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Abstract: Biogas technology, as a pro-poor renewable energy source, has been promoted in Uganda through the use of fixed dome and floating drum digester designs. However, these designs have proved to be too expensive for the average Ugandan to afford. A cheaper flexible balloon digester has been proposed to increase uptake. However, there has been lack of evidence on household's willingness to pay (WTP) for the flexible balloon digester. Primary data were obtained from survey of experimental households and 144 non-biogas households in central Uganda. A logistic regression model was used to estimate household's WTP and determine the factors that influence WTP. Results reveal that the majority of surveyed households showed their WTP, but an average household's maximum WTP (US$52) was ten times less than the actual cost of an imported digester unit (US$512). The results further indicate that household size, cost of fuelwood, and a household's perception on technology significantly influenced the WTP. Thus, government and NGOs interested in promoting this design should pay due attention on ensuring the availability of affordable flexible balloon digester from local sources. Otherwise, focus should be on promoting either different biogas designs or alternative affordable renewable energy technologies rather than the flexible balloon digester

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Are smallholder farmers willing to pay for a flexible balloon biogas digester? Evidence from a case study in Uganda

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To: The Editor

Energy Research & Social Science

Re: **Paper submission (new submission)**

Dear Editor,

My co-authors and I would like to submit our manuscript titled **"Are smallholder farmers willing to pay for a flexible balloon biogas digester? Evidence from a case study in Uganda"** a full-length research article for publication in 'Energy Research & Social Science' journal. The manuscript has not been published previously and is not considered for publication elsewhere. All the authors disclose that there is not conflict of interest in this submission. Thank you for your consideration of our work.

Sincerely yours,

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Highlights

- We examined households WTP for flexible balloon biogas design in Uganda.
- Household's maximum WTP is 10 times less than the actual cost of the biogas digester.
- Household size, cost of fuelwood, and environmental/health perception influence WTP.
- Affordable flexible balloon digester should be ensured from local sources if we were to promote up take.

Are smallholder farmers willing to pay for a flexible balloon biogas digester? Evidence from a case study in Uganda

Abstract

Biogas technology, as a pro-poor renewable energy source, has been promoted in Uganda through the use of fixed dome and floating drum digester designs. However, these designs have proved to be too expensive for the average Ugandan to afford. A cheaper flexible balloon digester has been proposed to increase uptake. However, there has been lack of evidence on household's willingness to pay (WTP) for the flexible balloon digester. Primary data were obtained from survey of experimental households and 144 non-biogas households in central Uganda. A logistic regression model was used to estimate household's WTP and determine the factors that influence WTP. Results reveal that the majority of surveyed households showed their WTP, but an average household's maximum WTP (US$52) was ten times less than the actual cost of an imported digester unit (US$512). The results further indicate that household size, cost of fuelwood, and a household's perception on technology significantly influenced the WTP. Thus, government and NGOs interested in promoting this design should pay due attention on ensuring the availability of affordable flexible balloon digester from local sources. Otherwise, focus should be on promoting either different biogas designs or alternative affordable renewable energy technologies rather than the flexible balloon digester.

Keywords

Biogas, Willingness to pay, Flexible balloon digester, Uganda

1. Introduction

It is estimated that 2.4 billion people, representing more than a third of the world's population, rely on biomass (wood, charcoal, crop residue and dung) for cooking and heating [1]. Current trends suggest that another 200 million people will be dependent on biomass to meet their thermal energy needs by 2030 [2]. In Uganda the main source of fuelwood for cooking is obtained by cutting down trees. Okure and Nabuma [3] observed that over 60% of the total wood produced in Uganda is used as fuelwood. Fuelwood still remains the most affordable source of energy to most rural and urban households in Uganda [1]. Malla et al. [4] asserted that incomplete combustion of fuelwood generates smoke that results in indoor air pollution (IAP). This thick acrid smoke from stoves and fires inside homes is one of the four leading causes of death and disease in the world's poorest countries [5]. The main victims of death from exposure to IAP are women and children with more than 1.5 million deaths annually [10].

There are a number of options that can be used to overcome the harmful effects associated with traditional uses of fuelwood [5]. Such interventions include behavioural change, improved kitchen ventilation, sustainable production of biomass, efficient wood/charcoal stoves and the use of cleaner fuels [6]. However, the most effective way of dealing with the problems, especially that of IAP, is to switch to cleaner burning fuels, such as LPG and kerosene that produce significantly lower emissions [4].

Although switching to cleaner fuels offer the first-best solution, current economic conditions and energy infrastructure in Uganda make cleaner petroleum-based fossil fuels an unlikely option. This is because commercial fuels such as LPG are in most cases deemed too expensive and not always available. Consequently, affordable alternatives that are cleaner and more sustainable, and also reduce households' workload are needed. Such energy interventions include biogas, which is produced from animal dung, human excrement and other organic materials by a biogas digester [7]. Biogas is also likely to produce lower emissions [8]. A study by Walekhwa et al. [2] indicated that Uganda has a potential to generate 1740 Mtoe of energy from animal waste at a recoverable rate of 30%. If this energy is fully utilised, Peipert et al. [9] reported that households would improve in health, economic and environmental outcomes. However, most efforts aimed at promoting biogas in Uganda have mainly focussed on feasibility of biogas production from fixed-dome digesters [2,10]. These digester designs have proved to be too expensive for the average Ugandan to afford [10].

A cheaper flexible balloon digester design was being promoted by a project – The Potential of Small-Scale Biogas Digesters to Improve Livelihoods and Long Term Sustainability of Ecosystem Services in Sub-Saharan Africa, funded by the UK Department for International Development (DFID) under the New and Emerging Technologies Research Competition (NET-RC) grant call– where flexible balloon digester were provided to a selected number of households in Tiribogo village in Mpigi district, central Uganda. The project aimed at providing information that would help the success of national programmes to establish affordable biogas digesters in Sub-Saharan Africa. It focused on investigating in cheaper designs of biogas digesters to encourage wider uptake of the technology amongst the poor members of the community and to provide a long-term energy supply. However, the preferences and willingness to pay (WTP) of smallholder households and the factors influencing their WTP for the flexible balloon digester have not been studied. In addition, the potential of the flexible balloon digester to enhance the livelihood of smallholder farm households has not yet been explored. It is against this background that this study was conducted to assess the willingness to pay for the flexible balloon digester and understand the factors that determine household's WTP using household survey data from central Uganda. The main objectives of the study were to: (i) estimate smallholder household's willingness to pay for the flexible balloon digester, and (ii) determine the key factors that influence the willingness to pay of households for a flexible balloon digester designs.

2. Approaches to willingness to pay estimation for renewable energy

Contingent valuation (CV) method has been employed for the estimation of willingness to pay for renewable energy and factors that affect it [11]. In addition, CV method has been used for evaluation of choice among various alternatives renewable energy choices such as wind, hydropower and biomass [12]. Most of the studies have explored willingness to pay for renewable energy by households using the binary or multinomial logit models. Garson et al. [13] investigated the willingness to pay for solar photovoltaic energy lighting using a multinomial logit and the results indicate that socioeconomic, demographic and environmental conditions influence willingness to pay. Multinomial Logit has limitations such as failure to account for varying levels of substitution between choice alternatives, taste homogeneity ignores the fact that preferences are unobservable and violates consumer axioms of transitivity and stability of choices by imposing independence of unobserved factors over time or across time [14]. Riccardo et al. [15] explored the willingness to pay for renewable energy in United Kingdom. This study compared the results from conditional and mixed logit models, which estimated the distribution of utility coefficients. This then derived willingness to pay values as a ratio of the attribute coefficient to the price coefficient, with such a model, the willingness to pay distribution is estimated directly from utility in the money space.

Mixed logit overcomes the limitations imposed by multinomial logit such as accounting for taste differences by allowing model coefficients of observed variables to vary randomly over individuals [16]. In addition, individual preferences are assumed to be heterogeneous and continuously distributed random variables for the whole population [16]. Sabah and Jeanty [11] examined the households' willingness to pay for electricity connection in Kenya and found out that households were willing to pay more for geothermal energy services than Photovoltaic using a binary logit. In addition, households favoured monthly connection payments over a lump sum amount. However, Daniel [17] explored the willingness to pay and attitudes regarding biogas digester and linear regression was used in determining the factors that influence willingness to pay for anaerobic digestion on dairy farms. The parameter estimates from the linear regression are unbiased, but inefficient and inconsistent [18].

Our present study adopted the logistic regression model to the conventional linear probability regression model in analysing the factors that influence willingness to pay for a flexible balloon digester. The reason is that parameter estimates from the former are asymptotically consistent and efficient [19]. The estimation procedure employed also resolves the problem of heteroscedasticity and constrains the conditional probability of making the decision to pay for the flexible balloon digester lie between zero and one. Other studies that have used logit model include [11,14] among others. The study therefore used a binary Logit because of the nature of the dependent variable.

3 Methods and Materials

3.1 Study area description

The study was conducted in Mpigi district, Muduuma Sub-county in Tiribogo village (Fig. 1). Muduuma Sub-count is located on 0°21'5" N and 32°17'56" E and the average minimum and maximum temperature recorded is 15 ^{o}C and 28 ^{o}C respectively. The areas experience a bi-modal rainfall pattern, with the first season starting in March-April and ending in May. The second rains start in July and go up to November and are usually more reliable. The annual rainfall ranges from 800mm and 1200mm. Tiribogo village is bordered by Muduuma forest reserve with dominant vegetation consisting of savannah woodland. The village has a total population of 4,800 whose main livelihood is mainly crop growing with livestock kept to supplement their incomes.

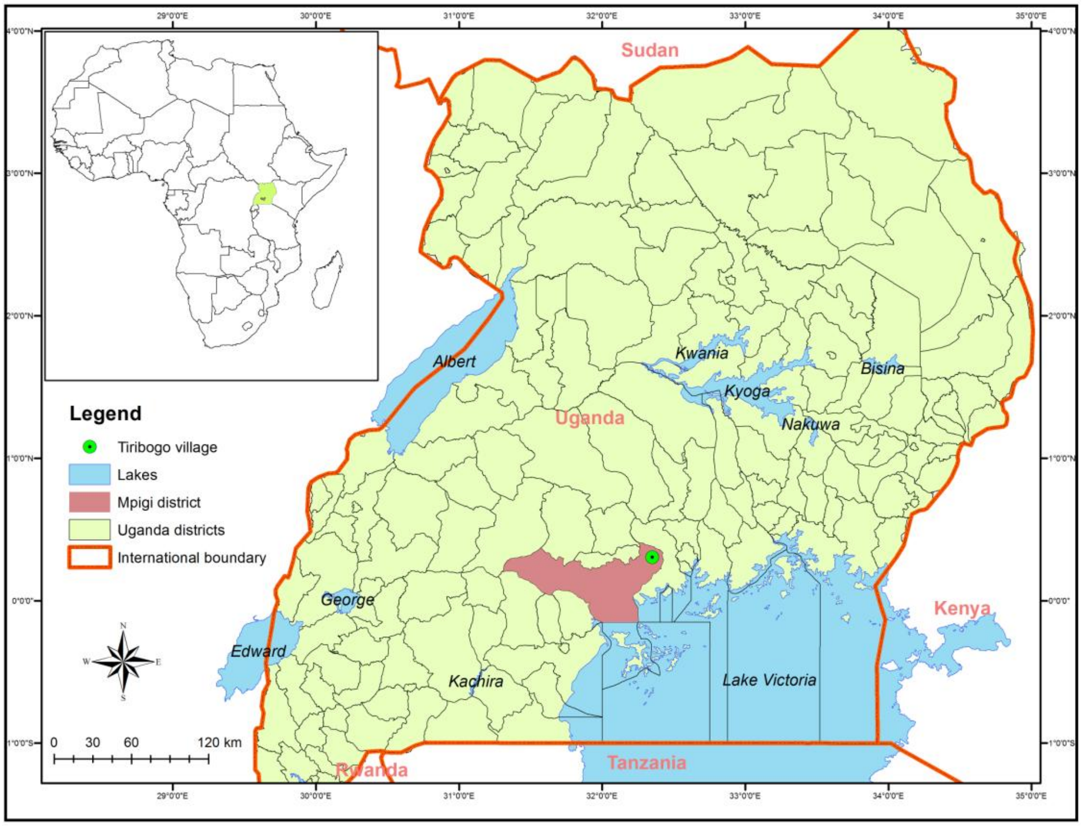

Figure 1. Map showing the study area

The main economic activity in Tiribogo is subsistence farming, with farmers rearing animals and growing both food and cash crops. The main food crops grown include banana, sweet potatoes, maize, beans and horticultural crops (cabbages, nakati, amaranthus) while coffee is the main cash crop in the area. The animals reared include pigs, goats and cattle, and these were reared on small scale with most households keeping at least one of these animals. Tiribogo village has no grid connection and the main source of energy used for lighting is kerosene. Most of the household use fuelwood as their main source of energy for cooking, although some of the households use charcoal for cooking. Fuel wood and charcoal are the main source of energy for cooking because the village is bordered by the forest where trees are cut and used for fuel wood and charcoal. Institutions like schools consume a lot of fuel for preparing students meals. The area was purposely selected because it is where the flexible balloon digesters were being promoted under DFID funded NET-RC grant. The project provided nine digesters to nine households in Tiribogo village and the rest of the community members were to observe the benefits that accrue to households with digesters so that they could adopt this technology. The overall objective of the project was to determine an alternative cheaper design that would motivate and increase the dissemination of biogas technology so as to provide a long term supply of energy to the community as well as ensure effective treatment of waste.

3.2 Sampling and field data collection

The data used in this study have come from the survey of Tiribogo community in central Uganda where the flexible balloon digesters was being experimented. This area was identified with the highest concentration of households with livestock that was to provide feedstock for the biogas digesters. The initial ground work began with identifying the nine households that would be given the nine flexible balloon digesters. To identify pilot households, all the 54 households in the community that produce animal manure were visited and interviewed for about 30-minutes each using a structured questionnaire, consisting of a list of closed questions on how the household manages its resources, such as farm, manure, water, fuel wood and kitchen residues. The data collected was used to generate fact sheets and to rank the suitability of households for installation of a flexible balloon biogas digester. A weighted multi criteria approach consisting of four factors – availability of feedstock, access to water, household's current fuelwood consumption and household labour availability – were used to identify pilot households. Once the pilot households identified, farm household data were collected in two different timelines: (i) Baseline survey (before digester installation): a baseline survey was conducted in July 2013 to determine the situation before the digesters were installed with the nine households selected. The sampling frame for the baseline survey included the nine experimental households and 144 randomly selected other households that were within a close proximity of each of the nine households i.e., 16 randomly selected households to each pilot household based on community's local council register. A face-to-face structured questionnaire interview was administered by the first author (as part his graduate study research) and supervised by his advisors. (ii) The second round follow-up survey was conducted six months after the installation of biogas digesters. This was to give time for the pilot households to undergo changes in biomass and energy consumption as a result of using biogas. The follow-up survey on the nine pilot households was focused on the use of biogas energy, feedstock supply, changes in the household's labour demand and other resources. All the 144 'non-biogas' households included in the baseline were also interviewed in the follow-up survey to understand neighborhood effects and the likelihood of technology adoption.

A payment card method was used to elicit the WTP of respondents. There are several studies where the payment card has been used to estimate willingness to pay such as [20, 21, 22]. The studies show that the payment card method increases efficiency over dichotomous choice in estimating WTP.

3.3 Analytical methods

The logistic model was used to estimate for the factors that influence willingness to pay for the digester. It applies the maximum likelihood estimation after transforming the dependent variable into a logit variable [13]. Logistic regression measures the relationship between the categorical dependent variable and one or more independent variables by estimating probabilities using a logistic function. It calculates the probability of an event occurring with the probability of it not occurring.

For our case study, let P_i be the probability that an individual is willing to pay (WTP) for the flexible balloon digester, X be a vector of explanatory variables and y is a binary variable taking the value of 0 or 1. The likelihood of willingness of an individual to pay for a digester is specified as:

$$P_i = f(X, \varepsilon) \qquad (1)$$

where ε is an error term with logistic distribution.

The conceptual logistic model is given as:

$$\ln\left[\frac{P_i}{1-P_i}\right] = \beta_0 + \sum_{j=1}^{n} \beta_j X_{ji} + \varepsilon \qquad (2)$$

where $'P_i = prob(y=1)'$ is the conditional probability for WTP; $'(1-P_i) = prob(y=0)'$ is the conditional probability for not WTP; β_0 and β_j are the coefficients that are to be estimated.

The estimated coefficients β_0 and β_j are measures of the changes in the ratio of the probabilities, termed as the odds ratio. The logistic prediction equation for this study was:

$$y = \ln(odds(event)) = \ln(\frac{prob(event)}{prob(nonevent)}) = \ln(\frac{prob(event)}{(1-prob(event))}) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

The empirical model specifying WTP is stated in equation 4 where the Xs (explanatory variables) are described in Table 1.

$$\ln\left[\frac{P_i}{1-P_i}\right] = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + \beta_n X_n + \varepsilon \ldots\ldots\ldots (4)$$

Table 1: Explanatory variables and their expected influence on WPT

Variable	Description	Measurement	Expected sign
X1	Perception that digester improves sanitation (1= completely agree, 0= otherwise)	Categorical	+
X2	Age of household head (years)	Continuous	-/+
X3	Sex of household head(1=Male, 0=Female)	Binary	-/+
X4	Maintenance costs of the digester in Uganda shillings	Continuous	-
X5	Household size	Continuous	-/+
X6	Total land owned (acres)	Continuous	+
X7	Number of livestock owned by household	Continuous	+
X8	Household monthly expenditure on fuel wood for cooking in Uganda shillings	Continuous	+

4 Results and Analysis

4.1 Descriptive Analysis

The findings reveal that 85% of the households were willing to pay for the flexible balloon digester. The high response to willingness to pay is due to the benefits being realised by the neighbouring households using biogas from the digester. Such benefits included reduced smoke in the kitchen, improved hygiene on the cooking utensils and convenience of using biogas at any time of the day or night [1]. The finding is consistent to the findings of [1,11,23,24] who reported high WTP scores. Of those willing to pay, they further reported that they were willing to pay UGX[1] 45,200 and 54,100 for maintaining the digester and contributing to its installation respectively if it was given at free cost. In addition, the households reported that they were willing to pay a maximum of UGX 135,000 (ca. US$52) (with a minimum estimated WTP amount of UGX 100, 000) to purchase a new flexible balloon digester. Considering the actual investment cost UGX 1,332,630 (ca.US$512) needed to install a flexible balloon digester, it portrays that the amount households were willing to pay for a new digester is 10 times less than the actual cost of the digester. This can be attributed to the low income earned by the households. It was found that households were not prepared to pay for the digester beyond the upper threshold (Table 2). This is consistent with the findings by Riccardo et al. [15] and Mugisha et al. [18] whose willingness to pay estimates was not sufficiently large to cover the higher capital costs of micro-generation energy technologies and biogas digester respectively.

Table 2. Willingness to pay values for the flexible balloon digester

Amount (UGX)	**Households (n=120)**		
	Definitely prepared to pay (%)	**Uncertain (%)**	**Definitely not prepared to pay (%)**
< 100,000	95	0	5
100,000	92	0	8
125,000	71	15	14
150,000	45	35	20
175,000	35	40	25
200,000	27	45	28
225,000	19	51	30
250,000	17	52	31
275,000	14	53	33
300,000	13	54	33
350,000	10	55	35
500,000	0	0	100
more than 500,000	0	0	100

Among the households, 15% were not willing to pay for the flexible balloon digester and the major reasons they provided are indicated in Table 3. The majority of the households (73%) who responded not willing to pay for the digester, because they could not afford it. A number of factors were indicated by other households such as the technology is complicated; the routine activities of the digester being

[1] UGX=Ugandan Shillings, the legal currency in Uganda, with exchange rate with the USD: 1 USD= 2600 UGX at the time of the survey.

demanding; absence of cows for the substrate; and lack not interest in having the digester and shifting from fuelwood to biogas.

Malla et al. [4] noted that the low level of biogas technology adoption in SSA was attributed partly to the low number of animals available for manure production. In addition, Malla et al. observed that the maturity of the programme promoting the flexible digesters could be another factor for the low adoption. For instance, the flexible balloon digester programme in Nepal was introduced in 1992, while in Africa, the first programme was introduced in Rwanda in 2007. This could partly explain why about 9% of the households in this study responded that they were not interested in the technology at all.

Table 3. Reported reasons for not willing to pay for the flexible balloon digester

Reasons for not paying for the digester	**Percent of households (Multiple response),**
Cannot afford initial investment cost	73
Technology is complicated	18
Routine activities are demanding	9
Have no cows	9
Not interested in having one	9

Malla et al. [4] further noted that limited water availability poses a constraint to biogas operation because biogas units typically require water and manure to be mixed in an equal ratio. The mixing of water and manure is a routine activity which demands significant household labour time which further limits household willingness to pay and adopt the technology.

This study finding is consistent to the finding by Anushiya [25] who reported that households' failure to afford initial investment, lack of interest in the installing the digester, and having no livestock were some of the reasons why farmers were not likely to install biogas plants in Nepal. Other studies also identified that the high initial investment cost the major factor for biogas digester adoption and WTP to the technology [10, 26 -28].

4.2 Factors Influencing Willingness to Pay for a Flexible Balloon Digester in Uganda

The logit regression results on factors influencing willingness to pay for a flexible balloon digester are presented in Table 4. The log likelihood ratio test statistic is significant at 1%, meaning that at least one of the variables in the model has coefficient that is significantly different from zero. The goodness of fit of the logit model is quite good, with a pseudo R^2 value of 0.1955. Breffle et al. [29] reported that a pseudo R^2 value of 0.12 is typical for cross sectional data. Therefore, it can be concluded that the logit model used has integrity and is appropriate. Of the nine variables used in the model, five variables were statistically significant (two variables at 1%, two at 5% and one at 10% levels). These include age of household head, household size, the digester improves sanitation or not, total land owned, and the cost of fuelwood. The number of livestock owned, gender of household head, maintenance cost and the frequency of buying kerosene were statistically not-significant. In addition, all the factors had their *a priori* expected signs correctly.

The positive sign on total land owned that is statistically significant ($p \leq .05$) indicated that households with a large land are more likely to pay for the flexible balloon digester. Land available to the farmer is very important in influencing a decision pertaining biogas technology. This is because with a biogas technolocgy, enough land is needed to provide space for keeping livestock and growing the pastures for livestock needed to provide the feedstock for biogas production [2]. The significant result in this study pertaining the total land owned reflects the study area status because land is the main factor of production, and over 85 % of the households rely on agriculture as their main source of earning. Ruto et al. [7] also reported that the farm size significantly had influence on farmers' preference for design of Agri-environment schemes in European Union.

The coefficient of age was found to have a significant ($p \leq 0.01$) and negative relationship with the likelihood to pay for the digester. The probability of younger household heads willing to pay for the flexible balloon digesters was higher than that of their older counterparts. This is because younger household heads can be assumed to be ambitious and willing to test new technologies. So they will have courage to pay for the capital cost and maintenance activities. Sabah and Jeanty [11] also reported that the age of the household head was negatively related to willingness to pay for renewable energy technologies. IFPRI [30] noted that the impact of farmers' age can be a combination of farming experience and a planning horizon. Although farming experience may have a positive effect, younger farmers may have a long planning horizon and, hence, may be more likely to invest in new technologies.

Table 4: Logistic regression estimates of willingness to pay for a flexible balloon digester in Uganda

Variables	**Coefficient**	**Standard error**
Constant	-1.7351*	1.0238
X1=Perception: digester improves sanitation	1.4732**	0.6664
X2=Age of household head (in years)	-0.0409***	0.0156
X3=Sex of household head (1= Male, 0= Female)	0.4458	0.4951
X4=Maintenance costs of a flexible balloon digester	-2.0300	4.5700
X5=Size of the household (head count)	0.1895**	0.0922
X6=Total land owned (acres)	0.1363**	0.0632
X7=Number of livestock owned by household	0.0826	0.0793
X8=Household monthly expenditure on fuel wood	0.00003***	0.00001

Significant level: * = 10%, ** = 5%, *** = 1%

The results (Table 4) revealed a positive relationship between household size and willingness to pay implying that households with a large household size are more likely to pay for type of digester. This is due to a large household size are more likely to have sufficient labour that can be deployed to carry out all the activities needed to produce biogas. Most households in Uganda prefer using family labour as compared to hired labour because of financial constraints. Mugisha et al. [18] noted that household size is considered an endowment in terms of family labour and is expected to positively affect the probability of adoption, given the labour intensive nature of agricultural technologies. Noor et al. [31], in their study on willingness to pay for health care in Malaysia, found that household size was statistically significant to willingness to pay for the healthcare services. The authors attributed this to a large household size that provided labour to carryout health related activities.

The perception that the flexible balloon digester improves sanitation in the household was positively correlated with willingness to pay and was statistically significant ($p \leq 0.05$) (Table 4). This is attributed to the reduced accumulation of waste either from livestock dung or kitchen refuses as a result of a digester. This improves the general hygiene and sanitation because the waste can be disposed of as manure [12].

The presence of good sanitation reduces flies which spreads pathogens that cause diseases. In addition, biogas produces smokeless flames that keep cooking utensils such as saucepan clean as well as keeping the kitchen environment clean. The smokeless biogas leads to improved environment in the kitchen which enhances indoor air quality. This is because with the acquisition of an improved clean renewable energy, indoor air pollution reduces [4], thus resulting into improved household welfare. The results of this study are consistent with the empirical findings by Noor et al. [31], who found out that the perceptions about healthcare services improving sanitation and hygiene were statistically and significantly influencing willingness to pay for the healthcare services in Malaysia. This is because households were facing health challenges especially disease outbreaks and acquiring healthcare services would reduce disease outbreaks. Previous research on uptake of biogas technology by Walekhwa et al. [2] revealed that perceptions play an important role in influencing the uptake as well as the willingness to pay. This was attributed to the importance attached by households to the effect of the technology on their health and environment. This is important because of the benefits they were expecting from paying for such technology. Other benefits of the biogas technology reported include provision of slurry as a fertilizer, use of the gas for cooking, lighting as well as improving on the general environment [32].

The cost of fuelwood was found to positively and significantly ($p \leq 0.01$) influence the willingness to pay for a flexible balloon digester. This suggests that a one UGX increase in cost of fuelwood, increase the likelihood of paying for the digester by 68%. As the price for fuelwood increases, household tend to substitute fuelwood for alternative source of energy such as biogas. Similarly, the scarcity and increase in the fuelwood costs increased the probability of households switching to a clean, renewable biogas energy. This is in agreement with the findings by Walekhwa et al. [2], who found out that the cost of fuelwood was statistically significant in influencing the adoption of biogas technology in Uganda. This was attributed to the increasing prices of fuelwood and other alternatives energy sources for cooking.

5 Conclusions and Recommendations

The study findings reveal that majority of the households (85%) were willing to pay for the flexible balloon digester but the amount they were prepared to pay was not sufficient to cover the initial investment cost of a digester. The study further suggests that the socio-economic and demographic factors significantly influence WTP for a flexible balloon digester in Uganda. The household's likelihood of paying for the digester increases with the household size, total land owned, and the increasing costs of fuel wood. In contrast, the likelihood of paying for a flexible balloon digester decreases with the increasing number of years of the household head. Therefore efforts aimed at promoting this digester design should focus on the above social and economic characteristics. Particularly, concerted efforts should be made on ensuring the availability of affordable flexible balloon digester from local sources. Because the principal reason for the high cost of flexible digester and unaffordability to smallholders was linked to the cost of import duties and other related trasancation costs along the supply chain. Efforts to lower the cost of digester means enhancing technology access to poor members of the society.

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