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# A New Value Proposition for Uganda's Maize Stover to Manufacture Moulded Pulp Packaging Material for Fruits and Vegetables

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**Abstract: -** Post harvest losses of fresh produce, including fruits and vegetables, have continued to be high. This realization has triggered numerous efforts to address this issue. One proposition is to utilize maize stover to produce sustainable moulded pulp bio-based packaging as a possible replacement for single plastics packaging. Maize stover is considered a burden to farmers to dispose after harvesting leading to its wastage. The objectives of this study were; to ascertain the current ways in which maize stover is utilized by farmers, the major packaging materials they use, and the determinants of demand for the quantity of packaging materials that farmers use. A total of 200 smallholder maize farmers from Kamuli district were interviewed. Findings show that a good percentage of farmers destroy the stover through burning, some farmers plough it back to replenish the lost soil nutrients, while others use it as livestock fodder. Polypropylene and polyethylene packaging materials are the most used and preferred packages due to availability, and affordability. The covariates that determine the demand for the number of packages purchased annually were; quantity of maize marketed, distance to the market, funds spent on marketing, and annual income. To increase the demand for maize stover packaging materials formal education, regular training, access to capital and formation of farmer groups are recommended.

**Key words:** Post harvest losses, maize stover, moulded pulp packaging materials

## I. Introduction

Post-harvest losses (PHL) are among the priority challenges that must be addressed to reduce food and nutrition insecurity in sub-Saharan Africa [1]. In Uganda, many farmers continue to experience high PHLs [2]. These losses are manifested through quantitative and qualitative losses that occur due to late harvesting, insufficient drying, improper threshing, poor storage, and poor packaging. Post-Harvest Losses have a massive impact on food and nutritional security, and farmer incomes in developing countries, in general and Uganda in particular, and are caused by fresh produce spoilage during storage and transportation from farm to market, partly resulting from the use of inefficient packaging materials. In Uganda's fruit and vegetable sector, it is estimated that 30-40% of fresh produce is wasted through PHLs, raising to 60% for tomatoes. Uganda has an estimated population of 42 million people, with 84 % living in the rural areas of the country and 82% of the workforce employed in agriculture. About 41% of the population is undernourished (3 year average to 2017) [3]. Women are more risk of Food and Nutrition Security [4], despite the fact that women contribute 70-80% of the agricultural labour force in Uganda [5]. Maize is a staple food crop in sub-Saharan Africa (SSA) [6]. It is the most important cereal crop in this region. It provides over 40% of the calories consumed in both rural and urban areas of Uganda [7]. Smallholders account for 80% of the rural poor in Uganda, but are also the major producers of maize. Maize is grown in every part of the country [8] and provides a direct source of income for over two million households, over 100,000 traders, and 600 millers [9]. Increasingly, maize has become a major non- traditional export cash crop particularly benefitting smallholder farmers and is therefore extremely important to many households for both food security and income

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[8].

It is estimated that the resultant maize stover, (or straw), that consist of variable proportions of stalks, and leaves of maize plants, are left in fields after harvest. This accounts for nearly 80% of the dry weight of harvested material, and is utilized in various forms. For some farmers,it is ploughed back into the soil, or used as crop mulch, and fuel. Sometimes the stover is mixed with some brans and/or molasses, and served to animals as dry stover (or haylage) [10]; [11]. There are currently no higher value outlets for the maize stover and a proportion of this material could be diverted from the aforementioned traditional uses to being used as raw materials to produce moulded pulp packaging materials. The effluent from the manufacturing process can also be used to maintain or improve soil fertility. The utilization of bio-based materials in Asia, Europe, and USA is growing. It grew at an estimated rate of 15- 20% from 2012 to 2017 [12]. In Africa, the proposition is also gathering speedbut the market data is not well established. Innovativeness is needed to create sustainable packaging to reduce food waste by preserving food quality, as well as food safety by preventing food-borne diseases and food chemical contamination.

The aim of this study was to raise awareness and promote the benefits of sustainable, bio-based packaging produced from what is seen by some farmers as waste, and to raise its demand. Among the anticipated benefits of such packaging materials is reduction in post-harvest losses of fresh produce, associated with use of inadequate packaging, which currently leads to bruising [13], rotting, discoloration [14] and formulation of off- flavors, during transportation from farm to market.

This article is made up of four sections. In the first section, the introduction and objectives of the study are made. The methodology section that follows this introduction highlights the study design, study areas, sampling and sample size, data collection, and analysis. Empirical findings and discussions are presented after methodology. In this section, the respondent's socio- demographic characteristics, crops raised and traded, the dominant packaging materials mainly used, most preferred packaging materials, price and environmental attributes, alternative packaging materials, and determinants of demand for packaging materials are described. The last section presents conclusions, policy implications and areas of further research that may define interventions and improvement of the maize value chain.

## II. Methodology

### 2.0 Field Methods

Field visits were preceded by preparations that included contacting key district level personnel, and research staff from the Makerere University-Iowa State University program based in Kamuli district that works with a local Non-Government Organization (NGO), called Volunteer Efforts forDevelopment Concerns (VEDCO). These contacts enabled the research team to make the relevant sampling frame from which the respondents were selected.

### 2.1 Study Design

This study took on a mixed-methods descriptive cross-sectional survey design, that used both qualitative and quantitative approaches. It was a highly participatory study, that addressed the study objectives through surveys using direct interviews of selected respondents. Further, the design allowed for an explorative and gender disaggregated approach. Desk reviews to obtain secondary data and observations were also used to triangulate the primary data.

### 2.2 Study Population and Study Area

Smallholder maize farmers were the target population. For this research Kamuli district (see Fig. 1) was selected partly because of its high maize production levels and it is in the ten leading producing regions of maize in Uganda. It is reported to have produced 81,969 metric tonnes in 2015 which accounted for 3.5% of the total production in the country [15]. Kamuli Districtis located in Eastern Uganda *(*Latitude: 1° 04' 60.00" N, Longitude: 33° 14' 60.00" E*)*, with an elevation of 1122 metres. It is bordered by Buyende district to the north, Luuka district to the east, Jinja district to the south, and Kayunga district to the west. The district headquarters at Kamuli are approximately 74 kilometers, by road, northof Jinja city (and about 160 kilometers from Kampala, the capital city). The current population is estimated at 640,000 (with close to 60% being female) [9]. The district is a multi- ethnic and multi-cultural society, with the predominant ethnic group being the Basoga comprising of 76 % of the population, followed by Iteso (3.9 %),the Banyoro and Bagungu (1.8%). The main language spoken in Kamuli District is Lusoga, with some Luganda and English. The major agricultural activities of this district are summarized in table I.

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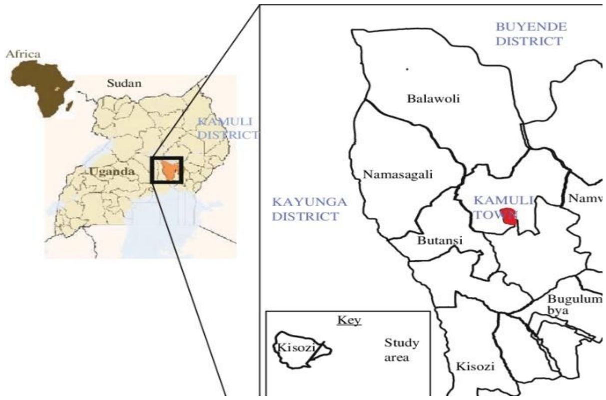


**Figure 1 Map of Uganda showing location of Kamuli district and the sub-counties**

The sub counties from which the respondents were selected were Butansi, Namasagali and Kitayunda.

**Table I. The major agricultural activities of Kamuli district are given in the matrix below;**

| The major livelihood activities | The major crops grown | | The major livestock types kept |
|---|---|---|---|
| • Fishing<br>• Ranching<br>• Farming<br>• Fish farming<br>• Bee keeping<br>• Retail trade<br>• Quarrying | • Rice<br>• Matooke<br>• Sweet bananas<br>• Maize<br>• Millet<br>• Soybeans<br>• Groundnuts<br>• Oranges<br>• Mangoes | • Potatoes<br>• Beans<br>• Simsim<br>• Sunflower<br>• Tomatoes<br>• Onions<br>• Coffee<br>• Cotton<br>• Sugarcane | • Cattle<br>• Goats<br>• Sheep<br>• Chicken. |

### 2.3 Data Types and Sources

This study is based on primary and secondary data that included; socio-demographic variables including sex, age, education, household size; utilization of maize stover by farming households after harvesting the main product, the quantity of packaging used and the reasons for the preference, and policy issues related to packaging materials. The data were collected from smallholder farmers of maize.

### 2.4 Data Collection Tools and Procedures

Primary data were collected using tools that were designed in tandem with the study objectives.The procedure that was followed to collect the data was face to face interactions. The interviewees were required to first explain to the respondent the purpose of the study. This included an assurance to them that the data was to be kept confidential. They were then interviewed and allowed to ask any pertinent questions related to the study and the interview. Observation were also made and used in the data triangulation and validation process to ensurethat what is captured is in tandem with what is observed. Cameras were also employed to take imagery evidence of project aspirations. Secondary data, of qualitative and quantitative nature, were collected using a literature review guide to support document review and, document relevant information. The documents reviewed included; the project proposal, Government reports, frameworks and policies that were accessed through internet searches.

### 2.5 Sampling Techniques and Sample Size

Sampling followed a purposive approach at the district, and sub-county levels. At lower levels (village level), simple random sampling techniques were used to avoid biased selection of respondents. The samples for the farmer respondents were selected from a sampling frame that was developed with the Iowa State University - Makerere Program. A total of 200 farmers were selected for the study. The sample size was determined using the formula below (equation (i) (based on the work of [16].

$$\frac{rd\,(1 - rd)\text{ pop size}}{rd\,(1 - rd) + (me/c)^{2} / (\text{pop size} - 1)} \quad \text{(i)}$$

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Where: sample size = the sample size required for the desired margin of error and population size, c = confidence level, rd = response distribution (50% = 0.5), popsize = the size of the population of interest = 400, me = the desired margin of error (i.e., 5% = 0.05). Using this formula, a credible sample size of the primary beneficiaries would be 196. This was rounded off to give a sample of 200. The majority of farmers interviewed were from Namasagali (61.0%), followed by Butansi (38.5%) and Kitayundwa (0.5%). This is one of the sub-counties where Iowa State University operates. The villages from which these farmers were drawn were; Bubiriki, Bubogo, Bukabi, Busuyi, Busambu, Kasaikye A and B, Kiwungu and Kisenyi.

### 2.6 Data Analysis and Presentation

The data were disaggregated by age, gender, district, and education and analyzed using SPSS (ver.21) and STATA (ver.17). To ascertain the use to which farmers put their maize stover, descriptive statistics that included; percentages, frequencies, measures of central tendency (e.g. mean) and measures of dispersion (ranges, minimum maximum, and standard errors) were used. In order to identify the major packaging materials used, and reasons for preference for packaging materials. To determine the covariates that influence demand for the quantity of packaging materials demanded by farmers econometric analysis was used, and the details for the regression model are given in the equation below The determinants of quantity of packaging materials used were estimated using a multiple linear robust regression model whose theoretical underpinning is given in equation (ii) below, was estimated as,

$$Y = \beta_o + \beta_i X_i + \varepsilon \qquad \text{……………………………………….. (ii)}$$

$$i = 1, 2 \ldots n$$

Where, **Y** is the regressand, a continuous variable estimated as number of bags purchased annually, ***Xi*** represents a vector of covariates of farmers', household and geographical location variables, $\boldsymbol{\beta}$ is a vector of parameters estimated and $\varepsilon$ is the error term that caters for covariates not included in the model, and **n,** refers to the number households in the analysis.

The empirical model that was estimated was defined as shown in equation (iii) below;

$$Yi = \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 \ldots + \beta_n X_n + e_i \qquad \text{…………………….……………(iii)}$$

$Y_i$ is the quantity of bags demanded by farmers, and is the dependent variable. *Xi……Xn* represent farmer specific independent variables, household and geographical location variables, $\beta_I$ ……$\beta n$ is a vector of parameters estimated and, *e* is the error term that caters for covariates not included in the model.

The covariates used in the empirical model were; age of the household head (in years), sex (dummy variables, 1 for female, 0 otherwise), education (number of years in school), quantity of maize marketed (in kilograms/year), distance to the maize market (in kilometres), funds spent on packaging materials (in UGX/year), annual income (in UGX/year), and quantity of maize spoilt during transportation (in Kilograms). The *apriori* expected sign for the coefficients of these regressors are given in column 3 (table II).

**Table II. Definition of variables and expected relationships between the covariates and wealth**

| Covariate | Units of measurement | *Apriori* relationship |
|---|---|---|
| Age of the household head | Complete years) | Positive |
| Sex of the household head | Dummy variable (1=Female, 0 otherwise) | Negative |
| Education | Number of years in school | Positive |
| Quantity of maize marketed | Kilograms per year | Positive |
| Distance to the maize market | Kilometres | Positive |
| Funds spent on packaging materials | UGX per year | Positive |
| Annual Income | UGX per year | Positive |
| Quantity of maize spoilt during transportation | Kilograms | Positive |

The choice of a robust regression was to produce estimators that are not unduly affected by small departures from model assumptions. Robust regressions are designed to circumvent some limitations of traditional parametric and non-parametric methods. In particular, least squares estimates for regression models are highly non-robust to outliers. In the presence of outliers, least squares estimation is inefficient. Another reason for the choice of a robust estimation was basedon a strong suspicion of heteroskedasticity [17]. The data is summarized using tables and graphs for ease of interpretation

## III. Empirical Results and Discussions

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### 3.1 Socio-Demographic and Economic Variables

The majority of farmers interviewed were female and this could be attributed tothe high population of females in Kamuli district. Furthermore, the interviews took place in the morning when majority of the men had proceeded to work for their respective jobs since majority of them consider agriculture (maize production) as a side job. On the other hand, most of the work on the maize crop is mainly left to females and the males come in later, during decision making for crucial activities such as marketing. With respect to education, the majority of the farmers had attained primary level education (64.5%) followed by Ordinary level (28.3%). Very few respondents had attained Advanced level of education (only 0.6%). However, a good percentage of farmers did not attain any formal education. Educated farmers are expected to yearn for, seek and easily understand agricultural instructions, manage and adopt technologies faster than uneducated farmers [18]. Education is crucial as it enhances the ability to derive, decode and evaluate useful information on agricultural production [19]. According to Kimaro *et al.,* (2015) [20] farmers who attained secondary education are eager to investin their own farms. This is due to the fact that they have wider knowledge than those who attained lower levels of education. It is reassuring that most of these farmers are literate, and possess basic reading and numeracy skills. The threats associated with low education level include; high percentage of early school drop outs, child marriages, [21], low knowledge and skills which compromise the future of these people regarding their competitiveness in the job market compared with people in other districts, in the country and globally. Such lowly educated farmers are relegated to the poorly remunerative levels of the maize value chain.

Apart from maize, the other common crop grown in the region is beans and this is because in the region,maize is processed to get maize flour and its consumed together with beans, a high crop protein source, hence forming a positive correlation in that the increase in maize production leads to an increase in beans production. Other major crops grown are; soybean, tomatoes, cassava, millet, and tomatoes. A number of these crops are grown as intercrops with maize. This is an enterprise diversification measure to mitigate a number of risks and uncertainties that farmers are likely tobe confronted with low yields. In Uganda, farmers' maize yields are far below what farmers achieve in other parts of the globe. Among the reasons for this disparity is lack of inputs, low mechanization, and inadequate knowledge of the recommended agronomic practices [22]. Low yields may also result from climate change (including onset and cessation of rains) [23], poor soils [24], poor planting materials [25]; low prices, price variability and unpredictability [26] , and inefficient markets.

The majority of farmers market individually (96%), with very few being involved in collective marketing. This result concurs well with the findings of Ssajakambwe *et al.,* (2020) [27] This could be partly explained by the maize buyers who always ply farms and villages in search of and to buy produce at farm gate prices, which are usually lower compared to prices set by farmer groups, associations and cooperatives. This result should also remind the leaders of these groupsto position their groups as marketing institutions to benefit from economies of scale.

### 3.2 Means Use to Transport Produce to Markets by Farmers

Use of foot and bicycle dominate the means of transport used by farmers to move their produce [28]. The importance of bicycles as a means of transport for small- scale farmers is increasing dramatically [29], and this is attributed to affordability compared to other options (figure 2). It is also a fact that bicycles can easily navigate the narrow paths and sometimes impassable rural roads. This dominant means of transport is also related to the low volume that is sold which may not necessitate big trucks.

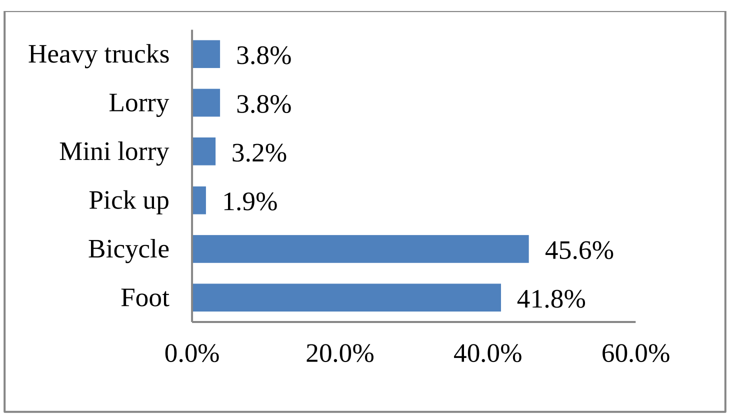


Figure 2: Major means of transport used by the farmers

### 3.2 Estimated Seasonal Income

Most farmers (over 64.5%) revealed that they earn less than UGX. 500,000 per season (which translates to about UGX. 1,000,000

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per year, or slightly more if realistic revelations are projected). This is below the $1 a day, which is the poverty line. Uganda's poverty estimate datais based on US$0.88–US$1.04 per person per day as the national poverty line. This measure is much lower than the World Bank's international figure of US$1.90. By and large, with this result, the farmers in the study area can be described as poor. This is attributed to most of the farmers being smallholders, with a higher likelihood of being inefficient in their resource allocation behaviours which has led to poverty [30]. This is also coupled with low capital investment, limited knowledge and skills, and low product prices that result from poor marketing strategies.

Small scale farmers dominate the maize value chain in Uganda [27]. However, they are characterized by low productivity (with yields of about 25-30% of the potential). During good seasons, they produce a marketable surplus, [31] , over and above their household food needs, which they sell to primary rural based bulkers (dominated by agents or brokers) usually in unprocessed form [32]. Only about 33% of the product can be considered as the marketable surplus. Going by empirical results, the small scale farmers sell about 450 kgs peryear. Farmers are, in most cases, forced to sell their products shortly after harvest [33], due to lack of adequate storage, and to solve pressing family needs such as school dues and health care [27]. The major maize varieties grown include; *the Longe series* (the commonest include 5 and 10) [7].

### 3.3 Packaging Materials and Related Issues

According to the results in figure 3, bags that are made out of polypropylene material are mainly used [34] by farmers and this accounted for 41.9% of the responses. Polypropylene (PP) is a thermoplastic "addition polymer" made from the combination of propylene monomers. It is used in a variety of applications Including packaging for a wide range of consumer products. The reasons given for this preference are dominated by the fact that these are big in size, and carry large quantities of 100 – 140kgs of grain or produce. As such, they are convenient to use and are also considered durable [35] and water proof to protect the produce in it. They are used during transportation of maize from their fields to homes (some of which are re-cycled over many seasons). These types of bags are also used to store the maize grain for their household food needs, and for transporting the grain to processing units, and the nearby and distant markets.

armers in Africa, and in Uganda increasingly store grains in polypropylene bags, but the poor aeration in these bags may encourage fungal growth, resulting in rapid deterioration of the produce [2]. Polyethylene bags are the next in ranking of the packaging materials used mainly by the maize farmers, and these are followed in ranking by sisal bags. Other packaging materials, namely woven baskets, paper bags, local mats, and bags of cloths are also used [36]. The major reasons that were given by farmers for using some of these types of bags are; being scarce, and their high prices. It has been documented that packaging is the dominant generator of plastic waste, responsible for almost half of the global total [37]

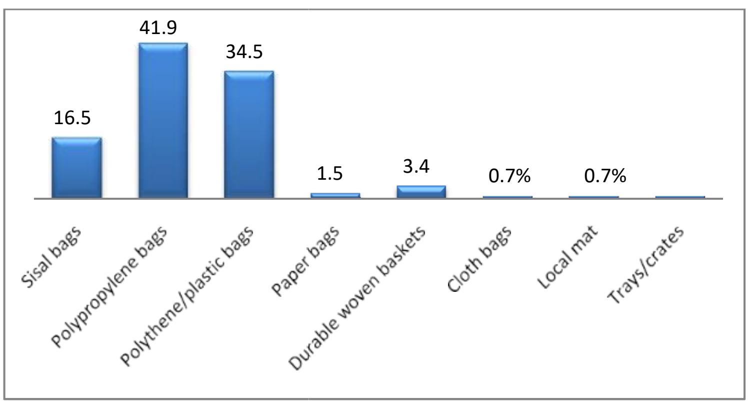


**Figure 5: Packaging materials mainly used by farmers**

### 3.4 Main Months of Purchase of Packaging Materials

Farmers mainly purchase packaging materials from July to August because it is during these months that most of the harvesting activities are undertaken. The months when packaging materials are least purchased are those when the maize crop is actively growing in the field. Farmers use bags during picking of maize grains in the field, transportation from the field to homesteads, storage [2] and transportation to the market [38].

### 3.5 Most Preferred Packaging Materials

Descending ranking of packaging materials according to preference indicate polypropylene bags (accounting for 33.9% of the

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responses) as the most dominant. These are followed by polythene/plastic bags and sisal bags (table III). The reasons given for this preference are; ease of access, durability, and convenience given their big size.

**Table III: Most preferred packaging materials**

| Packaging materials | Frequency | Percentage |
|---|---|---|
| Polypropylene bags | 119 | 33.9 |
| Polythene/plastic bags | 98 | 27.9 |
| Sisal bags | 93 | 26.5 |
| Durable woven baskets | 16 | 4.6 |
| Paper bags | 14 | 4.0 |
| Local mat | 7 | 2.0 |
| Cloth bags | 4 | 1.1 |
| **Total** | 351 | 100.0 |

Price is one of the key considerations that define the spending habits of an individual and guidein the purchasing of items. Farmers ranked the packaging materials according to prices. The results are summarised in table IV. The majority of farmers ranked polypropylene bags, polythene/plastic bags and sisal bags in descending order of price (from the cheapest). This is expected *apriori*, as rational farmers purchase more of the inputs that are of lower prices [39].

**Table IV: Ranking of packaging materials according to their prices and ease of access**

| Packaging material | Ranking based on prices | | Ranking based on ease of access | |
|---|---|---|---|---|
| | Frequency | Percentage | Frequency | Percentage |
| Polypropylene bags | 121 | 32.6 | 117 | 34.7 |
| Polythene/ plastic bags | 102 | 27.5 | 94 | 27.9 |
| Sisal bags | 92 | 24.8 | 84 | 24.9 |
| Paper bags | 20 | 5.4 | 19 | 5.6 |
| Durablewoven baskets | 15 | 4.0 | 13 | 3.9 |
| Local mat | 13 | 3.5 | 5 | 1.5 |
| Cloth bags | 7 | 1.9 | 5 | 1.5 |
| Trays/crates | 1 | 0.3 | Not ranked | |

With respect to ranking of packaging materials according to ease of access, polypropylene bags accounted for the biggest percentage (34.7%). This could be because they are the ones that are mostly demanded and used, hence they are brought closer by the suppliers which makes them available and accessible to the farmers. The order of ranking based on prices is positively correlated with the ease of access.

### 3.6 Awareness of the Raw Materials Used Make Packaging Bags

The results presented in figure 7 indicate that 96% of the respondents didn't know the materials used to make packaging bags. This is because most of the used bags are made out of synthetic materials which the farmers aren't familiar with. During the data collection process, the farmers were informed that some of the packaging materials are made out of crop residues such as maize stover, which was something new to them, and a typical surprise to many. The majority of the people had never heard about maize stover packaging, this is because of the limited innovations in the district and the country at large. Only 7% of the 200 farmers had heard about maize stover bags which isa small figure compared to 93% of those who don't know. When this information was shared with them, and asked to assess certain sampled (punnets) that were shown to them, a total of 96.5% indicated that they liked the sample. The majority (45.5%) ranked these punnets as the most environmentally friendly of all the existing and potential packaging material that can be used. This response is premised on the punnets being made from organic materials which have little or no effect to the environment and the soil. It is also believed that punnets decompose fast, hence adding manure to the soil.

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These were followed by sisal bags and paper bags as the top three most environmentally friendly.

### 3.7 Handling Of Maize Stover After Harvesting

Maize stover is harvested for multiple uses or left in the field. Farmers revealed that they mainlyuse maize stover for mulching (53.7%) (Table V). Other uses are ploughing the material back into the soil to sustain soil organic carbon (SOC), cycle essential plant nutrients, and protect soil health [40], following a harvest. It's a source of soil nutrients but the amount of macro and micronutrients in the maize stover of different varieties that are used, needs to be ascertained in order to attach the right value to it as a soil improver. Some farmers revealed that they burn it, and very few use it as second generation livestock feeds [11]. One clear attribute it has is the ability to improve soil structure, but it also has a high Carbon: Nutrient (C: N) ratio [41] (Mukai *et al.*, 2019).

**Table V: How maize stover is used after harvesting**

| Purpose | Frequency | Percentage |
|---|---|---|
| Mulching | 102 | 53.7 |
| Ploughed back into the soil | 37 | 19.5 |
| Livestock feed | 15 | 7.9 |
| Burnt | 32 | 16.8 |
| **Total** | **190** | **100.0** |

### 3.8 Other Packaging Materials Related Issues

Most farmers that were interviewed (80.1%) knew that some packaging bags were banned by the government and out of the 80.1%, only 79.5% knew that it was polythene. Though these people knew that the bags were banned [34], they were still using them. This is evidenced by earlier results that show their wide use of polythene bags. An inquiry into what would be their alternatives in case Government enforces the ban order on polythene bags, the majority indicated that sisal bags would be the number one alternative (23.5%), followed by paper bags. This was largely based on environmental friendliness. The majority of farmers (95.5%) claimed not to have used packaging material made out of maize stover. However, 99.0% prefer use of packaging materials made out of crop residues. Being farmers, the size of bags tends to matter because of the quantity they handle. Farmers tend to harvest goods in bulk. Therefore, big bags (of 70-100 kgs) account for the biggest percentage (53%) (Fig. 9). The bags are used during harvesting, storing and transporting of the produce to markets.

Post-harvest losses are some of the major problems facing the farmers in Kamuli [2]. These losses are mainly experienced during storage {42} and the losses in the store increasee if the bags in which the produce is kept are of poor quality. On this note, the majority of the people interviewed believed that the bio-based maize packaging materials will reduce on the post-harvest losses, as documented by [43]. This was indicatedby 95% of the farmers that were interviewed. The farmers interviewed indicated that they would recommend use of maize stover packaging materials to their fellow farmers (99%), retailers (97.4%), wholesalers (97.5%), processors (99.0%) and consumers (98.8%).

### 3.9 Selected Descriptive and Regression Analysis Results for Farmers

The mean age of farmers interviewed was 36.6 years (table VI), an indication that most of them are still energetic and would sustain production of maize to provide the desired raw materials for a package manufacturing factory. The mean quantity of maize usually marketed per farmer per season was reported to be 656 kilograms. Farmers reported that most of the maize is used for household food security needs. However, literature reports indicate that some of the farmers sell off most of the maizegrain they raise, for cash needs, which constrains the food security objective. The distance that farmers travel to market their produce is 5.2 kilometers. The quantity of produce damaged during transportation was estimated at 67 kilograms which is about 10%.

An estimated 29 bags are on average, purchased annually per farmer. Some of the bags are kept and re-used for 2-3 seasons, and this emphasizes the importance of durability of the packaging materials used. The amount of funds spent on packaging materials was UGX. 31,500[1] per annum. As aforementioned, some of the bags are kept for long and reused which reduces the amount of funds spent on bags in a year.

The punnet, produced from the pulped maize stover and presented to them was valued by farmers at UGX. 1,786 (about £ 0.39) per piece. Farmers also indicated that they are willing to pay an extra UGX. 2,292 (£ 0.50) for the same size of packaging materials that they are currently using, if it's made out of maize stover. This points to the value that farmers have attached to the bio-based maize stover packaging materials. There is a high level of doubt among farmers as to whether the packaging material made out of maize stover can replace the strong polypropylene bags in terms of durability and strength. Although farmers are not fully gaining known value for their stover, they indicated that if they are to sell off their maize stover, their asking price would be £26 per tonne. This needs to be compared with the values that can be earned through other potential uses of the stover that include mulching, and livestock feeds to ascertain whether its current use is optimal.

**Table VI: Selected descriptives for the respondents**

| Variable | n | Mean | Std. Error |
|---|---|---|---|
| Age (Years) | 129 | 36.6 | 1.0 |
| Quantity marketed (Kilograms/Season) | 197 | 656.1 | 77.6 |
| Distance travelled to markets (in Kilometres) | 26 | 5.2 | 1.1 |
| Quantity of produce damaged during transportation (in Kgs) | 53 | 67.2 | 14.5 |
| Number of bags needed annually | 200 | 29.4 | 3.9 |
| Funds spent on packaging materials annually (UGX/Kg) | 200 | 32,301.0 | 4,024.4 |
| Funds spent on packaging materials annually (pounds/kg) | 200 | 7.0 | 0.9 |
| Price offering (for the punnet) (in UGX/Kg) | 189 | 1,786.2 | 175.6 |
| How much more farmers are willing to buy compared to the current packaging materials (UGX) | 189 | 2,292.9 | 246.7 |
| Asking price for farmers maize stover (Pounds/Kg) | 102 | 0.026 | 0.0 |

**[1] The Exchange rate of UGX to Pound sterling is 4,500**

Analysis of selected variables by gender shows that female respondents reported significantly less years of education ($p<0.05$) compared to male farmers (table VII). They also reported less quantity of maize marketed, less distance travelled to markets and less produce that gets damaged while being transported. The asking price for the stover was significantly less for female compared to male farmers and this was significant at 10% ($p<0.10$). In this community, women are regarded as inferior due to being less educated, less exposed and with limited control over productive resources. Research findings show that joint implementation of farm activities leads to higher productivity [44], and this needs to be encouraged among maize farming households in order to improve and sustain maize production.

**Table VII: Comparisons of selected variables by gender**

| Variable | Sex | n | Mean | Std. Error Mean | P value |
|---|---|---|---|---|---|
| Education (Years in school) | Male | 70 | 7.140 | 0.321 | 0.002*** |
| | Female | 96 | 5.680 | 0.333 | |
| Quantity of maize marketed in a season (in Kgs) | Male | 77 | 777.140 | 137.530 | 0.232 |
| | Female | 120 | 578.500 | 91.773 | |
| Distance you travelled to market produce (in Kms) | Male | 12 | 5.717 | 1.949 | 0.667 |
| | Female | 14 | 4.686 | 1.332 | |
| Produce that gets damaged during transportation (in kgs) | Male | 14 | 70.860 | 33.748 | 0.896 |
| | Female | 39 | 65.900 | 15.826 | |
| Price for stover (in US Dollars) | Male | 44 | 0.039 | 0.006 | 0.062* |
| | Female | 58 | 0.024 | 0.005 | |

The price that farmers are willing to sell for the maize stover is correlated with age, sex and education. Results show some association between the asking price and age of the respondents (with an inverse relationship). Therefore the older the farmers the less price they ask for thestover. The relationship between the asking price, and sex of the respondents also exhibited an inverse relationship. This implies that female farmers ask for lower prices (inverse association) as compared to their male counterparts. With education, the more one is educated, the higher the asking price (positive association). However, these correlations were not significant at $p<0.05$.

### 3.11 Determinants of Number of Bags That Are Purchased Annually

A regression model that estimates the demand function for the packaging materials used by the farmers of maize was run. The results that are summarised in table VIII show that quantity of maize marketed has a significant influence on the number of bags purchased ($p<0.05$). This is expected *apriori* because the farmers transport their maize mainly in bags and as such those who market more maize, invariably buy more bags to hold their produce and safely transport it to the marketing destinations. Results also show that the further away the market where the maize is to be transported, the more bags that are purchased and this relationship is significant at 5% ($p<0.05$). This could be attributed to the need to have excess bags that may be used in case of emergencies such as heavy rains, or any unforeseen damages that may happen to the produce during the process of loading, transportation, off-loading, storage and actual marketing. It is also common practice for some farmers to pack the maize in sacks beyond the allowable 100 kgs. This is made possible by stuffing the maize grain with a stick, and adding additional weight on top to hold the produce.

There is a strong positive relationship between the funds spent, and bags purchased ($p<0.01$), implying that most bags are acquired through purchasing and this is in agreement with the findings of [45]. Sex of the head of the respondent showed a significant influence on number of bags purchased, with more male farmers spending more than their female counterparts ($p<0.10$) and this is also in tandem with the findings of Lavelle-Hill, et al, (2020) [45]. This could be attributed to more produce handled by male, and higher disposable income that is associated with more access to productive resources. Further, male farmers tend to operate more in the public domain, and as such move for long distances in search of more lucrative markets, compared to their female counterparts whose operations are relatively limited due to their household responsibilities.

**Table VIII: Regression results of number of bags that are purchased annually**

| Variable | Coefficient | t value | p value |
|---|---|---|---|
| (Constant) | | -6.381 | 0.000 |
| Age of the household head (in years) | -0.063 | -1.43 | 0.154 |
| Sex of the household head (1=Female, 0 otherwise) | -0.074 | -1.648 | 0.101 |
| Education (Number of years in school) | 0.033 | 0.728 | 0.467 |
| Quantity of maize marketed (kgs/year) | 0.225 | 4.583 | 0.000*** |
| Distance to the maize market | 0.093 | 2.194 | 0.029** |
| Funds spent on packaging materials (UGX/year) | 0.662 | 14.275 | 0.000*** |
| Annual Income (UGX) | 0.087 | 1.869 | 0.063* |
| Quantity of maize spoilt during transportation | 0.033 | 0.689 | 0.492 |
| | | | |
| **Model** | **Sum of Squares** | **df** | **Mean Square** |
| Regression | 47.561 | 7 | 6.794 |
| Residual | 113.006 | 192 | 0.589 |
| Total | 160.567 | 199 | |

F (11.544, $p<0.05$); Adjusted R=0.645

## IV. Conclusions and Recommendations

From the results it can be concluded that maize is a major crop in the business endeavors of the small scale farmers in the Kamuli District of Uganda. Both male and female farmers are involved in maize production, trade and processing activities. However, female farmers get crowded out as one moves to the more lucrative high end nodes of the chain. Most of the players possess modest education levels that enable them to have literacy and numeracy skills, but by and large, its low compared to the national average and international standards. This makes these farmers less competitive globally. A lot of maize is produced in Kamuli district, and invariably, maize stover which is not optimally utilized by farmers. A good percentage of farmers still destroy the maize stover through burning,a practice that is not recommended as a crop husbandry practice. However, on a good note, many of the farmers use the maize stover to replenish the lost soil nutrients following their harvests.The study showed farmers, and other stakeholders, that there are better maize stover utilization propositions, that can earn farmers more value. Regarding the use of maize stover, it has been ascertained that polypropylene is the most preferred and used packaging material. Choice of the packaging materials that farmers use and prefer is a function of availability and accessibility, and price. It is documented that polypropylene is readily available and relatively inexpensive, has high flexural and good impact strength, with slippery surface, resistant to absorbing moisture, possesses good fatigue resistance, and is a good electrical insulator [46].

Most of the respondents are willing to pay a higher price to use packaging materials made out of maize stover, as they believe that the packaging materials from stover will be moreenvironmentally friendly and will reduce post-harvest losses. Results showed that farmers need the big size bags (100 kgs) which are estimated on average, for each persons per year as 29.4 bags. The number of packaging materials purchased is influenced by quantity of maize marketed, distance to the market where the maize is to be transported, and being a male farmer. The price that farmers are willing to ask for their stover is associated with age, sex and education. The older the farmers the less price they ask for the stover. Likewise, female ask for lower prices (inverse association). With education, the more one is educated, the higher the asking price (positive association).

Based on the findings, it can be recommended that awareness creation should be enhanced to inform maize farmers that maize stover is not waste. It should therefore be put to more economic use that brings value to households, the environment and to the entire value chain. Since propylene packaging materials are the most preferred and used, the factors that drive this preference and demand need to be factored into the process of manufacturing maize stover packages. These include; availability, ease to access, appropriate size, durability, rain proof, and affordability. In order to increase the demand for packaging materials that will ultimately drive the purchase of maize stover packages with time, the determinants of demand for the quantity of packaging materials must be addressed. The quantity of maize produced and marketed need to increase. More sensitization and emphasis need to be put on female maize farmers to increase their production and marketing focus that will culminate into higher demand for packaging material. It is imperative to undertake a study to document the most efficient way to utilize the maize stover, given all the possible pathways available to the farmers. Through this, farmers willbe empowered to gain optimal value from their maize production venture.In terms of policy, the Government needs to invest further into exploring the requirements to manufacture packages from maize stover, and thereafter, terminally stop manufacture and use of packaging materials that enhance environmental degradation.

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