African Journal of Rural Development, Vol. 7 (1): January-April 2022: pp. 89-110. ISSN 2415-2838

Fuel from the Farm: An analysis of the profitability and factors driving farmers' decisions to produce bioethanol from cassava in Northern Uganda

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ABSTRACT

This study examined profitability of producing bioethanol and factors that drive farmers' decisions to produce bioethanol from cassava. Although small scale production of bioethanol was found to be profitable, selling cassava dry chips was found to be more profitable. In addition, selling fresh cassava roots was also more profitable than small scale production of bioethanol. However, bioethanol producers who grow cassava and process bioethanol get more returns on investment compared to those who buy cassava chips and process bioethanol. Sensitivity analysis results revealed that 40% decrease or increase in price of dry chips and firewood contributed remarkable change on profitability of bioethanol. The results also reveal that growing improved cassava variety, ownership of land of 2 acres (≈1 ha), allocating more proportion of land to cassava, engagement in off-farm work and profitability of bioethanol, positively influenced farmers' decisions to produce bioethanol while sex of household head, Pentecostal Christian, profitability of dry chips and condition of the road negatively influenced farmers' decisions to produce bioethanol. The paper concludes that promoting bioethanol production from cassava will require meeting the food security demands by increasing cassava production through expansion of acreage and promoting planting of improved high yielding varieties. This should be coupled with reduction of costs of processing bioethanol and expansion of market opportunities through extra value addition

Key words: Cassava bioethanol, drivers of production, profitability analysis, sensitivity analysis, Uganda

RÉSUMÉ

Cette étude examine la rentabilité de la production de bioéthanol et les facteurs qui influencent les décisions des agriculteurs de produire du bioéthanol à partir du manioc. Bien que la production de bioéthanol à petite échelle se soit avérée rentable, la vente de copeaux de manioc secs s'est révélée plus rentable. De plus, la vente de racines de manioc fraîches était également plus rentable que la production de bioéthanol à petite échelle. Cependant, les producteurs de bioéthanol qui cultivent le manioc et le transforment en bioéthanol obtiennent un meilleur retour sur investissement que ceux qui achètent des copeaux de manioc et les transforment en bioéthanol. Les résultats de l'analyse de sensibilité ont révélé qu'une diminution ou une augmentation de 40 % du prix des copeaux secs et du bois de chauffage entraînait un changement remarquable de la rentabilité du bioéthanol.

Cite as: Opolot, D., Ilukor, J., Mukasa, S. and Mugisha, J. 2022. Fuel from the Farm: An analysis of the profitability and factors driving farmers' decisions to produce bioethanol from cassava in Northern Uganda. *African Journal of Rural Development* 7 (1): 89-110.

Received: 11 November 2021
Accepted: 31 January 2022
Published: 30 April 2022

Les résultats révèlent également que la culture d'une variété de manioc améliorée, la possession d'un terrain de plus de 2 acres (environ 1 hectare), l'allocation d'une plus grande proportion de terre au manioc, l'engagement dans un travail hors exploitation agricole et la rentabilité du bioéthanol influencent positivement les décisions des agriculteurs de produire du bioéthanol, tandis que le sexe du chef de ménage, l'appartenance à l'église pentecôtiste, la rentabilité des copeaux secs et l'état de la route influencent négativement les décisions des agriculteurs de produire du bioéthanol. Le document conclut que la promotion de la production de bioéthanol à partir du manioc nécessitera de répondre aux exigences de sécurité alimentaire en augmentant la production de manioc par l'expansion des surfaces cultivées et la promotion de la plantation de variétés améliorées à haut rendement. Cela devrait s'accompagner d'une réduction des coûts de transformation du bioéthanol et d'une expansion des opportunités de marché grâce à une valeur ajoutée supplémentaire.

Mots-clés : Manioc bioéthanol, facteurs de production, analyse de rentabilité, analyse de sensibilité, Ouganda

INTRODUCTION

As the current global population continues to grow especially in developing countries like Uganda where the population growth rate (3.3%) is higher than the growth in agricultural sector (1.5%) (World Bank, 2016), the demand for food and fuel to enable people live a healthy and an improved life style continues to grow. Food demand is expected to increase anywhere between 59% to 98% by 2050 (Valin *et al.,* 2014). Similarly, fuel demand is expected to increase by 28% by 2040 (IEA, 2017). These increases in food and energy demand means extracting more fuel from the farms. However, food security activists contend that this is expected to worsen the food insecurity situation. Jean Ziegler, the United Nations (UN) special rapporteur on the Right to Food from 2000-2008 argued that, burning hundreds of millions of tonnes of staple foods to produce biofuels is a crime against humanity (Mathews, 2012). Similar sentiments have been echoed by Monbiot (2007) who castigated Swaziland's Government for deciding to export biofuel made from cassava when 40% of its population was facing acute food shortages. The argument is that extracting fuel from the farm will drive prices for food high thus leading to reduced food availability and increased land prices which results into increased hunger, land grabbing, environmental damage and loss of life (Mitchell, 2008; Schmitz and Moleva, 2013). Monbiot (2007) argued that even when the price of food was low, 850 million people went hungry because they could not afford to buy it and if promoting biofuels is not reversed, humanitarian impact will be greater than the Iraq war. Ziegler *et al*. (2011) contends that, every five seconds, a child under the age of 10 dies directly or indirectly because of hunger somewhere in the world.

The advocates of biofuel production on the other side argue that rapid food price increases, hunger and malnutrition have been widespread even before the boom on biofuel occurred (Tenenbaum, 2008). They argue that biofuels can play a very significant role in revitalizing agricultural land use and livelihoods in rural areas. Increased prices could benefit smallholders farmers and could drive farmers to adopt improved technologies thus leading to significant increase in both yields and incomes which is key to poverty reduction (Cotula *et al.,* 2008). Mathews (2012) argued that farmers in developing countries lack income to purchase inputs on the open market, therefore governments need to promote biofuels to generate income, employment, and export earning to boost input use and agricultural productivity. Production and processing of bioethanol also helps in reducing post-harvest losses in crops like cassava. FAO (2011) report notes that 40% of post-harvest losses in cassava and other root crops are reported in sub–Saharan Africa, 35% in Latin America and 31% in South and South-East Asia. Moreover, there is no guarantee that food production will increase if bioethanol production is avoided (Ejigu, 2008). Yet, bioethanol production has a potential to increase agricultural production which in turn will lead to increased food and fuel supplies by increasing input use (Kueneman *et al.,* 2012; Kristensen *et al.,* 2014; Thatoi *et al.,* 2016).

In Uganda, the demand for bio-fuel is expected to grow from 187 million litres in 2012 to 220 million litres by 2022 (NARO and NEMA, 2010). While sorghum, maize, millet and sugarcane molasses feedstocks are used for bioethanol production in Uganda, cassava is also commonly used and preferred feedstock to produce bioethanol. This is attributed to: firstly, the high productivity, high starch content and the availability of cassava (Adiotomre, 2015). Secondly, unlike other crops, cassava can be harvested all year round and can tolerate harsh natural conditions, especially drought (Jakrawatana *et al.,* 2015). Moreover, it can be planted on marginal lands where other crops do not grow well (Zhang *et al.,* 2003). Lastly, the processing of cassava into bioethanol is more efficient compared to crops like sugarcane, maize, wheat, and sweet potato (Liu *et al.,* 2013). For instance, cassava has a conversion rate of about 180 litres per tonne of cassava roots compared to 70 and 80 litres per tonne of sugarcane and sorghum, respectively (Balat and Balat, 2009; Ohimain, 2015)

Although production of bioethanol from cassava is the preferred option for producing biofuel and presents significant opportunities for improving rural livelihoods, current cassava bioethanol production in Uganda is low. Only about 11% of the bioethanol in Uganda is produced from cassava (Mutyaba *et al.,* 2016) and over 90% of bioethanol produced by smallholder farmers is mostly for local consumption and about 10% for industrial uses (Mutyaba *et al.,* 2016). This study examined the reasons for the low level of production of bioethanol from cassava. Specifically, the study examines whether or not, the smallholder farmers are making profits from the current cassava bioethanol production. The analysis of profitability is important because it influences investment decisions (Nguyen and Nguyen, 2020). Such investment decisions include decisions to process cassava into bioethanol or not. The study also examined the profitability of processing cassava into dry chips and selling cassava in form of fresh tubers. The study involved sensitivity analysis to incorporate uncertainty into economic evaluation so as to determine the best possible scenario of maximizing benefit from bioethanol production. In addition, the study also examined the factors that influence farmers' decisions to produce bioethanol.

Cassava production in Uganda. In Uganda, Cassava is the second most important staple crop after bananas (UBOS, 2010). The crop is reportedly more profitable than maize with a profit of about 30-60 Uganda shillings per kilogram of dry chips compared to 10-20 Uganda shillings per kilogram of dried maize grain at farm gate price (USAID, 2010). Mutyaba *et al.* (2016) indicated that production and processing of cassava has a potential of saving the country an estimated 300 million United States Dollars used for importing other products such as wheat that could otherwise be substituted by processed cassava products into products such as high quality cassava flour (HQCF). However, data from the Food and Agriculture Organization of the United Nations (FAOSTAT, 2017) revealed that production volumes of cassava between 2004 and 2016 in Uganda generally declined as shown in Figure 1.

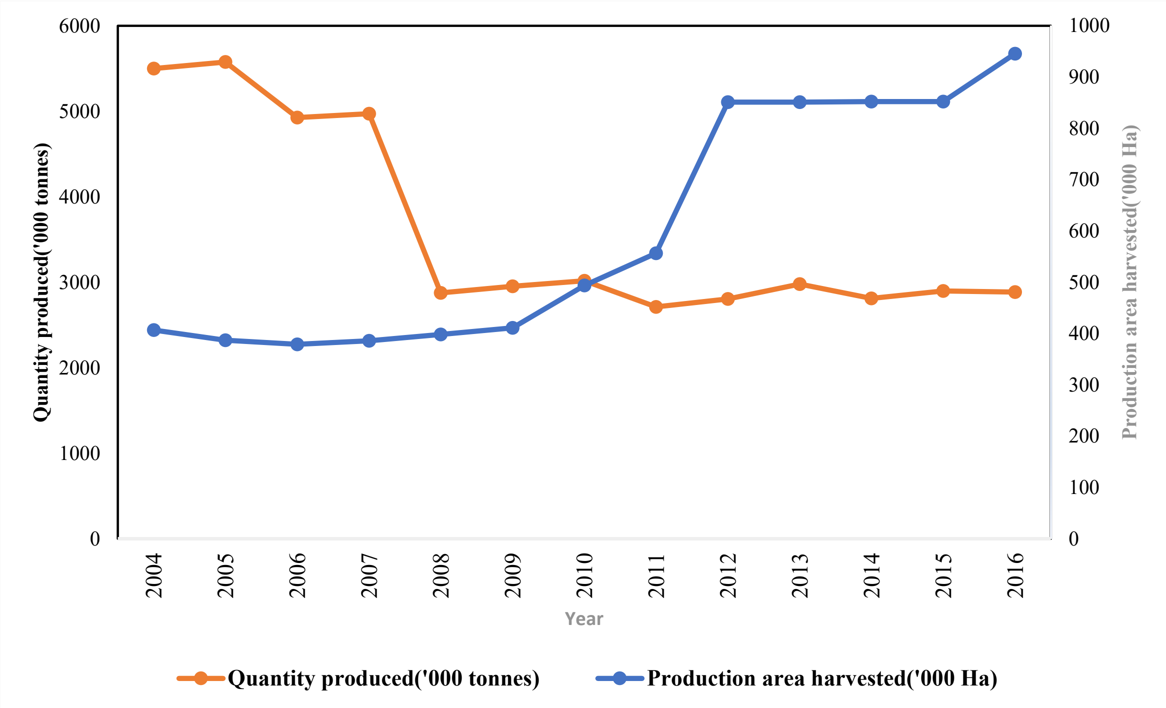

Figure 1. Area under cassava and volumes produced between 2005 and 2016 in Uganda
Source: (FAOSTAT, 2017) Retrieved 8th August 2017

The decline in volumes produced is attributed to re-occurrence and spread of Cassava Brown Streak Disease (CBSD) into new areas, a devastating cassava viral disease (Alicai *et al.,* 2007). Despite the decline, the area under cultivation increased steadily during the period probably indicating importance of cassava in farmer households. In 2009, the Government of Uganda with the financial support from the World Bank established the Cassava Regional Centre of excellence under the East African Agricultural Productivity Programme (EAAPP). One of the mandates of the centre was to generate cassava technologies that address the challenges of cassava productivity such as development of high yielding cassava varieties that are resistant to cassava pests and diseases. Additionally, the centre was expected to spearhead commercialization of cassava and its by-products. Thus, early maturing, high yielding and CBSD tolerant varieties such as NAROCass 1, NASE 19 and NASE 14, among others, were released to boost production and commercialization of cassava (Mukasa, 2015).

However, with expected increase in production, the other challenges such as perishability of cassava roots due to rapid post-harvest physiological deterioration presents serious impediment to the production and commercialization of cassava especially during periods of glut supply (Naziri *et al.,* 2014). For instance, in the season or year when there is glut supply, farmers are forced to sell their cassava at very low prices to avoid spoilage hence most farmers plant less the season that follows. This sometimes leads to insufficient supplies in next season while in certain periods of the planting season, farmers are offered prices that are more attractive which encourages them to plant more than they can store in the next season (Abass *et al.,* 2012). Other options such as storage of roots in the garden and only harvesting when needed are not sustainable. This is compounded by the fact that some of the newly released varieties do not store for more than one and half years before they rot while in the field. Moreover, selling as fresh tubers is also hindered by long distance to the markets, lack of access to market information and poor roads.

On the other hand, while interventions such as processing of cassava into dry chips is particularly important in addressing the challenge of perishability, quality is compromised by the nature of peeling and drying done on roadsides and bare floors drastically reducing the value of the chips. Adebayo *et al*. (2012) asserts that this vicious cycle causes major distortions in the farmers' production system and leads to disincentives as well as lack of confidence in cassava as a cash crop. Therefore, processing cassava into bioethanol could play an important role in addressing some of the challenges.

Cassava bioethanol production in Uganda. The annual demand for bioethanol in Uganda is estimated to be 16 million litres and it is expected to grow at an annual rate of 10-15% (Kleih *et al*., 2012). However, 90% of the bioethanol in Uganda is imported (Kleih *et al*., 2012) and only 10% is produced within Uganda. Of the 10% produced within the country, 90% is produced by smallholder farmers and it is mostly for local consumption with only 10% being for industrial use (Mutyaba *et al*., 2016). Production of bioethanol from cassava is done by the resource-poor smallholder farmers who cultivate less than 2 hectares of land (1 ha) using rudimentary tools (Mutyaba *et al*., 2016; Nakabonge *et al*., 2017). These resource-poor farmers also account for 85% of total cassava production in the country and only about 2 % of the production is processed in to bioethanol (Nuwamanya *et al*., 2012).

The main industrial users of bioethanol in Uganda include research laboratories, schools, pharmaceutical and cosmetic industries. Research laboratories use bioethanol as preservative of biological specimens, cleaning agent, a reagent for laboratory analysis and sanitary purposes in hospitals and schools (Graffham and Kalunda, 2000). Brewing companies especially Uganda Breweries use bioethanol to make alcoholic beverages such as Uganda Waragi, industries use bioethanol to make cosmetics while pharmaceutical industries use it in the preparation of essences and flavourings in pharmaceutical products (Graffham and Kalunda, 2000).

The production of bioethanol by smallholder cassava farmers is characterized by use of rudimentary tools and equipment and firewood as the source of energy and all these compromise its quality (Nuwamanya *et al*., 2012; Ohimain, 2015). A summary of the production process of bioethanol as shown in Figure 2 indicates that the cycle takes a minimum of two weeks for the distillation process to occur. Moreover, the equipment used is unable to produce anhydrous ethanol, but can distil ethanol to 50–70%. Large scale cassava ethanol extraction factory has been built in Lira district in Northern Uganda for industrial extraction of bioethanol from cassava and has led to increased cassava production northern Uganda because farmers have assured market (Oketch, 2016).

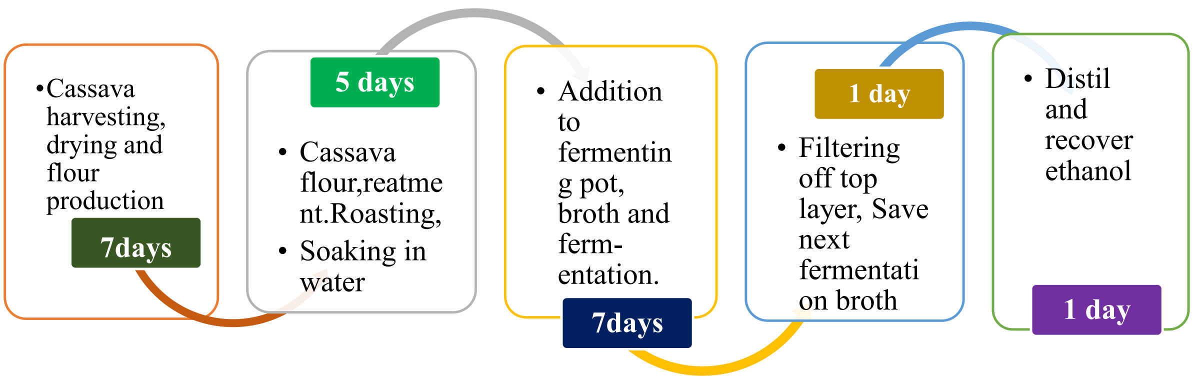

Figure 2. Production process for bioethanol production by smallholder cassava farmers in Northern Uganda
Adapted from: (Nuwamanya, 2017 Unpublished)

METHODOLOGY

Study area and data collection. The data used in this study were collected in June 2016 in Apac, Kole and Lira districts in Northern Uganda. The districts were selected because cassava is a staple in the three districts and is eaten and processed in different forms such as fresh tubers, dry chips and bioethanol. Production of bioethanol in the three districts is done by individual farmers using rudimentary processing technology from cassava chips bought from the market or from cassava grown in their own farms. Specifically, Apac and Kole district were the leading cassava producing district in the country allocating 42,836 ha and producing 239,932 Mt of Cassava (UBOS, 2010). On the other hand, Lira district is the end market for most of the cassava products such as fresh tubers and dry chips. Lira district also hosts the only bioethanol processing factory called Kamtech Technologies located in Northern Uganda (Oketch, 2016).

A multistage sampling technique was employed to get a representative sample of farmers from the study area. In the first stage, one sub county was purposively selected from each of the three districts based on numbers of active farmers involved in cassava production. Through the local and farmer group leaders, farmers who either grew cassava or did not grow cassava but were involved in processing and marketing of cassava products and belonged to each of the selected sub counties were purposively selected. A total of 515 farmers; 165 farmers from Chegere in Apac, 265 from Bala in Kole and 85 farmers from Adekokwok in Lira district were selected. In the third stage, from the list of 515 farmers selected in the second stage, proportionate sampling was used whereby the number of respondents were randomly selected based on the number of farmers purposively selected in each sub county during second stage. Specifically, 76 farmers from Chegere in Apac district, 132 farmers from Bala in Kole and 42 farmers from Adekokwok in Lira were selected for the interview. Overall, 250 respondents were selected for the study. The results are presented for 243 farmer beneficiaries from data cleaning exercise undertaken. To eliminate bias, farmers who were selected but could not be accessed at the time of interview were replaced by other farmers within the sampling frame. The quantitative data collected included; all household activities (farm and non-farm), enterprise types, crop area and production levels, input and expenditures for the first and second season. Socio-economic and institutional data such as household characteristics, land size and farm characteristics and investment in assets were also captured. Other questions in the questionnaire tool administered were related to the supply of on-farm family and hired labour and educational status and religion, costs and revenues incurred in production, processing and marketing of cassava products including fresh tubers, bioethanol and dry chips.

Empirical methods. To examine whether smallholder farmers were making profit from the cassava bioethanol production compared to selling cassava dry chips, gross margins analysis approach was employed. Although other methods such as cost benefit analysis, and enterprise budgeting can be used to assess profitability, the gross margins approached was used because it is reasonably straight forward, easy to understand and allows for easier comparison (Rushton, 2009). Additionally, the focus of the study was mainly on financial outputs without fixed costs. Rushton (2009) argues that gross margins are computed as the difference between total revenue (TR) and Total Variable Costs (TVC) which is expressed mathematically in the equation below:

$$GM_i = TR - TVC \quad 1$$

Where GM= Gross margin

$$TR = \sum_{j=1}^{n} P_j Q_j \; ; for\ j = 1,2,3 \ldots n$$

$$TVC = \sum_{i=1}^{n} P_i X_i \; ; for\ i = 1,2,3 \ldots n$$

Where GM= Gross margin of ith cassava product category in Uganda shillings normalized at hectare level

P_j=Unit price of one litre or kilogram of output sold of cassava product by jth farmer

Q_j= Total output sold of cassava product by the jth normalized at hectare level.

P_i= Unit cost/price of a given input used by ith farmer to produce cassava product (Ushs/ha)
X_i = Quantity of input used in production of bioethanol (UShs/ha)

Normalization per hectare level was based on Katungi *et al*. (2011) and Tebeka *et al*. (2017). Total variable costs computed included all costs incurred in production of cassava such as costs of land clearing and land preparation, cost of purchase of inputs such as planting materials, planting costs, weeding, harvesting and transportation costs for both hired and family labour. For the category of farmers who bought chips for bioethanol production, the variable costs included cost of purchasing chips per kilogram which were computed and then normalized at hectare level. Transport costs to milling and processing facility were also computed. In addition, processing costs such as, peeling, drying and packaging costs, milling, fermentation, roasting and distillation costs were calculated for both farmers who bought chips and farmers who grew cassava for bioethanol production. Other costs computed included costs of yeast and cost of firewood used for distillation process, packaging, transportation and market dues for bioethanol. Revenues were then generated by multiplying the average price of one litre of bioethanol at market price at the time of data collection and the number of litres of bioethanol produced using quantity of chips purchased and normalized at hectare level.

Sensitivity analysis of the costs of cassava bioethanol production was conducted. From the reconnaissance visit to the farmers, the three most essential factors affecting bioethanol production were price of cassava chips, cost of roasting and cost of firewood. The influence of price of cassava chips, costs of roasting and costing of firewood on the gross profits were determined by creating four scenarios which included varying the costs by plus or minus 40% from the base figure taken as 0% which was the profit computed for each category from bioethanol category following Hanif *et al*. (2016). The values obtained were presented in an excel tornado plot.

To determine the factors influencing farmer decision to produce bioethanol, discrete choice model was considered as appropriate because of the discrete nature of cassava farmers' decisions. Therefore, qualitative choice models including linear probability, logit and probit models were considered the most suitable (Scott and Freese, 2006). Using binary models, the probability of a cassava farmer processing cassava into bioethanol is expressed as a function of the underlying predictor variables represented by a vector x. The outcomes of the models can be given a latent variable interpretation to provide a link with the linear regression model. Since the observed binary outcome is that a cassava farmer processed cassava into bioethanol, the underlying continuous unobservable or latent variable can be expressed using the following single index model:

$$y^* = x'\beta + \mu \quad (1)$$

Although y^* is not observed, we can observe that

$$y = \begin{cases} 1, & y^* > 0 \\ 0, & y^* \leq 0 \end{cases} \quad (2)$$

Therefore,

$$Pr(y = 1/x) = Pr(x'\beta + \mu > 0) = F(x'\beta) \quad (3)$$

The linear probability model suffers from three important shortcomings: the error term μ is heteroscedastic and may possess elements of non-normality; and the predicted value of the dependent variable may not fall within the unit interval (Wooldridge, 2002). Whereas generalized least square models may solve the problem of heteroscedasticity, the problem of estimating parameters of a threshold decision model remains unresolved when truncating values of the dependent variable through logit analysis (Press and Wilson, 1978; Jones *et al*., 1989; Scott and Freese, 2006). The probit model overcomes these problems of the other models because of its ability to generate bounded probability estimates for each observation (Tambi, 1999). For this reason, we estimated a probit model in this study.

However, to produce bioethanol from cassava, farmers must first process cassava into dry chips. Depending on the utility generated from producing dry chips, farmers can choose to process cassava into dry chips and sell them if the dry chips maximize their utility (net returns). Similarly, if bioethanol production is more utility maximizing than selling dry chips, farmers are likely to produce bioethanol than selling dry chips. Therefore, the decision to produce bioethanol and sell cassava dry chips are linked thus creating a problem of endogeneity. As a result, a bivariate probit model was estimated because it solves the endogeneity problem by accounting for the correlation while testing for existence of correlation (Greene, 2003). The joint probability function for a farmer j of choosing to produce bioethanol given dry chips the same time $(Y_{1j} = Y_{2j} = 1)$ would be; at

$$\gamma_{sj} = p(Y_{1j} = 1 Y_{2j} = 1) = \int_{-\infty}^{\varepsilon_{1j}} \int_{-\infty}^{\varepsilon_{2j}}$$

$$\emptyset_2 (X_{1j}\beta_1, X_{2j}\beta_2, \rho) d\varepsilon_{1j} d\varepsilon_{2j}$$

$$= \emptyset_2(X_{1j}\beta_1 X_{2j}\beta_2) \qquad 5$$

The log-likelihood is then a sum across the four possible contracting variables (that is, four possible combinations of production of bioethanol $(Y_{1j} = Y_{2j} = 1)$ and no production of bioethanol $(Y_{1j} = Y_{2j} = 0)$ times their associated probabilities (Greene, 2003).

To estimate the bivariate probit model, the observed outcome equals 1 if farmer produces and markets bioethanol, zero otherwise, and equals 1 if a farmer produces and markets dry chips, zero otherwise. Production and marketing of bioethanol and dry chips are binary outcomes with the underlying continuous unobservable variables. In effect, there are two binary dependent variables namely; production and marketing of bioethanol and production and marketing of dry chips Y_i, j = 1, 2. These represent two interrelated decisions with correlated disturbances and allows the equations to be estimated simultaneously (Greene, 2003). Following Greene (2003), the bivariate probit model is joint model for two binary outcomes that generalizes the index function model from one latent variable to two latent variables that may be correlated and specified as;

$$y_{i1}^* = x_{i1}\beta_1 + e_1, \; ..$$

$$y_{i2}^* = x_{i2}\beta_2 + e_2,$$

Where the e_1 and e_2 are joint normal with means zero, variances one, and correlation ρ. Then y_j^* are unobservable and related to the binary dependent variables y_j by the following rule

$$y_1 = \begin{Bmatrix} 1 \; if \; y_2^* > 0 \\ 0 \; if y_2^* \leq 0 \end{Bmatrix} \quad y_2 = \begin{Bmatrix} 1 \; if \; y_2^* > 0 \\ 0 \; if y_2^* \leq 0 \end{Bmatrix}$$

This model collapses to two separate probit models for and when the error correlation ρ = 0. The error terms are normally distributed with a zero mean, variance equal to 1 and q denoting their covariance term

$$\begin{pmatrix} \varepsilon_{1it} \\ \varepsilon_{2it} \end{pmatrix} \sim N \left[\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} 1 & p \\ p & 1 \end{pmatrix} \right]$$

RESULTS AND DISCUSSION

Smallholder farmers' characteristics based on the major cassava products produced. Table 2 presents the characteristics of farmers based on the cassava products produced and marketed. The results show that individuals who produced and marketed bioethanol were more educated, involved in off farm work, used local cassava varieties and reported better road conditions than their counterparts who produced and marketed dry chips. Also, households who produced and marketed dry chips were more experienced in marketing chips and belonged to Pentecostal church in comparison to their counterparts.

Association between study variables for determining farmer decisions to produce bioethanol. Table 3 show the results of the Pearson correlation coefficients. The results suggest that female headed households, farmers who do not belong to the Pentecostal church, farmers who use better roads and grow improved varieties were more likely to produce and market bioethanol. On the other hand, being a Pentecostal Christian, experience in cassava growing, poor road conditions and growing improved variety were positively and significantly associated with the production and marketing of dry chips. In addition, there were significant correlations between various predictor variables for example marital status, experience, Total Livestock Units (TLU), and land size were found to be positively correlated with age. The results suggest that as farmers get older, they are more likely to get married, rear livestock and own more land. However, their variance inflation factors (vif) between the various predictor variables revealed absence of collinearity problem.

Table 1. Description of variables used to analyse the factors influencing farmer decisions to produce and market bioethanol

Variable	Description	Expected impact	
		D.C	Bio
Dry chips	1 if farmer produced dry chips from cassava, 0 otherwise	NA	-
Bioethanol	1 if farmer processed bioethanol from cassava,0 otherwise	-	NA
Age	Age of the household head in years	+	+
Sex	1 if Male, 0 Female	+	+
Marital status	1if respondent is married, 0 otherwise)	+	+
Education	1 highest level of education attained by household head, 0 otherwise	-	-
Religion	1if respondent is Pentecostal Christian, 0 otherwise	-+	-
Household size	Number of people in household at the time of interview	+	+
Experience	Farming experience of the household head (Years)	+	+
Land size	Land size owned (Acres)	-	+
Off-farm employment	1 if farmer is engaged in off-farm job, 0 otherwise	-	-
TLU	Total livestock units in each household	-	-
Membership to farmer group	1 if farmer belongs to group 0, Otherwise	+	+
Access to Credit	1 if farmer had access to credit, 0 otherwise	+	+
Distance to output market	Distance to output market (km)	-	-
Improved road condition	1 if the road condition is very good, 0 otherwise	+	+
Improved cassava variety	1 If variety planted is improved, 0 otherwise	+	-/+
Profitability of dry chips	1if dry chips production is profitable, 0 otherwise	+	+-
Profitability of Bioethanol	1if Bioethanol production is profitable, 0 otherwise	-+	+

(+) Represents a positive hypothesized impact of given variable on farmer's decision and (-) represents negative impact. NA (Not applicable); TLU as defined in Stock *et al*. (1991) (Cattle =0.7; calves =0.4; Goats =0.1; Sheep =0.1; Pigs= 0.2; chickens =0.01)

Table 2. Characteristics of farmers based on cassava products produced

Variable	Overall Sample	Dry chips	Bioethanol	T-test value/ Chi-square
Age(years)	39.88	41.73 (15.23)	39.24 (13.67)	-1.52
Household size	6.22	5.92 (2.27)	6.19 (2.084)	0.84
Experience(years)	17.41	19.69(13.55)	16.77 (12.10)	-1.97*
Land size(ha)	3.14	3.44 (3.66)	3.05 (1.701)	-1.15
Proportion under cassava(ha)	0.43	0.446 (0.28)	0.41 (0.246)	-1.4
Total Livestock Units	2.19	2.054 (2.23)	2.17 (1.94)	0.38
Distance to nearest market (Km)	2.75	2.776 (1.81)	2.69 (2.77)	-0.31
Improved Cassava variety (%)	34.00	23.44	51.06	-3.44***
Membership to farmer group (%)	70.00	68.75	62.38	0.32
Access to Credit (%)	57.00	60.94	51.06	0.93
Marital status (%)	84.00	83.00	86.00	0.52
Education (%)	83.00	70.31	89.11	3.26**
Pentecostal Christians (%)	10.00	27.00	1.00	-6.08***
Households participate in Off-farm work (%)	49.00	17.19	66.34	6.99***
Use Improved road (%)	58.00	44.00	66.00	2.90***
Male Headed households (%)	73.00	25.26	23.33	0.64

Note: Level of significance: *p < 0.05, **p < 0.01, ***p < 0.001.

Table 3. The association of the predictor variables for production and marketing of fresh tubers, bioethanol and dry chips, Pearson correlation coefficients

	D.C	Bio	Age	Gender	M.S	EDU	Religion	HHS	EXP	GRP	C.A	Out MKT	RD CN	OFF^{-I}	TLU	Land size		PRPN-Cas	CAS V	Prof-Bio	Prof D.C
D.C	1.000																				
Bio	-0.437*	1.000																			
Age	0.069	-0.042	1.000																		
Gender	-0.035	-0.106*	0.021	1.000																	
M.S	0.082	-0.058	0.199***	0.234***	1.000																
EDU	-0.107*	0.0709	-0.339***		0.087	-0.253***		1.000													
Religion	0.226***	-0.379***		0.039	0.055	0.047	0.020	1.000													
HHS	-0.055	0.064	0.290***	-0.027	-0.169**	-0.050	0.065	1.000													
EXP	0.135*	-0.078	0.807***	0.167**	0.314***	-0.310***		0.016	0.221***	1.000											
GRP	-0.045	0.017	-0.106	-0.148*	0.031	-0.103	0.011	-0.125*	-0.114*	1.000											
C.A	-0.077	0.0297	-0.139	-0.021	-0.030	0.033	-0.014	-0.084	-0.186***		0.369***	1.000									
Out MKT	-0.005	-0.047	0.103	0.053	0.165**	-0.029	0.032	-0.003	0.159	-0.107	-0.176***		1.000								
RD CN	0.107*	-0.171**	0.007	0.040	0.037	-0.006	-0.0589	-0.0823	-0.0435	0.0537	0.0613	-0.105	1.000								
OFF-I	-0.199***		0.533***	-0.021	-0.028	0.018	0.054	-0.174***		0.032	0.029	0.044	-0.02	0.037	-0.156*	1.000					
TLU	-0.072	-0.045	0.172**	0.218***	-0.05	0.157*	0.2083***		0.342***	0.181***	-0.066	-0.036	0.038	-0.036	0.110	1.000					
Land size	0.065	-0.083	0.1736*	0.074	0.017	0.0262	0.2587*	0.211*	0.174*	-0.088	-0.007	0.056	0.1096	-0.007*	0.522***	1.000					
PRPN-C	0.065	-0.083	-0.114**	-0.059	0.029	0.062	-0.050	-0.155*	-0.088	0.037	0.053	-0.018	0.109	-0.106**	-0.185***		-0.362***		1.000		
Cas V	0.119*	-0.237***		-0.087	0.094	-0.06	-0.019	0.073	-0.044	-0.120*	-0.049	-0.066	0.022	0.0863	-0.136*	0.116	0.097	0.098	1.000		
Prof Bio	-0.190***		0.560***	-0.022	-0.003	-0.103	0.061	-0.276***		0.076	-0.056	0.067	0.042	0.292***	-0.070	-0.124*	0.073	-0.123*	-0.123	-0.069	1.000
Prof-D.C	0.359***	-0.234***		0.093	0.028	0.137*	0.037	0.265***	-0.012	0.111*	0.085	0.030	-0.166**	0.063	-0.009	-0.008	0.026	0.026	0.042	-0.063	1.0000

Note: Level of significance of Pearson correlation coefficient *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$.

D.C-Dry chips, Bio-Bioethanol, M.S- Marital status of Household head, EDU-Education, HHS- Household size, EXP-Experience of Household head, GRP-Membership to farmer's, C.A Access to credit., Out MKT-Output Market, RD CN-Road condition, OFF-Income earned from off-farm work, TLU -Total Livestock Units, PRPN-C Proportion of land under cassava. Cas-V Improved cassava variety Profitability of bioethanol production

Profitability of bioethanol production. Table 4 presents the results of the production costs incurred for fresh tubers, dry chips and bioethanol. The results reveal that the highest production costs are incurred for fresh tubers, followed by bioethanol from cassava chips bought then by dry chips and least production costs are incurred by farmers who produce bioethanol from cassava grown at home. Specifically, weeding contributed the highest production costs for fresh tubers, dry chips and bioethanol produced by farmers who grow their own cassava followed by ploughing while transport of planting material contributed the least production costs for the three products. For bioethanol produced by farmers who buy cassava chips, the cost of purchase of cassava chips was the only single and the highest production cost incurred.

The processing and marketing costs of fresh tubers, dry chips and bioethanol. The results show that the processing costs were highest in bioethanol produced by farmers who grow their own cassava followed by dry chips and the least costs were incurred by farmers who buy chips for bioethanol production. There were no processing costs reported for fresh tubers. The processing costs for bioethanol from cassava grown were higher than the processing costs for cassava bought for bioethanol production. This is attributed to extra costs of peeling and drying incurred during processing of cassava grown. The results also showed that the marketing costs were highest in fresh tubers followed by bioethanol produced by farmers who grow own cassava for its production followed by dry chips and least marketing costs were incurred by farmers who buy cassava chips for bioethanol production. The high marketing costs of bioethanol could be attributed to the extra packaging costs, long distances to the market which is mainly in urban centres and market dues incurred during the marketing process.
Table 5 presents a summary of the production, processing and marketing costs as well as revenues for each of the three products including computations of gross margins and gross margin percentages. The results show that on average about 23 tonnes per hectare of fresh roots are produced by farmers in the three districts of northern Uganda. This is equivalent to about 8 tonnes of dry cassava chips per hectare indicating conversion ratio of 3 to 1 for fresh tubers and dry chips. The results further show that about 23 tonnes of fresh tubers per hectare produce about 3000 litres of bioethanol indicating an average production of 139 litres of bioethanol per one tonne of fresh cassava roots. At the time of data collection, on average farmers sold one kilogram of fresh tubers at 235 shillings, one kilogram of dry chips was 927 shillings and one litre of bioethanol was being sold at 4175 Uganda shillings per litre (1 US$=3364.65 Ugsh approximately). However, these prices vary greatly depending on season and availability of cassava.

The results indicated that households who bought chips for bioethanol production incurred much higher total variable costs than households who produced own cassava for sale as fresh tubers, dry chips or processed into bioethanol (Table 5). This is probably because most of the work is done by household labour and farmers have a tendency of undervaluing their cassava below the market price. Among the cassava farmers producing fresh tubers, dry chips and bioethanol from cassava grown by the farmers, the results showed that production costs were highest in fresh tubers followed by dry chips and bioethanol with the least production. This is probably because fresh tubers are perishable and considered of high value. It may also be because there are no additional costs such as processing costs incurred in production of fresh tubers.

Table 4. Summary of the production, processing and marketing costs of Fresh tubers, dry chips and bioethanol

Item description	Fresh tubers	(%)	Dry Chips	(%)	Bioethanol from Cassava Grown	(%)	Bioethanol from Cassava Bought	(%)
Quantity of dry cassava bought (kg)	N/A		N/A		N/A		7942.05	
Price per kilogram of Dry chips(Ugx/kg)	N/A		N/A		N/A		927	
Cost of purchasing dry chips (Ugx)							7,362,280	74.99
Bush clearing (Ugx)	106,846.60	6.89	102,566.48	5.2	109,247.58	2.53	N/A	
Ploughing(Ugx)	292,410.20	18.85	236,647.80	12	254,549.40	5.9	N/A	
Planting material(Ugx)	162,857.50	10.5	126,043.85	6.39	128,167.68	2.97	N/A	
Cutting and bagging of planting material(Ugx)	28,129.45	1.81	265,87.07	1.35	291,62.47	0.68	N/A	
Transport of planting material (Ugx)	21,834.35	1.41	245,81.58	1.25	26,418.51	0.61	N/A	
Planting (Ugx)	42,945.89	2.77	359,01.66	1.82	35,902.39	0.83	N/A	
Fertilizers	0	0	0	0	0	0	N/A	
Weeding (Ugx)	385,021.90	24.82	440,978.57	22.4	445,413.60	10.32		
Uprooting (Ugx)	134,125.30	8.65	166,455.66	8.44	108,545.64	2.51	N/A	
Packaging and transport home (Ugx)	86,656.87	5.59	65,321.67	3.31	70,321.75	1.63	N/A	
Total Production Costs (Ugx)	1,260,828.00	81.29	1,225,084.30	62.1	1,207,729.02	27.97	7,362,280	74.99
Processing Costs								
Peeling(Ugx)			313,312.88	15.9	588,121.28	13.62	N/A	N/A
Drying(Ugx)			164,741.93	8.35	216,741.56	5.02	N/A	N/A
Milling (Ugx)					201,003.47	4.66	135,559.32	1.38
Fermentation (Ugx)					241,535.04	5.59	303,530.07	3.09
Roasting (Ugx)					264,730.07	6.13	279,108.11	2.84

Distillation (Ugx)					320,943.82	7.43	313,996.63	3.2
Yeast (Ugx)					242,362.21	5.61	266,373.81	2.71
Firewood (Ugx)					325,121.62	7.53	342,779.65	3.49
Total Processing costs			478,054.81	24.2	2,400,559.07	55.6	1,641,347.59	16.72
Marketing Costs								
Packaging (Ugx)	100,682.71	6.49	87,406.61	4.43	341,092.14	7.9	408,195.62	4.16
Transport (Ugx)	143,880.94	9.28	134,374.58	6.81	231,638.81	5.36	256,430.58	2.61
Market Dues (Ugx)	45,644.60	2.94	47,570.71	2.41	136,639.11	3.16	150,020.61	1.53
Total marketing costs	290,208.25	18.71	269,351.90	13.7	709,370.06	16.43	814,646.81	8.3
Total processing and marketing costs	290,208.25	18.71	747,406.71	37.9	3,109,929.13	72.03	2,455,994.40	25.01

Source: Survey Data 2016; UGX- Uganda shillings; 1 USD = 3364.65 UGX

Table 5. Gross margin analysis of fresh tubers, dry chips and bioethanol

Item description	Fresh tubers	Dry chips	Bioethanol from cassava grown	Bioethanol from cassava bought
Revenues				
Quantity of fresh cassava (kg/Ha)	22,862.51	22,862.51	22,862.51	N/A
Quantity of Dry chips (kg/Ha)		7,942.05	7,942.05	7,942.05
Bioethanol yield (L/Ha)			3,171.75	3,502.34
Average price per litre or Kilogram (Ugx)	235.00	927.00	4,175.00	4,175.00
Total Revenues (TR)	5,372,689.85	7,362,280.35	13,242,056.25	14,622,269.50
Total Variable costs (TVC)				
Total Production Costs (Ugx)	1,260,828.07	1,225,084.34	1,207,729.02	7,362,280.35
Total Processing costs (Ugx)	0.00	478,054.81	2,400,559.07	1,641,347.59
Total marketing costs (Ugx)	290,208.25	269,351.90	709,370.06	814,646.81
Total Variable Costs (TVC) (Ugx)	1,551,036.32	1,972,491.05	4,317,658.15	9,818,274.74
Gross Margin (TR-TVC) (Ugx)	3,821,653.53	5,389,789.30	8,924,398.10	4,803,994.76
Gross Margin (%)	71.13	73.21	67.39	32.85

Source: Survey Data 2016; UGX- Uganda shillings, 1 USD = 3364.65 UGX

As indicated in Table 6, the results show that bioethanol generated the highest revenue followed by dry chips and fresh tubers. Farmers who produced bioethanol from cassava bought generated more revenues than farmers who grew cassava for bioethanol production. Bioethanol produced from cassava grown generated the highest gross margins followed by dry chips and bioethanol produced from cassava chips bought and fresh tubers generated the lowest gross contribution. Although bioethanol generated the highest revenues, bioethanol generally generated the least gross margin percentages of 67.39% while dry chips generated the highest gross margin of 73.21% and fresh tubers generated gross margin of 71.13%. Bioethanol produced from cassava grown generated higher gross margin percentage of 67.39% than for bioethanol produced by farmers who buy cassava chips which generated gross margin percentage of 32.85%.

Figure 3 presents the results from the sensitivity analysis to investigate the changes in production costs on the profitability of cassava bioethanol produced using cassava chips bought. The investigated elements included price of buying dry chips, cost of firewood and cost of roasting. The results reveal that a 40 % decrease in the price of cassava dry chips increases the gross profit of bioethanol by 61% from 4.8 to 7.75 million Uganda shillings but on the contrary increasing the price of dry chips by 40% reduces the gross profits of bioethanol by 61%. Similarly, reducing cost of roasting of fermented broth by 40% increases the gross profit of bioethanol by only 2.50% from 4.80 million Uganda shillings to 4.92 million Uganda shillings. Likewise, reducing the cost of firewood by 40% increased the profitability of bioethanol by 2.30% from 4.80 to 4.91 million Uganda shillings. The above results demonstrate that price of buying cassava chips has significant effect on the gross profits of bioethanol, unlike the cost of firewood and costs incurred during roasting of the fermented broth.

Figure 4 presents the outcomes of sensitivity analysis which investigated the effects of changes in production costs of some elements on the gross profits of bioethanol produced from cassava grown by farmers in their households. The elements investigated include cost of peeling cassava, cost of firewood and roasting of fermented broth. The results revealed that a 40% decrease in peeling cost increases gross profit of bioethanol by 2.80% from 8.9 to 9.15 million Uganda shillings. Similarly, reducing the cost of firewood by 40% increases the gross profits by 1.46% from 8.90 to 9.03 million Uganda shillings. Likewise, a 40% reduction in cost of roasting of fermented broth increases the gross profit of bioethanol by 1.46% from 8.90 to 9.03 million Uganda shillings.

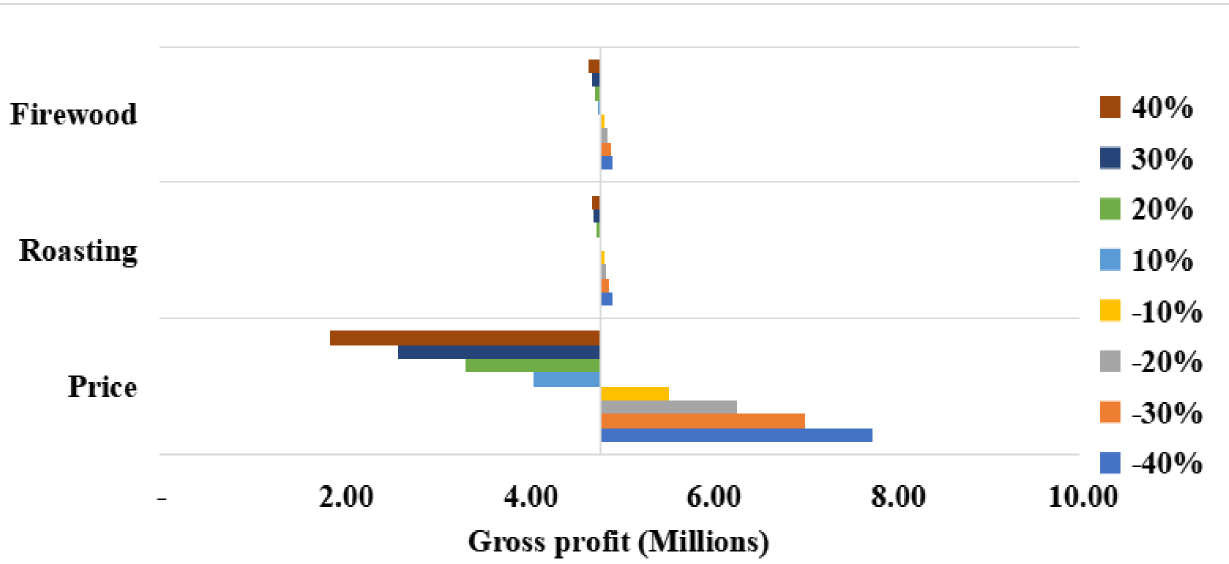

Figure 3. Sensitivity analysis of costs of cassava bioethanol production for farmers buying cassava chips

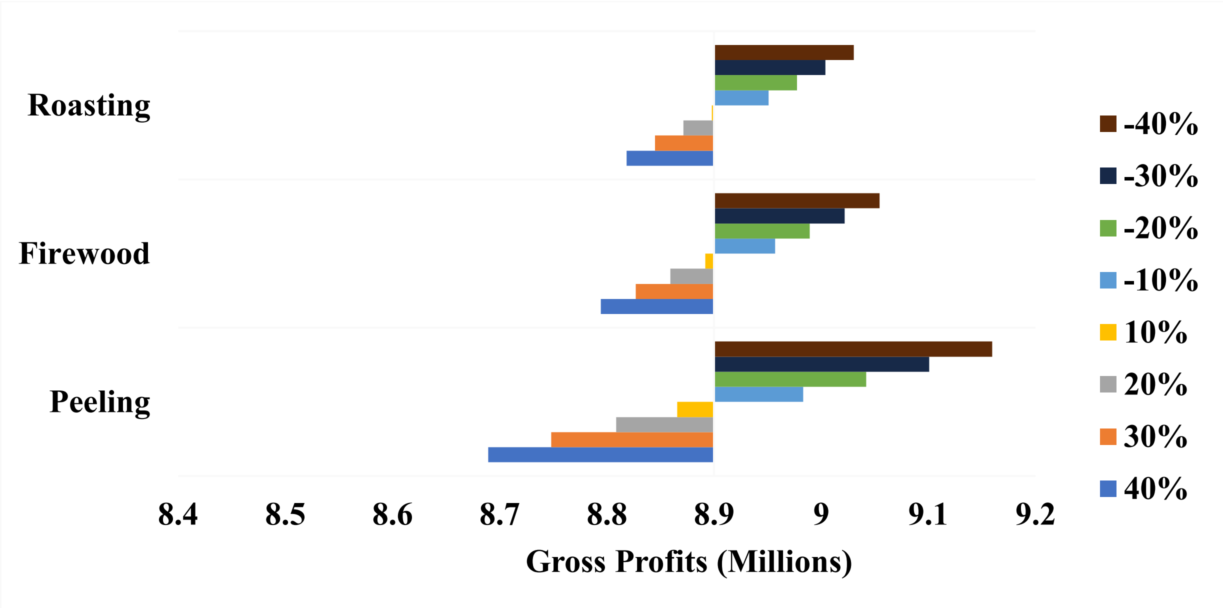

Figure 4. Sensitivity analysis of costs of cassava bioethanol production for farmers growing cassava

Factors influencing smallholder farmer's decisions to participate in bioethanol production

Table 6 presents results of the bivariate probit and probit model to determine the factors influencing farmer decisions to produce bioethanol. The results reveal that when bivariate model is estimated without including the profitability variables of bioethanol and dry chips, correlation coefficients between the errors (rho) was negative and significant at one percent. The inclusion of the profitability variables renders the correlation coefficients between the errors (rho) (0.416) insignificant. The result suggests that the profitability of producing and selling cassava dry chips is negatively associated with producing and selling bioethanol. In addition, results reveal that the decision to produce and sell bioethanol and the decision to produce, and market dry chips are jointly correlated.

The results also suggest that the inclusion of profit variable in estimation of a bivariate probit and probit models provides similar results. Indeed, as shown in Table 7 results from bivariate probit I and the Probit Model I are identical. Exclusion of the profitability variables for bioethanol and dry chips results into variables such as experience of the household head becoming significant for bioethanol while sex of the household head becomes insignificant. Variables such as use of improved cassava variety, improved road condition reduced in the level of significance after elimination of the profitability variable indicating that omission of variable has significant influence on goodness of fit of the model (Gujarati, 2004). In this section present the results from the models for which profit variables are included.

The results show that the age of the household head influenced farmers' decisions to produce bioethanol at $p<0.05$. For an additional increase in age of the household head, the likelihood of a farmer being involved in bioethanol production increases by 10.6%. Female headed households were more likely involved in bioethanol production than their male counterparts. Marital status of the household head also significantly influenced farmers' decisions to produce and market bioethanol at $p<0.01$. Married couples were more likely to produce bioethanol than their counterparts. The chances of married households being involved in bioethanol production was 87.3 %. Furthermore, belonging to a Pentecostal church negatively affects the production of bioethanol at $p<0.001$. Farmers who belong to a Pentecostal church were indeed less involved in bioethanol production.

In addition, land size and proportion of land under cassava positively influenced farmers' decisions to produce bioethanol at $p<0.01$. The higher the acreage of land and proportion of land under cassava planted, the more likely these households are to engage in production and marketing of bioethanol. In addition, farmers earning from an off-farm employment were more likely involved in bioethanol production than their counterparts and farmers growing local or native varieties are more likely using them for bioethanol production than farmers growing improved varieties at $p<0.001$. As expected, farmers earning profits from dry chips are less likely going to be involved in bioethanol production. Furthermore, profitability of bioethanol also greatly influenced farmers' decisions to produce bioethanol at $p<0.001$. The more profitable bioethanol is, the more likely the farmers were involved in its production. On the other hand, poor road conditions negatively affected the production of bioethanol.

Farmers in very poor road conditions are less likely involved in bioethanol production. The results show that being a Pentecostal Christian, land size, and condition of the road more likely positively influence smallholder farmers' decisions to produce dry chips while total livestock units, negatively influenced smallholders' decision to produce dry chips.

Table 6. Bivariate probit and probit estimates for smallholder farmers' decisions to produce bioethanol

Variables	Bivariate Probit I		Bivariate Probit II		Probit Model I		Probit Model II	
	Dry chips	Bioethanol	Dry Chips	Bioethanol	Dry chips	Bioethanol	Dry chips	Bioethanol
Age of the household head	-0.007(0.012)	0.106* (0.046)	-0.006(0.010)	0.031*(0.01)	-0.007(0.012)	0.092*(0.043)	-0.005 (0.012)	0.031*(0.014)
Sex of the household head	-0.122 (0.206)	-2.845***(0.854)	-0.166 (0.200)	-0.347(0.23)	-0.120(0.207)	-2.276**(0.857)	-0.177 (0.211)	-0.359(0.232)
Marital status of household head	-0.053 (0.136)	1.308**(0.422)	0.052 (0.130)	0.164 (0.15)	-0.054(0.137)	0.873* (0.437)	0.04(0.141)	0.113(0.157)
Education level of household head	-0.090 (0.124)	0.089(0.399)	-0.066(0.120)	0.140(0.14)	-0.090(0.125)	-0.047 (0.409)	-0.065 (0.123)	0.129(0.137)
Religion of the household head	0.262*(0.113)	-1.990**(0.655)	0.300** (0.100)	0.701***(0.130)	0.260*(0.112)	-1.659* (0.696)	0.304**(0.106)	-0.661***(0.125)
Household size	-0.041(0.045)	0.109(0.164)	-0.057 (0.050)	0.090(0.06)	-0.039(0.045)	0.052 (0.160)	-0.052 (0.045)	0.073(0.056)
Land size of the household	0.153**(0.051)	-0.213**(0.081)	0.163**(0.060)	-0.022(0.040)	0.150**(0.050)	- 0.212* (0.087)	0.153**(0.048)	-0.027 (0.041)
Proportion of land under cassava	0.704(0.397)	2.612**(1.010)	0.717(0.390)	-0.560 (0.41)	0.705(0.397)	3.083** (1.029)	0.705 (0.378)	-0.605 (0.411)
Off farm employment	-0.001 (0.002)	0.047***(0.013)	-0.002(0.000)	0.018*** (0.00)	-0.001(0.002)	0.036**(0.011)	-0.003(0.002)	0.018*** (0.003)
Total Livestock Units(TLU)	-0.154**(0.050)	-0.136(0.173)	-0.154**(0.050)	-0.019 (0.07)	-0.153**(0.050)	-0.076(0.162)	-0.159**(0.054)	-0.015 (0.070)

Experience in farming	0.020 (0.013)	-0.089(0.047)	0.024 (0.010)	-0.048* (0.02)	0.020(0.013)	-0.078 (0.043)	0.023(0.013)	-0.045** (0.017)
Membership to farmer group	-0.190 (0.215)	-0.594(0.760)	-0.058 (0.220)	-0.205 (0.24)	-0.184(0.214)	-0.476 (0.788)	-0.038 (0.218)	-0.116 (0.241)
Access to Credit	-0.259 (0.203)	-0.366 (0.572)	-0.200 (0.200)	0.119 (0.22)	-0.253 (0.202)	-0.214 (0.670	-0.220(0.201)	0.042 (0.219)
Distance to input/output market	-0.032 (0.032)	0.148(0.104)	-0.014(0.030)	-0.037 (0.04)	-0.0292(0.032)	0.089(0.104)	-0.013 (0.033)	-0.041 (0.041)
Improved road condition to nearest market	0.189* (0.090)	-0.857**(0.296)	0.168 (0.090)	-0.217(0.12)	0.1192* (0.090)	-0.866**(0.318)	0.168 (0.090)	-0.217(0.115)
Improved cassava variety grown	0.303(0.187)	-2.264***(0.580)	0.285 (0.190)	-0.519* (0.22)	0.3010(0.187)	-2.222***(0.585)	0.296 (0.186)	-0.568*(0.225)
Profitability of bioethanol	-0.000(0.000)	0.000***(0.000)			-0.000(0.000)	0.000***(0.000)		
Profitability of Dry chips	0.000(0.000)	-0.000***(0.000)			0.000(0.000)	-0.000***(0.000)		
Constant	-0.837(0.907)	4.220(3.302)	-1.450 (0.89)	1.362 (0.96)	-0.858(0.898)	5.122 (3.192)	-1.460 (0.882)	1.618 (0.969)
Rho	-0.579 (0.416)	-0.651 (0.086)						
$Chi^2(1)$	1.932	26.8602						
R^2				0.2086	0.9207	0.1434	0.4108	
Prob chi^2	0.164	0.0000	0.0005	0.0009	0.0009	0.0000		
Log likelihood	-137.913	-217.61102	-125.638	-127.159		-94.479		
n	237	237	237	237	237	237		
Wald(X2)(36)	92.098	Wald(X2)(32) 131.55	44.36	42.520	39.57	81.50		

All numbers shown in parentheses are robust standard errors.. *** p < 0.01, ** p < 0.05, * p <0.1 represent statistical significance at the 1%, 5%, and 10% alpha levels

DISCUSSION

The main objective of the study was to examine why bioethanol production from cassava is low in Uganda. To achieve this objective, the paper examined three research questions (1) Are smallholder farmers making profits from the current cassava bioethanol production? (2) Is selling dry cassava chips and fresh cassava tubers more profitable than selling bioethanol produced from cassava?, and (3) What factors drive rural households to produce bioethanol from cassava?

The results from the study reveal that small scale farmers are making profits from small scale bioethanol production which is consistent with the results from a study by Ogbonna and Okoli (2013) which demonstrated that small scale bioethanol production is profitable. The results also revealed that producing bioethanol from cassava grown at home is more profitable that bioethanol produced from dry chips bought because of the costs of dry chips is high. Indeed, the price of dry chips was found to have a significant effect on the gross margins of bioethanol for farmers producing bioethanol from cassava chips bought. Price volatility on the other hand, contributes to high cost of production from farmers buying chips consequently leading to reduced profits.

In addition, the high prices of cassava dry chips is attributed to low cassava production in Uganda which is associated with to re-occurrence and spread of Cassava Brown Streak Disease (CBSD) (Alicai *et al.,* 2007). Because of the CBSD, Uganda has annual net deficit of cassava and cassava derived products ranging from 70,000 MT to 900,000 MT (fresh root equivalent) (Kilimo-Trust, 2017). With these deficit and high price of cassava chips, extraction of bioethanol from cassava can only be achieved in Uganda through: (i) boosting production and productivity of cassava, and (ii) increasing returns from bioethanol production.

Boosting cassava production and productivity can only be achieved by improving agronomic practices and promoting improved cassava varieties that are resistant to CBSD such as NAROCass 1 & 2. Indeed, results from this study revealed that the higher the proportion of land under cassava, the higher the likelihood of a farmer engaging in the production of bioethanol. Similarly, the results show that farmers who grow improved varieties are more likely to produce and sell bioethanol. This is because expanding land area under cassava and promoting improved cassava varieties that resistant to disease would lead to glut supply and to offset losses, and as such farmers get involved in production of bioethanol (Naziri *et al.,* 2014). The glut supply means reduction in prices of cassava chips and roots which would make selling cassava chips less profitable. Extraction of bioethanol from cassava would therefore play significant role raising the value of cassava, sustaining household income and enhancing adoption of improved cassava technologies thus leading to significant increase in both yields and incomes which is key to poverty reduction (Cotula *et al.,* 2008).

As highlighted above, in addition to boosting production and productivity of cassava, there is need to increase the returns from bioethanol production by reducing the costs of processing bioethanol and expansion of the market opportunities through extra value addition and packaging. The recent outbreak of the Corona virus is such opportunity that raised the value of producing bioethanol from cassava. Globally many breweries and distilleries either shifted or diversified into production of the hand sanitizers which contains 70% bioethanol to sustain revenues (Thomson and Bullied, 2020). In Uganda, initially, there were only two companies producing sanitizers. However, with COVID 19 and declaration of tax exemption to transform ethanol to sanitizers about 48 companies joined the sanitizer production. However, only 10% of ethanol is produced in Uganda and of the 10%, over 90% of the ethanol is produced by small scale farmers using rudimentary tools. Of 90% of the farmers, 85% of these small-scale farmers are cassava farmers who produce only 11% of the ethanol from cassava (Mutyaba *et al.,* 2016; Nakabonge *et al.,* 2017). Therefore, promoting extraction of bioethanol production from cassava requires significant investment to establish bioethanol plants to extract the ethanol from cassava.

Results from this paper reveal that the use of rudimentary tools in processing of cassava to bioethanol reduces the profitability of bioethanol. This suggests that, increasing bioethanol production from cassava requires improved labour-saving technologies with very high processing power. In addition, the use of modern bioethanol processing technologies would help address the religious and social concerns that have negatively considered bioethanol production as evil. As the results from this study reveal being a Pentecostal Christian negatively affected production of bioethanol. Focusing on transforming individual farmers processing bioethanol into medium-scale industrial cassava processing units would address social factors like religion which impede bioethanol production. Evidence show that organizing social groups in Thailand by supporting them to form small and medium enterprises to produce high quality chips for bioethanol production increased farm incomes by 300% Graffham *et al*. (2017)

CONCLUSIONS AND RECOMMENDATION

The objective of this study was to assess why production of bioethanol from cassava is low in Uganda considering that it most efficient in production of bioethanol than any other crops used in Uganda. The results reveal that the low production of bioethanol from cassava is a result of the fact that: (1) there is low production arising from the growing local varieties that are susceptible to diseases moreover on small acreage; (ii) the technology used is rudimentary and less efficient leading to higher cost of production and generally less attractive; and (iii) the social cultural factors such religious beliefs that view bioethanol production as un Christian have negatively affected the extraction of bioethanol from cassava. To promote the extraction of bioethanol from Cassava in Uganda; we recommend increasing production of cassava and high-quality cassava chips to reduce the cost of bioethanol production and increase the gross margins and modernizing the cassava bioethanol extraction process. This will require strengthening and organizing farmer organizations and supporting them to produce high quality cassava chips for bioethanol production.

ACKNOWLEDGEMENT

This publication has been made possible through financial support provided by Regional Universities Forum for Capacity Building in Agriculture (RUFORUM) under the Cassava Community Action Research Programme (CARP) (RUFORUM Grant No. RU 2014 CARP 04).

STATEMENT OF NO-CONFLICT OF INTEREST

The authors declare that there is no conflict of interest in this paper.

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