogas	

4. Results

4.1 Descriptive statistics of variables used in the regression analysis

The mean, minimum, maximum and standard deviation of the variables used in the regression are presented in Table 2. The study used seven dummy variables and eight continuous variables in the analysis. The dependent variables of the econometric model were households' WTP for participating in poultry waste recycling (PWR), and the amount households were willing to pay for PWR. Many factors affect households' WTP, such as their perception of resource and environmental protection derived from PWR. Similarly to previous research, this study regarded farmers' personal characteristics (gender, age and education level), households' economic conditions and environmental awareness and psychological features (including an assessment of environmental conditions), etc. as factors that might affect households' WTP and the WTP value (Mijinyawa & Dlamini 2006; Ojolo *et al*. 2007). The assessment of environmental conditions refers to households' comprehensive evaluation of current water quality, air quality, cultivated land quality and sanitary conditions (Onu *et al*. 2015; Santos Dalólio *et al*. 2017). Further, mean monthly household income stood at N732 000 ($1 710.28, while N185 000 ($2 432.24) was calculated to be the average amount farmers were willing to pay. The results also show that the standard deviation was relatively high in bid value, monthly income and fee paid in waste management, suggesting high income inequality in the study area.

Table 2: Descriptive statistics of the variable used in the regression model

Variables	Minimum	Maximum	Mean	Standard deviation
WTP for participating in biogas production using poultry manure	0	1	0.642	0.480
Bid (WTP value)	0	1 000 000	185 000	221 559
Gender	0	1	0.69	0.46
Age	21	87	50.85	13.506
Management system	0	1	0.73	0.44
Years spent in school	12	18	15	1.75
Household size	2	12	5	1.835
Assessment of environmental conditions	1	5	2.9	0.826
Distance to residential area	2	31	8.19	6.59
Major occupation	0	1	0.415	0.494
Farm location	0	1	0.363	0.482
Monthly income	20 000	1 700 000	732 000	8 828.51
Farm product	0	1	0.621	0.486
Amount paid as waste management fees (monthly)	0	75 000	18 500	498
Vandalism	0	1	0.489	0.501

Source: Computed from field survey, 2020

4.2 Waste management practices in the poultry industry in Nigeria

The current waste management strategies used by poultry farmers show that the most popular (82.63%) method of waste disposal is selling the waste to crop farmers, while most poultry wastes are utilised as manure. Most notably, as few as 4% of poultry farmers used modern poultry waste management system to produce biogas. Poultry waste collection is mostly by manual scraping with a shovel (68%), while the collection frequency of poultry manure was mostly fortnightly (36%). During the focus group discussion, the farmers reported that those operating the battery cage system collected the waste at least daily because the faeces do not mix with wood shavings and therefore produce wet litter. However, as many as 29% of farmers did not have any means of controlling poultry odour.

4.3 Sources of energy used in various poultry production enterprises

Energy is essential in poultry production. Energy is one of the most easily controllable costs on most farms; therefore there is room to reduce energy consumption and costs on farms. The advantages are directly reflected in the organisation's profit, while it also contributes to energy conservation. In the utilisation of energy by the poultry sector in Nigeria, direct biogas energy conversion devices are used to produce electricity, and the systems could also produce mechanical power for other uses on the farm. Energy from biogas can be used for agricultural processes that require heating or cooling, such as drying, refrigeration and lighting, water pumping, grinding, cooking and other size-reduction processes. As the study shows, biogas energy is used for incubation, brooding, chicken growing, manure drying, processing and storage. The major energy sources for processing and storage are electricity and fossil fuels while brooding and chicken growing used electricity, fossil fuel and charcoal in descending order. It is important to note, however, that the use of biogas as energy source was only used in chicken growing, processing and storage; fewer than 9% of respondents used this type of energy.

4.4 Level of awareness of modern poultry waste management among farmers

The respondents' knowledge about modern poultry waste management was examined using a four-point Likert scale. The results shows that the farmers' had very low levels of awareness that biogas energy could be sourced from poultry waste and other modern poultry waste disposal methods.

Specifically, few respondents were familiar with green disposal (2.469) and proper timing on land (2.656), while a majority of respondents were not aware that poultry waste can be recycled to biogas (1.012). Most farmers disposed of their poultry manure in bags and pits or scattered it in fields. In addition, most respondents were unfamiliar with vermiculture and had only recently heard about it. The analysis did however show that the respondents were familiar with composting. Most respondents needed to learn about litter liquidation technology (gasification), and the majority learnt about it for the first time during this study.

4.5 Perception of biogas production from poultry waste among poultry farmers

Based on the four-point Likert scale, the results show that the respondents were not knowledgeable about biogas. Further analysis shows that knowledge, cost of maintaining the technology, and lack of skills were common reasons for adopting and using biogas in South East Nigeria. Although many farmers acknowledged the existence of biogas as an energy source, few were aware that it could be generated from poultry waste (Table 3). This result shows that factors such as a lack of information and the cost of maintenance of technology may have hindered the use of biogas technology in poultry farming. Some farmers rejected the use of biogas as they believed it would not reduce costs. This has implication for willingness to pay.

Table 3: Perceptions of farmers of biogas production from poultry waste

Variables	Likert score	Decision
I have knowledge of biogas technology	2.17	Not significant
Biogas can be generated from poultry waste	2.12	Not significant
Biogas is very expensive to maintain	2.80	Significant
I have no skill to use biogas on my poultry farm	2.98	Significant
Biogas production is a government matter and has nothing to do with me	2.34	Not significant
Biogas production cannot reduce my costs for energy use	2.51	Significant

Note: A four-point rating scale was used; this was graded as significant and not significant. The mean score of respondents based on the four-point rating scale was computed as $\frac{4+3+2+1}{4} = \frac{10}{4} = 2.50$ cut-off point

Source: Computed from field survey, 2020

Therefore, using the average interval scale of 2.50, any mean score below 2.50 (ms $<$ 2.50) was taken as not significant, while those items with mean values of more than 2.50 were considered significant in terms of perception.

4.6 The willingness of the farmers to pay for the production of biogas using poultry manure

Of the 250 respondents who completed the entire interview, 240 farmers (96%) provided valid answers to the valuation questions, while 10 provided invalid answers (4%) and were dropped from the final analysis.

The study also discovered that the majority of respondents, at 64%, were willing to pay for the modern recycling of poultry waste, while the remaining 36% were not willing to pay for it. Furthermore, the median was used to estimate the WTP value of households to ensure statistical validity. The findings indicate that a large number of respondents (38%) were willing to pay a median premium price of N50 000 ($117), while fewer than 2% were willing to pay N450 000 ($1 051) or more than N900 000 ($2 102) (Table 4). Without considering the influence of households' characteristics and other relevant variables, the non-parametric estimation method was adopted to measure the mean WTP value for PWR, which was N185 000 ($432). The estimated formula of the maximum average standard of households' WTP value is as follows:

$E\,(Bid)_{max} = \sum_{i=1}^{n} BidiAi,$

where Bid represents the WTP value; *i* (I = 1, 2..., j) represents the number of bid values; Bid_i represents households' choice of the bid value for alternative i; A_i represents the probability of choosing the bid value *i*, which is calculated using the number of households choosing a bid value *i*, divided by the total sample number. While $E(WTP) = \hat{b}x/_{100}$ (González *et al*. 2009). This value translates into N185 000 × 64.21/100 = N118 789/household. Therefore, considering the already established average household monthly income of N732 000 ($1 714) from the survey, the mean WTP represents 6.16% of the households' total monthly income.

Table 4: Distribution of households' WTP value

Bid (WTP value) (naira)	Ratio (%)
0	35.79
≤ 100 000	38.33
101 000 – 200 000	20.53
201 000 – 300 000	5.23
301 000 – 400 000	2.63
401 000 – 500 000	1.052
501 000 – 600 000	5.79
601 000 – 700 000	3.16
701 000 – 800 000	0
801 000 – 900 000	0
≥ 901 000	1.58

Source: Field survey, 2020

4.7 Determinants of willingness to participate in poultry waste recycling (PWR) and amount willing to pay for PWR (biogas generation)

Farmers' willingness to pay (WTP) for poultry waste recycling (PWR), and the amount farmers were willing to pay (WTP), were the dependent variables in the econometric model. The parameter estimation method employed Heckman's two-step estimation, and the expected value of households' WTP for participating in PWR was calculated to be N118 789 ($277.54) using non-parametric formula. Before running logit and tobit regressions, all model fitness tests were done. The test results also reveal no significant multicollinearity problem.

As shown in Table 5, the *rho* was statistically different from zero, validating the use of a Heckman sample selection model, which similarly gives consistent and efficient parameter estimations. In addition, the results indicate that some variables strongly influenced the respondents' willingness to pay for PWR and the amount they were willing to pay. A Wald statistic p-value of 0.000 (less than 0.01) implies that the entire regression validly explains the relationship between the dependent and independent variables.

Table 5: Estimates of the willingness to pay and amount willing to pay using the Heckman model

Variables	Willingness to pay		Amount willing to pay	
	Coeff.	MFX	Coeff.	
Age	.0009915	0.092	2.578***	0.168
	.0135171		0.091	
Gender	-.795584*	0.003	-0.586	0.039
	.4103604		0.7870	
Management system	.4096727	0.188	8.783***	0.286
	.3101417		0.0510	
Education	.099288***	0.049	-1.987***	0.437
	.0399923		0.0702	
Distance to the farm	-.0835906***	0.172	2.198***	0.113
	.0207195		0.036	
Household size	-.0378288	0.0004	2.501***	0.011
	.0869907		0.035	
Major occupation	-.5505685**	0.0211	-0.353	0.856
	.2606425		0.655	
Location of the farm	1.002616***	0.117	-1.553***	0.014
	.2996223		0.0452	
Farm type of product	1.077538***	0.076	0.311***	0.372
	.259546		0.0271	
Amount paid for waste management fees (monthly)			1.986***	0.069
			0.0365	
Monthly income	4.096***	.094	3.421***	0.107
	0.023		0.011	
Vandalism	-.9152474***	0.060	-5.869***	0.010
	.2792061		0.496	
Environmental assessment	-2.700	0.045	-6.611***	0.071
	2.100		0.020	
_Cons	-2.035		-44.524	
	0.028		1.851	
Rho Inverse Mills ratio	-0.086			
Wald $chi^2(13)$	62.68			
Prob > chi^2	0.000			

Number of observations = 240; selected = 153; not selected = 87; * significant at 10%, ** significant at 5%, *** significant at 1%
Source: Computed from field survey, 2020

Age did not statistically influence farmers' WTP, but was significant and positive in relation to the amount they were willing to pay. Specifically, the results show that, as the poultry farmers' age increases, the probability of the amount they are willing to pay increases by 0.9%. Gender negatively influenced farmers' WTP, suggesting that being female increased the likelihood of paying for modern poultry waste by 0.3% compared to male farmers. The management system (battery cage) positively influenced the amount they were willing to pay, indicating that farmers with battery cages were more willing to pay for the poultry waste by 2% than those with deep litter. A farmer's WTP was positively influenced by the number of years spent at school, which means that a farmer with higher education will have a higher WTP attitude than a farmer with lower education, and this increases the likelihood of paying and the amount willing to pay for biogas energy by 5% and 4%, respectively.

Farm distance to the residential area negatively influenced farmers' WTP. In contrast, it had a positive influence on the amount that poultry farmers were willing to pay. This suggests that the further a farm is from human habitation, the less likely farmers will pay for poultry waste recycling – by 17%. The study observed that an increase in household size raises the amount willing to pay by 1%. Farmers' WTP was negatively affected by a farmer with farming as their primary occupation. As a result, being a full-time farmer reduces the chances of willingness to pay for PWR by 2% compared to being a part-time farmer. As expected, farmers' WTP was positively influenced by farm location. This result suggests that residing in urban areas increases the farmer's willingness to pay by 12%. Household income positively and significantly correlates with willingness to pay and the amount willing to pay for biogas. A one-unit increase in income increased the likelihood of willingness to pay for poultry waste recycling by 4%, and the amount willing to pay for biogas energy by 6%.

Farm products had a positive relationship with farmers' WTP, suggesting that egg production increased the probability of WTP by 7% more than broilers. Vandalism had a negative relationship with farmers' WTP for biogas production. However, vandalism positively influenced the amount poultry farmers were willing to pay for biogas energy, as having a history of vandalism decreased the farmers' willingness to pay for PWR by 6%. An assessment of environmental conditions and farmers' WTP amounts were negatively related, suggesting that farmers who have successfully protected the environment are willing to pay less by 1%.

4.8 Constraints on poultry waste recycling (biogas production from poultry waste)

Table 6 shows the constraints on poultry waste recycling and on biogas production as an energy source for poultry production using a five-point Likert scale. The results show that the respondents are constrained by inadequate and intermittent government support (3.7474), a lack of skilled labour for installation and operation (3.3947), limited awareness of opportunities for biogas applications (3.2842), the need for consistent maintenance (3.2526), and the initial cost of the installation (3.1895).

Table 6: Distribution of respondents according to constraints to participating in poultry waste recycling

	Modern methods of waste disposal	**Constraints**
1	Limited information about opportunities for biogas applications	3.2842*
2	Initial cost of installations	3.1895*
3	Lack of skilled labour for installation and operation	3.3947*
4	Inadequate and intermittent government support	3.7474*
5	Feedstock availability	2.1632
6	Need for consistent maintenance	3.2526*
7	Competition from fossil-based alternatives	1.4632
8	Behavioural and social acceptance	1.8895

* = Serious constraints
Source: Field survey, 2020

5. Results and discussion

Modern poultry recycling is an innovative method of mitigating climate change and reducing the cost of energy in the poultry business. The marketing of and demand for poultry manure among crop farmers is a serious business on farms located in crop-producing areas, although the business is driven by season. As observed in the study, most poultry farmers earn enough income from organic manure, especially in urban areas, where manure from poultry wastes reduces urban farmers' reliance on inorganic fertilisers for soil fertility (Adedayo 2012). The high number of respondents without means of controlling odour will give rise to high GHG emissions, as reported by Abioye *et al*. (2022). This finding, however, is contrary to findings of Carlini *et al*. (2015). The attitude of respondents to odour control has also generated health challenges among the people living near the poultry farms, ranging from minor to major health issues. This was observed during the focus group discussions, suggesting that urgent measures are required to arrest the situation.

The study identified that many energy sources were used differently in poultry farming in Nigeria. However, it is important to note that the use of biogas as one of the sources of energy was only identified in chicken growing, processing and storage. This finding is contrary to the situation in Pakistan, where biogas has remained a prominent source of energy in all poultry value chains (Arshad *et al*. 2018). The reasons for this low usage were mainly tied to a lack of knowledge about the technology and the cost involved in procuring materials and equipment for biogas generation. The study identified a low level of awareness, and this finding differs significantly from that of Zhang *et al*. (2020), but is comparable to the findings of Omid *et al*. (2018) and Situmeang *et al*. (2022). However, because of the level of education in the study area, farmers may have heard the term ‘gasification’ and viewed it as the same as biogas production. Due to storage problems, farmers choose to litter the land around farms, even though they are aware that it is more appropriate to spread the manure to coincide with crop farming. This finding is not different from that of Štreimikienė and Baležentis (2015), while Zobeidi *et al*. (2022) disagree with this finding. Home gardeners in developed countries have embraced this practice of using green waste and vegetable scraps (Martinho 2018).

In terms of determining willingness to pay and the amount willing to pay, it was found that older farmers were more willing to pay for biogas. This was expected, because older farmers have been engaged in agricultural production for a long time and have acquired knowledge about climate change mitigation. Similar results have been found elsewhere (Yilmaz & Şahan 2020; Situmeang *et al*. 2022). In contrast, some studies have reported a negative relationship (Arshad *et al*. 2018), as they argue that age has little to do with the willingness to pay for poultry biogas, especially when it is not tied to income and experience. The fact that women are more willing to pay for biogas is supported by the literature (Omid *et al*. 2018). One possible explanation could be that women are more altruistic in relation to their health and the environment and have a greater passion for mother earth. However, studies have reported otherwise, as they argue that women in developing countries command little or no resources that can guarantee an adequate financial obligation (Onyia *et al*. 2022), hence they find it difficult to meet their financial obligations, including payment for alternative energy for poultry production.

Battery cage farmers are willing to pay more for PWR because of their commercial orientation, higher energy needs and, on average, higher waste levels due to higher stocking levels. This makes sense, and other researchers have found similar results (Arshad *et al*. 2018). In addition to having a larger flock of birds, egg-producing poultry farmers are more commercially oriented, which may make them more inclined to participate in PWR. In support of the findings of Yilmaz and Şahan (2020), most egg producers stock their birds in battery cages to produce wet poultry waste, which negatively affects the environment, while broiler producers stock birds in deep litter to produce dry matter. The implication of this is that egg-producing poultry farmers produce more waste that requires more attention in modern poultry recycling than do broiler producers. This was also the finding of Situmeang *et al*. (2022).

The education of farmers was found to influence their willingness to pay. According to some theories, the higher the educational level, the more likely people will prefer comfort, a clean environment, healthy living, and innovation (Michel 2021). The possible explanation may be that educated people can easily understand the consequences of the mismanagement of waste. Aryal *et al*. (2020) emphasise the importance of education in ensuring sustainable development and improving people’s ability to deal with environmental issues through enhanced income or wages. Nevertheless, some studies have shown that education can only achieve a willingness to pay when it is tied to higher income or a pay rise (Wojuoal & Alant 2017). Furthermore, many poultry farms are located outside residential areas because there is an environmental law in Nigeria that mandates government to sanction poultry farmers who locate their farms near residential areas. This means that the further the farm from human residences, the more likely the farmers' willingness to pay for biogas production. This is expected, as farms further away from residences are usually the least disturbed by their families, neighbours and local government regarding waste disposal notices. Similar results have been found in Iran, where poultry farms located far from residential areas do not receive pressure from households or the government to pay environmental fees (Caputo *et al*. 2022). In addition, since poultry farms are far from residential areas, they need not adhere to strict environmental quality regulations because they do not receive pressure from households or the government (Caputo *et al*. 2022). It therefore is less likely that these farms would opt for biogas production or other modern waste management options.

Farmers with larger households were willing to pay more than farmers with fewer members, hence smaller households, suggesting more financial resilience in the former as there are more members who can contribute to paying for biogas. This finding is the same as that of Ashish and Uttam (2013). However, other authors have argued that the increase in household size will burden households' financial stability and they will be less willing to spend more money on PWR. The finding that being a full-time farmer reduces the willingness to pay for PWR is expected, because farmers with other sources of income are more likely to pay for PWR. In Nigeria, non-farm income has been acknowledged as a major buffer in relation to financial shocks and a catalyst for the payment of services (Abioye *et al*. 2022). Urban farmers are more aware of poultry pollution and have to comply with stricter environmental regulations and standards than farmers in rural areas (Michel *et al*. 2021). Thus, it is less likely that farmers in rural areas would opt for biogas production or other modern waste management options. Farms in rural areas are without electricity and may choose a cheaper alternative source rather than paying for complicated biogas. In addition, some studies have suggested that farmers in urban areas have larger flocks and might choose a higher WTP amount (Bozorgparvar *et al*. 2018). The household's income is positive and significant in relation to willingness to pay and amount willing to pay. Income-driven demand for environmental improvements is consistent with findings in the field of environmental economics (Wang & Tao 2020). This may be because people are now better equipped and understand the consequences of improper waste disposal. In addition, poor farmers largely rely on farming for their income; wealthier farmers rely more on off-farm occupations – primarily self-employed operations, as reported in other studies (Arshad *et al*. 2018).

Vandalism raises the cost and lowers the willingness to pay the amount, implying a lower interest in willingness to pay. Farmers with a history of experience of vandalism are generally reluctant to install any components that will attract vandals (Zhang *et al*. 2020). Therefore, fear of vandalism will keep farmers from adopting new technologies that require installation (Situmeang *et al*. 2022). In contrast, the positive effect of farmers' willingness to pay for poultry waste recycling is unexpected and not supported by most of the literature on willingness to pay (Arshad 2018; Khoshgoftar Manesh *et al*. 2020). In addition, the reason for this sign could be that, when their electricity cable connections to the national grid were vandalised, farmers were willing to pay to generate an alternative energy source as a preventive measure against further vandalism.

Generally, the serious constraints on the use of a modern poultry waste management methods, namely recycling poultry waste, were inadequate and intermittent government support; a lack of skilled labour for installation and operation; limited awareness of opportunities for biogas applications; the need for consistent maintenance; and the initial cost of installation. This finding is supported by Ashish and Saraswat (2022), who found that financial, economic, market, infrastructural, regulatory and institutional barriers constrained poultry waste recycling to produce biogas for poultry production.

6. Policy recommendations

Modern poultry recycling is a widely accepted strategy that could promote a sustainable improvement in agricultural productivity and food security, increase farmers' adaptive capacity and resilience to climate shocks, and contribute to GHG mitigation by converting waste to biogas. Considering the importance of income in enhancing willingness to pay for biogas, the results reported in this study are valuable decision-support tools for governments, NGOs, associations and companies interested in promoting biogas technology in Nigeria and other developing countries. In addition, the results provide a basis for the setting of poultry waste disposal fees by poultry farmers in Nigeria, given the willingness of a majority of households to pay for such services.

In view of this, government investment in the future should have a private sector-driven target and achieve it by genuinely factoring in differences in types of poultry product, household endowment and environmental conditions in the design of sustainable biogas in poultry production. In addition, integrated projects that offer farmers some opportunity to diversify and broaden their livelihood and economic base should be prioritised in such eco-friendly policy, as evidenced by biogas production using poultry waste to increase the capacity of the farmers to pay. In the light of this, the study also recommends public education on the economic and health benefits of poultry waste recycling through the formal and informal education sectors. The environmental department should work collaboratively with the ministry of education and farmers' organisations to build a strong awareness component, including on the importance of protecting the environment through alternative energy sources in the poultry industry by way of waste recycling. The fact that the majority of participants were willing to pay less than the government-proposed installation means that the poverty level of the farmers is still high. The government should encourage farmers by providing an enabling environment and appropriate subsidy to promote the use of biogas, which will benefit society in the long run.

7. Conclusion

Some of the findings agreed, while others disagreed, with previously published literature in other countries – mainly Asia. The study identified a low level of awareness of biogas among poultry farmers. In addition, the current study established a differential and demonstrated that households' WTP and the amount willing to pay are influenced not only by personal or family endowments, but also by non-economic factors such as their assessment of environmental conditions. Farmers' willingness to pay was mostly responsive to variables tied to location, type of farm product, years spent in school, age, management system, distance from residential areas, household size, and vandalism. The amount willing to pay was tied to variables associated with income, such as gender, distance of farm from a residential area, type of occupation of the farmer, vandalism, and environmental conditions. The general view is that poultry farmers are willing to pay a certain amount for poultry recycling tied to their income.

References

Abioye OM, Adeniran KA & Abadunmi T, 2022. Poultry wastes effect on water quality of shallow wells of farms in two locations of Kwara State, Nigeria. Nature Environment & Pollution Technology 21(1): 303–8.

Adedayo V, 2012. Poultry waste management techniques in urban agriculture and its implications: A case of metropolitan Lagos, Nigeria. Asian Journal of Agricultural Sciences 4(4): 258–63.
Adeoye PA, Hasfalina CM, Amin MSM, Thamer AM & Akinbile CO, 2014. Environmental implication of poultry waste generation and management techniques in Minna, semi-arid region of Nigeria. Annual Research & Review in Biology 4(10): 1669–81.
Arshad M, Bano I, Khan N, Shahzad MI, Younus M, Abbas M & Iqbal M, 2018. Electricity generation from biogas of poultry waste: An assessment of potential and feasibility in Pakistan. Renewable and Sustainable Energy Reviews 81(1): 1241–6. https://doi.org/10.1016/j.rser.2017.09.007
Aryal JP, Sapkota TB, Khurana R & Khatri-Chhetri A, 2020. Climate change mitigation options among farmers in South Asia. Environment, Development and Sustainability 22: 3267–89.
Ashish S & Saraswat AK, 2022. Two inventory models for growing items under different payment policies with deterioration. International Journal of Procurement Management 15(4): 447–62.
Ashish T & Uttam D, 2013. Households willingness to pay for improved waste management in Silchar Municipal Area: A case study in Cachar District, Assam. IOSR Journal of Humanities and Social Science 6(5): 21–33.
Atinkut HB, Yan T, Arega Y & Raza MH, 2020. Farmers' willingness-to-pay for eco-friendly agricultural waste management in Ethiopia: A contingent valuation. Journal of Cleaner Production 261: 121211. https://doi.org/10.1016/j.jclepro.2020.121211
Bakhtiyari Z, Yazdanpanah M, Forouzani M & Kazemi N, 2017. Intention of agricultural professionals toward biofuels in Iran: Implications for energy security, society, and policy. Renewable and Sustainable Energy Reviews 69:341–49.
Bozorgparvar E, Yazdanpanah M, Forouzani M & Khosravipour B, 2018 Cleaner and greener livestock production: Appraising producers' perceptions regarding renewable energy in Iran. Journal of Cleaner Production 203: 769–76.
Calia P & Strazzera E, 2000. Bias and efficiency of single versus double bound models for contingent valuation studies: A Monte Carlo analysis. Applied Economics 32(10): 1329–36. https://doi.org/10.1080/000368400404489
Caputo V, Sogari G & Van Loo EJ, 2022. Do plant-based and blend meat alternatives taste like meat? A combined sensory and choice experiment study. Applied Economic Perspectives and Policy 45(1): 86–105. https://doi.org/10.1002/aepp.13247
Carlini M, Castellucci S & Moneti M, 2015. Biogas production from poultry manure and cheese whey wastewater under mesophilic conditions in batch reactor. Energy Procedia 82: 811–8. https://doi.org/10.1016/j.egypro.2015.11.817
Da Silva Lima ND, De Alencar Nääs I, Garcia RG & De Moura DJ, 2019. Environmental impact of Brazilian broiler production process: Evaluation using life cycle assessment. Journal of Cleaner Production 237: 117752. https://doi.org/10.1016/j.jclepro.2019.117752
Federal Ministry of Lands, Housing and Urban Development (FMLHUD), 2018. Geographical location of southeastern Nigeria. Abuja, Nigeria: Government Press.
González C, Johnson N & Qaim M, 2009. Consumer acceptance of second-generation GM foods: The case of biofortified cassava in the north-east of Brazil. *Journal of Agricultural Economics* 60(3): 604–24. https://doi.org/10.1111/j.1477-9552.2009.00219.x
Greene WH, 2011. Econometric analysis. New York: Prentice Hall.
Halder P, Pietarinen J, Havu-Nuutinen S, Pöllänen S & Pelkonen P, 2016. The theory of planned behavior model and students' intentions to use bioenergy: A cross-cultural perspective. Renewable Energy 89: 627–35. https://doi.org/10.1016/j.renene.2015.12.023
Hanemann MW, Loomis JB & Kanninen B, 1999. Statistical efficiency of double-bounded dichotomous choice contingent valuation. American Journal of Agricultural Economics 73(4): 1255–63.

He K, Zhang J & Zeng Y, 2020. Households' willingness to pay for energy utilization of crop straw in rural China: Based on an improved UTAUT model. Energy Policy 140: 111373. https://doi.org/10.1016/j.enpol.2020.111373

He K, Zhang J, Zeng Y & Zhang L, 2016. Household's willingness to accept compensation for agricultural waste recycling: Taking biogas production from livestock manure waste in Hubei, PR China as an example. Journal of Cleaner Production 131: 410–20.

International Renewable Energy Agency (IRENA), 2012. Renewable power generation costs in 2012: An overview. Available at https://www.irena.org/publications/2013/Jan/Renewable-Power-Generation-Costs-in-2012-An-Overview

Kheiralipour K, Rafiee S, Karimi M, Nadimi M & Paliwal J, 2023. The environmental impacts of commercial poultry production systems using life cycle assessment: A review. World's Poultry Science Journal. https://doi.org/10.1080/00439339.2023.2250326

Khoshgoftar Manesh MH, Rezazadeh A & Kabiri S, 2020. A feasibility study on the potential, economic, and environmental advantages of biogas production from poultry manure in Iran Renewable Energy 159: 87–106. https://doi.org/10.1016/j.renene.2020.05.173

Kimenju SC & De Groote H, 2008. Consumer willingness to pay for genetically modified food in Kenya. Agricultural Economics 38(1): 35–46.

Kling CL, 1997. The gains from combining travel cost and contingent valuation data to value non-market goods. Land Economics 73: 428–39.

Martinho VJPD, 2018. Interrelationships between renewable energy and agricultural economics: An overview. Energy Strategy Reviews 22: 396–409.

Michel F, Hartmann C & Siegrist M, 2021. Consumers' associations, perceptions and acceptance of meat and plant-based meat alternatives. Food Quality and Preference 87: 104063.

Mijinyawa Y & Dlamini BJ, 2006. Livestock and poultry wastes management in Swaziland. Livestock Research for Rural Development 18(6): 3–9.

Muriithi BW, Gathogo N, Rwomushana I, Diiro G, Faris SM, Khamis F, Tanga C & Ekesi S, 2021. Farmers' knowledge and perceptions on fruit flies and willingness to pay for a fruit fly integrated pest management strategy in Gamo Gofa zone, Ethiopia. International Journal of Agricultural Sustainability 19(2): 199–212.

Ogunleye IO & Awogbemi O, 2010. Constraints to the use of solar photovoltaic as a sustainable power source in Nigeria. American Journal of Scientific and Industrial Research 2(1): 11–6.

Ojolo SJ, Oke SA, Animasahun K & Adesuyi BK, 2007. Utilization of poultry, cow and kitchen wastes for biogas production: A comparative analysis. Iranian Journal of Environmental Health Science & Engineering 4(4): 223–8.

Omid M, Khanali M & Zand S, 2018. Energy analysis and greenhouse gas emission in broiler farms: A case study in Alborz province, Iran. Agricultural Engineering International: The CIGR e-Journal 19(4): 83–90.

Onu DO, Offor EI & Okpara BO, 2015. Poultry wastes management strategies and environmental implications in Abia State. International Research Journal of Agricultural Science and Soil Science 5(6): 159–64.

Onyia CC, Okpukpara BC & Onyekuru A, 2022. Economics of poultry waste management policy in South East Nigeria: Exploring the determinants using choice experiment model. Agricultural Science Digest – A Research Journal 42(4): 494–9.

Santos Dalólio F, Da Silva JN, Carneiro de Oliveira AC, Ferreira Tinôco IdF, Christiam Barbosa R, Resende MdO, Teixeira Albino LF & Teixeira Coelho S, 2017. Poultry litter as biomass energy: A review and future perspectives. Renewable and Sustainable Energy Reviews 76: 941–9.

Sillano M, Ortuzar JdeD, 2004. Willingness-to-pay estimation with mixed logit models: Some new evidence. Environment and Planning A: Economy and Space 37(3): 525–50.

Situmeang R, Mazancová J & Roubík H, 2022. Technological, economic, social and environmental barriers to adoption of small-scale biogas plants: Case of Indonesia. Energies 15(14): 5105. https://doi.org/10.3390/en15145105

Štreimikienė D & Baležentis A, 2015. Assessment of willingness to pay for renewables in Lithuanian households. Clean Technologies and Environmental Policy 17: 515–31. https://doi.org/10.1007/s10098-014-0810-z

Wairimu E, Obare G & Odendo M, 2016. Factors affecting weather index-based crop insurance in Laikipia County, Kenya. Journal of Agricultural Extension and Rural Development 8(7): 111–21.

Wang J & Tao J, 2020. An analysis of farmers' resource disposal methods for livestock and poultry waste and their determinants. Chinese Journal of Population, Resources and Environment 18(1): 49–58. https://doi.org/10.1016/j.cjpre.2021.04.017

Wang ZQ, Yun YL & Qin ZZ, 2020. Design and test of data collector for agricultural machine operation parameters based on internet of things. Journal of Agricultural Mechanization Research 42(01): 75–79. https://doi.org/10.13427/j.cnki.njyi.2020.01.014

Wojuola RN & Alant BP, 2017. Public perceptions about renewable energy technologies in Nigeria. African Journal of Science, Technology, Innovation and Development 9(4): 399–409.

Yılmaz Ş & Şahan T, 2020. Utilization of pumice for improving biogas production from poultry manure by anaerobic digestion: A modelling and process optimization study using response surface methodology. Biomass and Bioenergy 138: 105601. https://doi.org/10.1016/j.biombioe.2020.105601

Zhang L, Ruiz-Menjivar J, Luo B, Liang Z & Swisher ME, 2020. Predicting climate change mitigation and adaptation behaviours in agricultural production: A comparison of the theory of planned behaviour and the value-belief-norm theory. Journal of Environmental Psychology 68: 101408.

Zobeidi T, Komendantova N & Yazdanpanah M, 2022. Social media as a driver of the use of renewable energy: The perceptions of Instagram users in Iran. Energy Policy 161: 112721.