EBAFOSA
Ecosystem Based Adaptation for Food Security Assembly

SOLAR DRYER FEASIBILITY REPORT FOR UGANDA

SOLAR DRYING TECHNOLOGY FOR POST-HARVEST HANDLING OF CASSAVA IN BUGANDA KINGDOM REGION

WWW.EBAFOSA.ORG

TABLE OF CONTENTS

CONTEXT

Uganda's largest employer is the agriculture sector, which provides livelihoods for up to 70% of the country's working population. The sector contributes up to 22% of GDP and 34% of export earnings. The country's national development blueprint, the 3rd National Development Plan (NDP3), a derivative of the vision 2040, underscores the agriculture sector as the critical pathway to enhance the productivity of Uganda's economies to middle-income status. However, one of the significant limiting productivity factors in this strategic sector is post-harvest losses (PHLs). The country experiences on average up to 17.6% in annual postharvest losses (PHLs), which reach a high of 45%. In two of the vital food groups consumed in the country – grains and root crops – the country faces about 10-15% and 20-25% of PHLs respectively for each food group, and the key driver is inadequate value addition. For example, over 80% of Cassava farmers dry their products by traditional drying methods such as open sun drying. However, these drying practices produce a varying quality of dried products, including long drying times that may result in discoloration, inadequate drying that results in yeast, mold, and aflatoxin attacks, which render the cassava unusable for humans industrial use. The quality of dried products depends on factors like cassava chip size, drying technology, temperature, airflow and relative humidity. Farmers in Central Uganda are faced with challenges of inadequate knowledge on post-harvest handling and food waste reduction; this was evidenced among farmers. Gaps experienced by farmers along the agro-value chain include post-harvest losses, harsh weather conditions, losses in income due to poor storage of harvest, traditional drying techniques, and insufficient bargaining power for agriculture commodities on the market.

Application of accessible climate action solutions of solar dryers has been shown capable of reversing these losses affordably. For example, informal food traders in markets across Africa have revolutionized solutions to these losses by embracing solar dryers. Instead of counting losses of stocks that remain unsold at the end of day, the entry of a solar dryer enables traders to dehydrate their unsold stocks and convert into dry products sold in the market. The result is an up to 30 times increase in revenues, a highly effective solution to mitigate even losses occasioned by the COVID-19 containment measures that have meant a closure of markets and a big loss in the stock of perishables – increasing by up to 50% in some cases across Africa.

These solar dryer climate action solutions also align with Uganda's strategic climate aims. Uganda is also among countries that have submitted revised climate commitments popularly called Nationally Determined Contributions (NDCs) where it aims to reduce emissions by up to 22%. Increased investment in solar is among priority actions. Therefore, the solar dryer stands out as an accessible climate action solution to drive the building of climate resilience while actualizing strategic socioeconomic & climate objectives of the country. In addition, these dryers have been endorsed by the statutory national standards body of Uganda – the Uganda National Bureau of Standards (UNBS). As an effective, affordable tool that stakeholders can use to achieve compliance in key areas of food safety & quality and environmental compliance by actualizing the moisture content thresholds needed to prevent growth of mycotoxins in a hygienic environment that does also not cause emissions.

Based on these socioeconomic, policy, and climate alignments benefits of solar dryers through reversing PHLs and enhancing food & livelihood security, this study was undertaken to gauge the potential for uptake at scale. This study aims at:

- establishing productivity gaps experienced by agro-value chain actors engaged in diverse value chains, especially the cassava value chain, which is the second most important staple in Uganda farmed by over 70% of the population in the country,

- establishing the viability of introducing climate action solutions of solar dryers for uptake by the communities in converting losses into productivity to enhance food & livelihood security.

Based on these findings, a case for the market uptake of these climate action solutions at the community level can be made. Beyond this, the results will be timely to inform optimal implementation pathways of relevant UNBS standards. Findings will also be timely to inform areas for policy prioritization in enhancing the Sustainable Development Goals (SDGs) implementation through leveraging food systems. The gaps to be studied include postharvest losses, losses in incomes, as well as readiness and willingness of the communities to take up and implement the climate action solutions of solar dryers to reverse these losses. This study adopted a combination of literature review and survey strategy.

LITERATURE REVIEWED

SOLAR DRYING TECHNOLOGY

SOLAR DRYING PRINCIPLE AND MECHANISMS

Drying is a food preservation technique that has been practised for centuries (Saleh et al., 2017). It is common to extend the shelf life of different kinds of food products, from fruits, herbs, and animal and marine-based products.

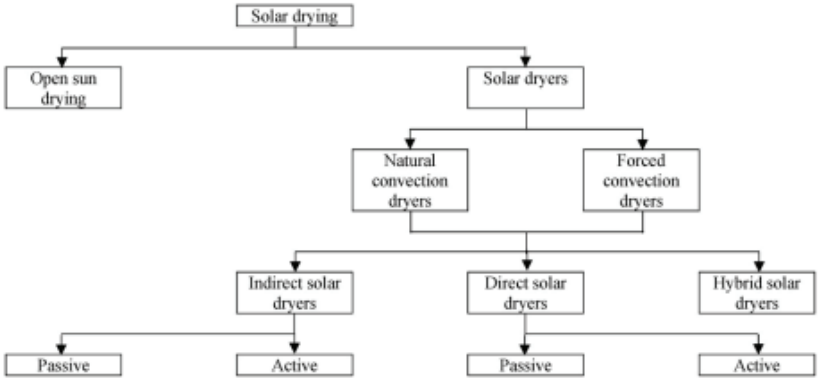
- In drying, excess moisture from food products is removed due to thermal action. The resulting end products with moisture reduction inhibit microbial growth, which can be stored for future use. During moisture removal, simultaneous mass and heat transfer occur within the sample, outer surface, and heating air. Solar drying provides an alternative to the conventional drying process. Contrary to sun drying, where food products are being exposed to dry directly under the sun, solar drying utilizes a heat entrapment mechanism to enhance the moisture removal process. The application of solar dryer converts solar energy using solar collector UV Polythene sheet into useful thermal energy. Thus, solar dryer systems are capable to increase the operating temperature to 50-60 °C which resulted in perfect drying and product quality.
- Due to higher drying temperature, solar dryer minimizes the area needed to expose the products to hot air. Solar dryer is also less dependent on sunshine availability, as it can utilized thermal energy storage systems and auxiliary heating unit for heat supply. Construction of solar dryers includes drying chamber, which isolates the products from ambient surroundings. Thus, final products from solar driers are less susceptible to contamination from dust, insects, and microbial growth.
- In general, bacterial pathogens, fungi, and most waterborne viruses are highly sensitive to solar radiation

and high temperatures. During solar drying, especially in direct solar drying, food products are exposed to relatively high temperatures and ultraviolet (UV) radiation, which can prevent microorganisms from replicating[1].

TYPES OF SOLAR DRYERS

Solar dryers are grouped into direct solar dryer, indirect solar dryer, mixed mode solar dryer, and hybrid solar dryer. The working principle and mechanism are different in terms of solar energy conversion to thermal energy.

Solar dryer classification



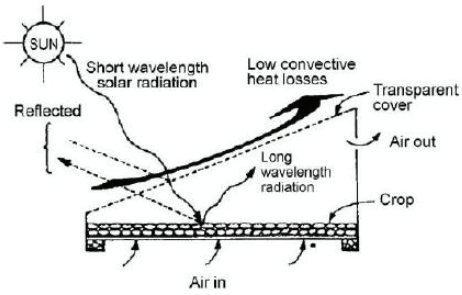
Source ***(Udomkun, 2020)***

Direct solar dryer; Direct mode of drying usually consists of the drying chamber covered by a transparent material. This transparent material acting as the glazing, allows solar radiation into the chamber to heat up and increase the temperature of the air and the crop being dried (Saleh et al., 2017).

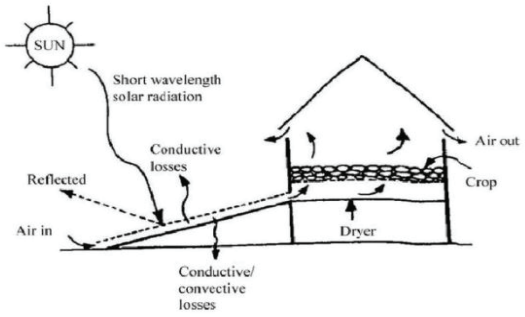
Indirect solar dryer; the crops in these indirect solar dryers are located in trays or shelves inside an opaque drying cabinet. A separate unit termed as solar collector is used for heating the entering air into the cabinet. The heated air is allowed to flow through/over the wet crop that provides the heat for moisture evaporation by convective heat transfer between the hot air and the wet crop. Drying occurs due to the difference in moisture concentration between the drying air and the air in the vicinity of the crop surface.

Mixed Mode solar dryer Mixed-mode dryer utilizes both direct mode in drying chamber, and indirect mode in its collector unit, where as hybrid dryer on the other hand refers to the usage of supplementary source of energy i.e. biomass, diesel engine, photovoltaic integration to supply heat.

1 https://doi.org/10.1007/s43621-021-00049-4



Working principle of direct drying



Working principle of indirect solar dryer

Benefits of the solar drying technology to the farming system in Uganda

During the last decades, various types of solar dryers have been developed to reduce post-harvest losses and to improve product quality[2]. Solar drying is an emerging technology to preserve a wide range of products in the agriculture sector[3]. In Uganda, using solar drying technology enables rural communities to consume healthy food and diet, improving food security and nutrition. This work has heightened some of the economic, social, and environmental benefits of the solar drying technology in the village savings and loans association food system actors. The application of solar dryers, however, must be evaluated to determine their benefit and effectiveness.

ECONOMIC BENEFITS AND RISKS

Compared to traditional sun drying methods, solar dryers offer several economic advantages such as; lower costs for fossil fuel and combustion equipment. They also achieve high-quality products and thus increase the market value, secure stable and high income even under various climatic conditions. Specifically, the use of solar dryers enables small-scale producers to significantly reduce post-harvest losses in a cost-effective and energy-efficient manner, improve the quality of food, and generate additional income and employment opportunities for youth and women, enabling the development of small-scale industries for cassava packing, fruit for sale both local and international markets.

ENVIRONMENTAL BENEFITS

Fossil fuels and electricity are widely used as energy sources in most drying systems, resulting in high operational costs and environmental problems by increasing greenhouse gas (GHG) emissions. As a result, food producers have shifted towards clean energy-based technologies such as solar and thermal energy in both direct and indirect forms

2 Review of solar dryers for agricultural products in Asia and Africa: An innovation landscape approach

3 Energy-economic-environmental analysis of solar drying system: a review https://www.researchgate.net/publication/341835476_Energy-economic-environmental_analysis_of_solar_drying_system_a_review

SOCIAL BENEFITS

Climate change impacts are at a high level in the world, and they are caused due to human activities contributing to high levels of greenhouse gas emission, which pose a significant threat to the global. Government, organizations and people worldwide have attempted to combat emission by switching from fossil fuel-based energy to solar energy.

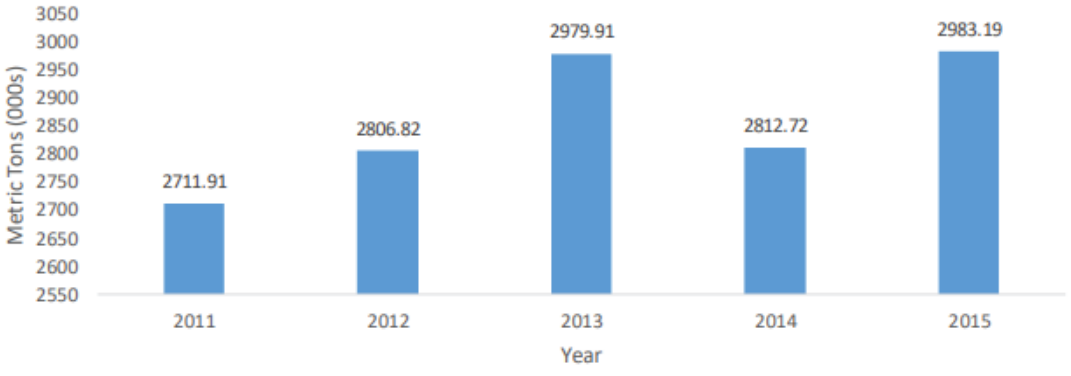
The social benefit includes the following;

- provided the most jobs, income-generating activities, social networking and cohesion. For example, in 2016, the renewable energy sector created employment opportunities for about 9.8 million people. Most of these employment opportunities are from Asia, particularly in China, which accounts for 62% of all the renewable energy jobs
- In addition, solar energy would significantly improve public health as various epidemiological studies have found that GHG emissions can elevate risks of non-allergic respiratory and cardiovascular morbidity, cancer, allergic illnesses, and adverse outcomes in pregnancy and birth
- preserve the quality of agricultural products. Small-scale farmers mostly use open-air sun-drying, which compromises the quality of food dried
- use of; solar drying has been developed to respond to the high demand from both domestic and international markets for dried agricultural products. For example, in Uganda for decades, drying of agricultural commodities on dirty surfaces has been widely used by farmers in Mukono district; food develops microorganisms and worms, which negatively affect the health of the population
- Using solar drying reduce on lengthy drying time required for any given commodity (5–7 days), resulting in high yield losses. For example, a solar dryer developed takes two days for food to dry to a moisture content below 12 per cent compared to intervals of up to 5 days for open-air/sun drying.

POSTHARVEST GAPS IN CASSAVA FARMING IN UGANDA

According to (MAAIF, 2017)requires utilization of a mutual accountability tool in the form of national level Joint Sector Reviews (JSRs Cassava is one of the 12 priority crops being promoted under ASSP (2015/16 – 2019/2020) in Uganda. Trends in Cassava production from 2011 to 2015 as indicated in Fig 1

.Figure 2 Cassava Production Trends in Uganda 2011 to 2016



Source: MAAIF Statistical abstract 2015/16

The literate shows that cassava production has been increasing, but postharvest handling development has not kept pace.

JUSTIFICATION FOR AREA OF WORK

Two key priorities informed the selection of study areas.

First was the need to focus on leading food basket areas of Uganda, which also experienced significant postharvest losses. Accordingly, the study area in the Buganda kingdom is a leading food basket area in the country that experiences high postharvest losses and food waste, low prices for agriculture products.

The second was the need to respond to positive interest expressed by local government in driving uptake of climate action solutions to meet their socio-economic development needs. Accordingly, there has been high interest from local government in the Buganda kingdom, including through their cassava agro-industrialization strategy, to take up climate action solutions to enhance the productivity of agro-value chains of the target communities. This is delivered through a low risk, cooperative structure for accountability and traceability of actions. Accordingly, the opportunity of leveraging on the Buganda Kingdom CBS-PEWOSA cooperative Village savings and loans associations (Vsla) provided a timely entry point. Groups of agro-value chain actors in Mukono, Buikwe, Luwero districts in counties of Kyaggwe, Bulemezi, counties in the Buganda Kingdom were engaged.

SURVEY AREAS

A 2014 baseline survey revealed that an average Ugandan farmer loses about 30% of their yields due to poor post-handlingpractices.

This study was conducted in Central Uganda in areas where UNEP-EBAFOSA Uganda implements the EBAFOSA / Buganda Cassava initiative. This aims to establish gaps experienced by agro-value chain actors in central Uganda, investigating and validating postharvest technologies and enhancing post-harvest handling practices. The feasibility study aims to improve post-harvest methods and reduce food loss by rural farmers and communities in the broader context. The study focused on four districts that were purposively selected based on their vulnerability and food loss. In Uganda, districts prominent in cassava production in the central region include; Mukono, Buikwe, Luwero and Gomba districts in the central part of Uganda.

The Central Region, Uganda/ Buganda region has the highest population as of Uganda's 2014 census; the region's population was 9,529,227[4] (NPHC, 2016). With Buikwe district population, the mid-2011 Sub National projections report of the central region (2008-2012) indicate that Buikwe's population is 407,100 with 200200 males and 206,900 females[5]The 2014 Population Census Final Results put Mukono's population at 599,817 and the projected population at 601,516 by mid-2015 (including Municipal council)[6] Luwero's population at 599,817 and the projected population at 601,516 by mid-2015 (including Municipal council)[7]

In Buikwe district the study was at Ggera Village with Ggera Village saving and Loans Association (VSLA) , sugu village

4 National Population and Housing Census 2014 https://unstats.un.org/unsd/demographic-social/census/documents/Uganda/UGA-2014-11.pdf
5 https://buikwe.go.ug/district/population
6 https://mukono.go.ug/lg/location-size
7 https://www.luwero.go.ug/lg/population-culture

with Sugu Aglyawamu VSLA and Mukono at Nsonga Village with Nsonga VSLA and Luwero Kalungu village, Mukama Mulungi VSLA and Twekimbe Kakoma Women and Men group Gomba

Therefore, the study analyses the available market opportunities and market performance of value chains originating from the central region of Uganda, where EBAFOSA Uganda has project sites and potential beneficiaries of its agribusiness development and storage construction intervention.

THE GENERAL OBJECTIVE OF THE FEASIBILITY STUDY

The study was to establish gaps on the ground experienced by agro-value chain actors – in the form of PHLs and losses in income in Buganda kingdom with emphasis on introducing a climate action solution of communal solar dryers to cut these losses using a Pay as You Go, model. The study's overall objective was to establish gaps on the ground experienced by agro-value chain actors in the form of PHLs and losses in income in the Buganda kingdom central, Uganda. And to assess the practicality of introducing a climate action solution of communal solar dryers to cut these losses through communal rather than individualized use.

Specific objectives

- To gather data on the extent of post-harvest losses incurred by farmers – both in weight and monetary and the gaps in drying technology driving losses
- To document existing value addition/drying techniques currently applied by farmers and establish their acceptability for uptake of solar dryers
- To map potential areas that will be used to apply the solar dryer solutions.

METHODOLOGY

The study used desk and field research methods, interviews, and field observation, focusing primarily on smallholder cassava farmers and associated value chains in the Buganda Kingdom, including districts near Lake Victoria and others in the cattle corridor. One hundred twenty-five members (125) were interviewed and, in this study, purposive sampling technique from 5 village savings and loans associations. These were sampled judgementally based on their high level of activity in the agro-value chains. Hence, more comprehensive experience to share to provide more data inform more details of the study. These were in the areas of Mukono, Buikwe, Luwero districts. Their members were primary cassava producers, and coffee, vegetables, beans, and some grew groundnuts as a group.

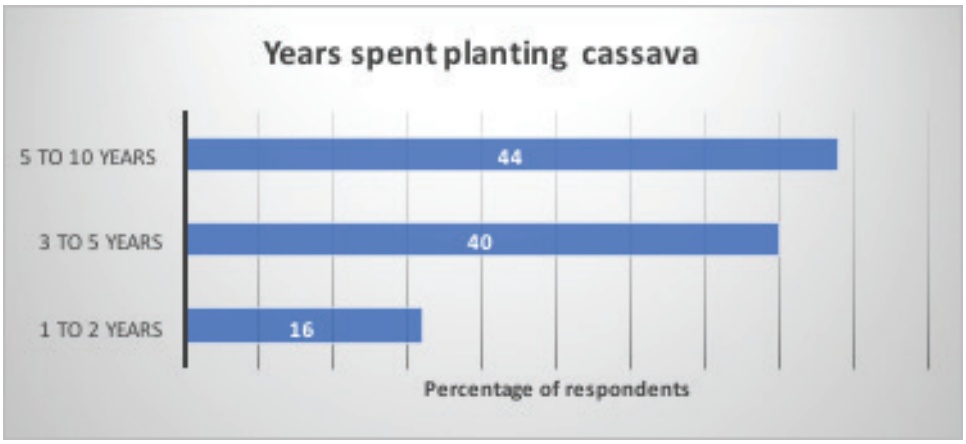
Overall, the farmers interviewed cited challenges experienced along the cassava value chain, methods used for drying and storage of food after drying. In the focus group discussions (FGDs), farmers reported that their cassava and other agricultural products are sold mainly in raw form. Primary agriculture production is farmers' main activity, which means minimal value addition and increased risk for PHLs. For example, during the harvest period in the wet season, crops rot, which reduces their harvest because they lack technologies of drying food to increase its shelf life. Dried food is mainly for home consumption.

Results and data collected

In the Village Savings and loans association, farmers interviewed and observed in this report most food loss takes place after harvesting between the field, drying, storage and market; some of the post-harvest handling challenges cited by farmers include:

i. Insufficient training on post-harvest handling
ii. Poor storage facilitates when the crops are fresh, after drying of cassava
iii. Limited information and data on food handling

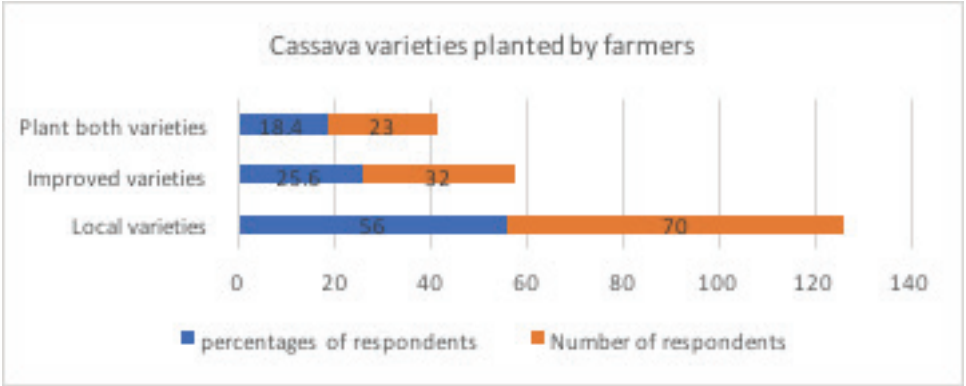
44% of respondents interviewed have spent 5 to 10 years growing cassava in their community for food and commercial consumption. 40% of those have planted cassava 3-to-5-year duration, and the 16% of the respondents have just started planting cassava, they have been planting coffee and banana, carrying out trade mainly retail business.



Cassava Varieties planted by farmers

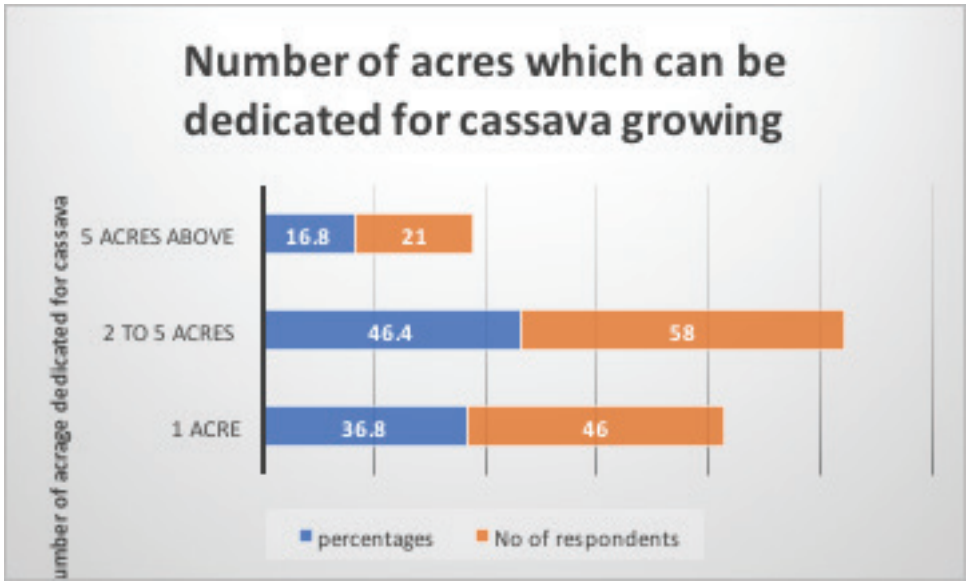
Farmers over the years have cultivated a variety of cassava varieties on their farms that are adapted to particular needs and conditions. Most farmers plant varieties in multiple plots, replanting immediately after harvesting, sharing with fellow neighbours and friends planting disease-free materials. 56% of respondents ensure that they preserve local varieties of interest for decades to be replanted. 25.6% of farmers plant improved varieties of NASE 14, NAROCAS1, Nigeria and Migera were some of the listed improved varieties.

Whereas 18.4% plant both varieties on their farms, most of them commented that their local varieties are weak and not resistant to cassava brown stalk diseases (CBSD). Some of the local varieties preserved, including Njule and Kwatamumpale, were common in the study.



Number of acreages dedicated to cassava by farmers during the study

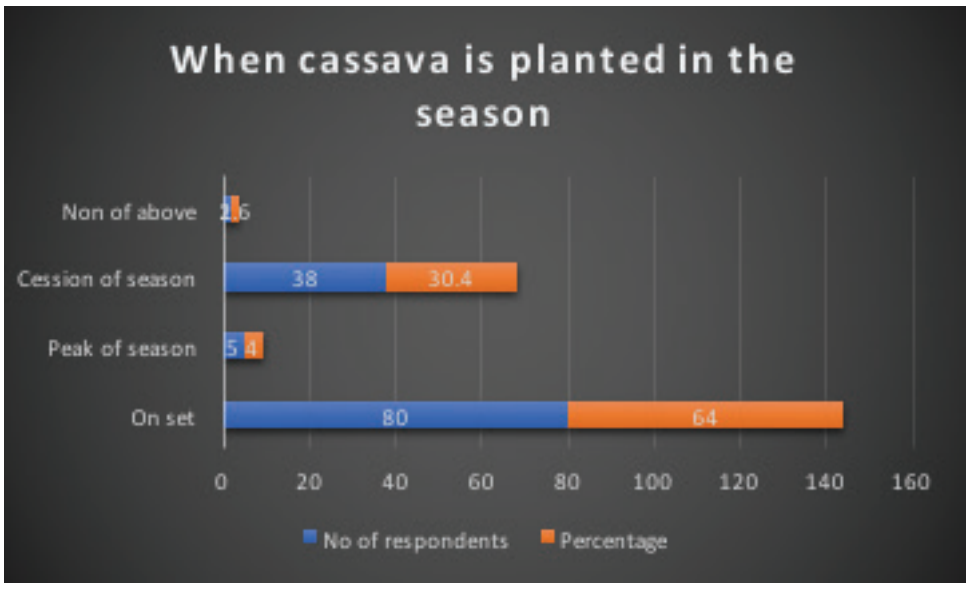
During the study, 46.4% of dedicate 2 to 5 acres of land for cassava growing and 16.8% have 5 acres above and I acre 36.8%. Although land fragment is affecting the land system in the central region due to high population and high urbanization, agriculture isn't taken as a priority by most of the farmers in rural areas have sold off their land to commercial farmers to prefer planting exotic trees Eucalyptus.



Time of season when cassava is planted

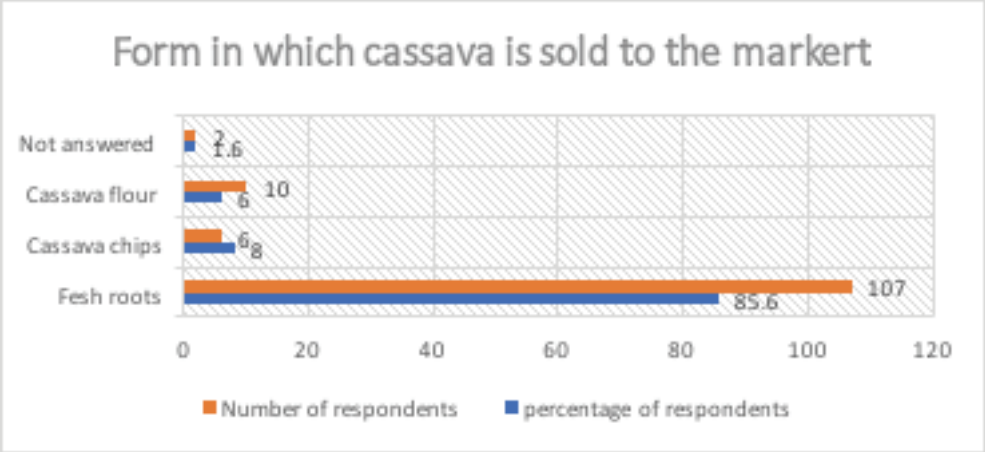
Uganda experiences three major seasons, which farmers use to make decisions when to plant their crops. Seasons include May- April and May (MAM), June, July and August (JJA), September, October, November and December (SOND); in all those seasons, the central region at least receives some rainfall to enable crops like cassava to grow.

In any of the seasons, 64% of the respondents prefer planting crops during the onset of the rain season and 38% during the cessation of the season; only 4% of respondents grow cassava during the peak of the rains. Farmers cite that when cassava plants at the onset of rains most times the weather condition is still hot to enable sprouting of cassava roots compared during the peak of the rains in a season.



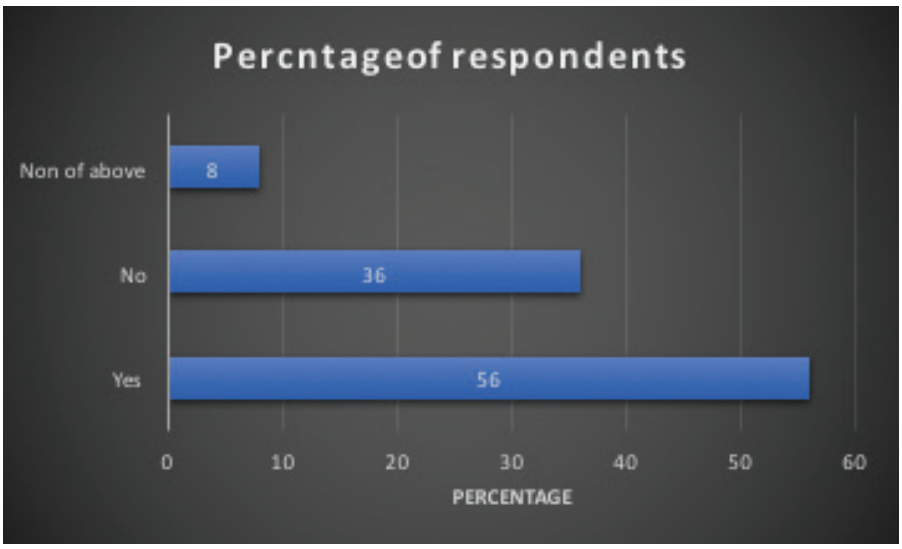
Forms in which cassava is sold to the market

85.6% of farmers sell their cassava roots fresh farmers present reason that needs quick cash to buy basic needs. 8 % sell cassava chips dried using traditional open methods. Dried cassava roots are prepared both for home consumption and for sale. Women sell them directly in the local markets, and traders sell them across Uganda markets in Kisenyi, Kawempe. None of the farmers sells to bakery or biscuit companies due to poor post-harvest handling methods, which makes cassava contain dust, foreign matter, and insects after drying see Figure 4, especially in the northern and western parts of the country. This product represents a vital economic resource for the rural families of central region districts. The product is packed In suckers ranging from 50kg and 100kgs, mainly flour and chips.

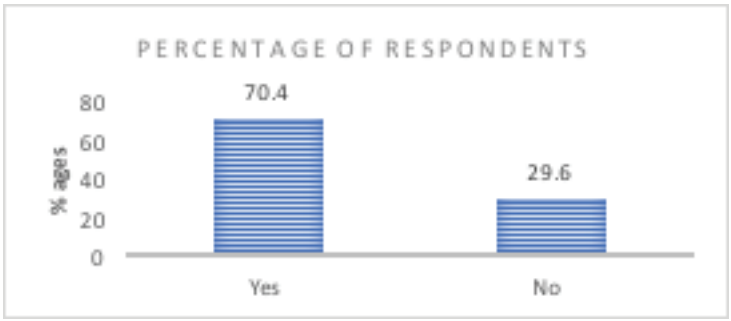


Respondents who know about the solar dryer usage

Cassava farmers use different drying methods. Traditional open sun drying is a highly used method of drying cassava seen in Figures 4 and 5. 56% of the respondents know that the solar dryer exists and usage. 36% don't know about the solar dryer. This work strives to scale the program of increasing the fabrication of solar dryers centres to enable reduction of post-harvest losses and food waster, Village savings and loans association of Suugu Aglyawamu VSLAs, Nsonga VSLA, Ggera VSLA, Mukama Mulungi VSLA and Twekembe Kakoma Women and Men group Bukandula know the usage and how the solar dryer operates.



70.4% of members of the village savings and loans association (VSLA) are willing to accept and use the solar drying centre communally with fellow members of VSLAs and village when given the support of the fabrication by EBAFOSA Uganda. 29.6% are willing to use a solar dryer individually to dry cassava and other agricultural produce.



Methods of drying agriculture products

Using observation and interviews, most respondents of the study use traditional open-air sun drying of cassava and other agriculture commodities. The product is dried on dirt and dusty surfaces, which can lead to mold development, compromising the quality of food in local and international markets. A member of Suugu Village saving and loans association, iron sheets to dry food in open sun drying and cassava chips cut had big diameters that took at least 10 days.

Cassava chips have taken one week outside day & night

Cassava Chips dried in open air on an iron sheet

Coffee is dried on dirty traplines by VSLA members

Drying of coffee on clean trapline but farmers are distributed by harsh weather

Figure 3 open sun drying of cassava chips

For agricultural products, traditional open-air sun drying is still the most commonly employed method for cassava chips in many villages of the Mukono district. However, this traditional method leads to severe post-harvest and food losses, especially for highly perishable agriculture products such as vegetables, fruits and cassava. Exposure of cassava chips to rain, wind, dust and insects and other contaminants lead to increased microbial populations (Fig 2)

Figure 4 Drying methods by used by farmers

Cassava chips dried on dirty polythene sheets

Cassava developed molds which cause aflatoxins to human beings

Test pilots introducing solar dryer Solution to reduce Post-harvest losses

Based on these gaps, solar dryers were decentralized to the study area on a pilot basis to validate potential uptake. EBAFOSA Uganda introduced locally made mechanical solar drying technology to the rural village saving and loans associations in Mukono, Buikwe district. The solar dryer consists of a structure with a size of 5 feet by 6 feet built with a blower which enables air to enter to reduce moisture content on the food, with a UV polytene and black sheet at the bottom to allow absorption of heat, which later fasten drying of food in the lower trays. The solar dryer introduced is a direct solar dryer and is easy to be fabricated by youth and farmers.

Figure 5 Solar dryer centres used to reduce post-harvest losses and food waste

Kakoma VSLA Farmers spread Cassava chips on the trays

Suugu VSLA Farmers inserting a tray of casava chips in the dryer

Structure of direct solar dryer fabricated by EBAFOSA Innovative Volunteerism actors

Food inside the solar dryer

Using this solar drying system, the product quality (Fig.2) is improved because no foreign matter, insects and dust can enter inside the solar dryer; the solar dryer is enclosed with UV polythene. The volume of dried products increased compared to traditional drying. For example, households in Ggera Village savings and loans association lack enough space to dry products when they come to drying centre in arrange of 2 to 3 days 200 kilograms of cassava has dried, because in the solar dryer the farmer harvests once the crops and dry's once hence providing them time to plan for other activities like marketing

The drying time was reduced from 5-7 days to 3–4 days, and the price significantly tripled compared to the open-air sun-dried products. For example, In Mukono district Nsonga Village, cassava chips dried on bear ground, dirty surfaces, and dust roofs cost UGX 300 - 400; when dried with a solar dryer, cassava chips can cost at farm gate price of UGX 700 to 800. Hence making a solar dryer a game-changer for agriculture systems in Uganda when adopted by farmers.

The establishment of the solar dryer centre successfully encouraged other small-scale producers in the same district to use solar dryers on a contract basis. For example, EBAFOSA Uganda supported Mukama Mulungi Village saving and Loans Association in Luwero district with a solar dryer. This attracted other farmers who had a bumper harvest of pumpkins to contract members of this VSLA to dry over one 1tonne of pumpkins into chips.

EBAFOSA Uganda provides Zero-cost training under the EBAFOSA/Buganda kingdom cassava initiative. This has been observed through monitoring visits of the village's farmers changing from traditional drying methods to solar

drying, a positive impact in the community.

To increase the sense of ownership and confidence in the program, EBAFOSA Uganda established a contract with the Village Savings and Loans Association. For example, in the 6 centres established by this work, farmers are encouraged to pay at least UGX 100 on the kilograms dried to act as a maintenance fee and enable the programme's sustainability.

The full empirical results of solar dryer pilot application were achieved in a test report attached here:

Drying rates of cassava chips in the \s

The dryers were also tested for their effectiveness compared to the traditional drying approach of open sun drying. The results demonstrate the increased efficiency of solar dryers compared to open sun drying, which is the alternative used by communities in the areas

Table showing* performance of cassava chips *Moisture content and temperature rates of cassava inside the dryer Vs traditional open sun drying for day one -Sugu Agalyawamu Women group

Crop dried	Drying rates intervals / Record-ings	The weather condi-tion of the area	Time inter-val of read-ing samples in the solar dryer	Time interval of reading samples on the open sunshine/ ground	Diameters of the samples dried in both	Kilo-grams dried in a solar dryer	Kilo-grams dried in the open sun	Solar dryer drying rates Moisture) levels/con-(tent (ages%)	Solar dryer Temp readings in degrees Centigrade C°	Open sun drying rates Moisture) (levels	Open sun drying Temp In degrees Centigrade C°
Cas-sava chips	1st read-ing	Cloudy	am 10:00	10:05am	Grated cassava	20kgs	20kg	31.5%	32.1	31.5%	28.2
	2nd reading	Cloudy	noon 12:00	12:05	Grated cassava			26.0%	38.3	29.0%	31.2
	3rd reading	Sunny	3:00pm	3:05pm	Grated cassava			28.5%	42.0	29.5%	31.6
	4th reading	Sunny	4:00pm	4:05	Grated cassava			27.5%	40.3	26.5%	28.1
	5th reading	Sunny	5:00pm	5:05pm	Grated cassava			23.0%	29.0	23.5%	27.8

Table 2 below shows the performance of cassava chips moisture content readings of cassava chips of the solar dryer and .samples dried in the open on day two

Crop dried	Drying rates intervals / Record-ings	The weather condi-tion of the area	Time inter-val of read-ing samples in the solar dryer	Time interval of reading samples on the open sunshine/ ground	Diameters of the samples dried in both	Kilo-grams dried in a solar dryer	Kilo-grams dried in the open sun	Solar dryer drying rates Moisture) (content (ages%)	Solar dryer Temp readings in degrees Centigrade C°	Open sun drying rates Moisture) (content age%	Open sun drying Temp In degrees Centigrade C°
Cas-sava chips	1st reading	Cloudy	am 10:00	10:05am	Grated cassava	20kg	20kg	24.0%	36.2	18.5%	30.7
	2nd reading	Sunny	noon 12:00	12:05	Grated cassava			14.0%	47.1	18.0%	38.8
	3rd reading	Sunny	2:00pm	2:00pm	Grated cassava			13.0%	52.3	10.5%	40.5
	4th reading	Sunny	4:30pm	4:32	Grated cassava			8.5%	34.1	9.0%	32.5

Table 1 Drying rates of cassava chips in the solar dryer and tradition open sun drying Source UNEP- EBAFOSA UGANDA REPORT

IMPACT OF COOPERATING AROUND SOLAR DRYER SOLUTION

The pilot test drying centres were installed for communal use by members of different local cooperatives / VSLAs. 5 VSLAs were engaged in these pilot studies, Including; Suugu Aglyawamu VSLAs, Nsonga VSLA, Ggera Fortune VSLA, Mukama Mulungi VSLA and Twekembe Kakoma Men And Women Group, with each getting their dryer. A total of 125 persons used the dryers to generate impact over a period of 10 months. The approach of "co-operating" around accessing and using the solar dryers as a shared service, as opposed to each being required to get their own solar dryer, was hailed by the communities as low risk. This impact-oriented method was practical in ensuring affordable access to solar dryer solutions that would otherwise be unaffordable for farmers to purchase out of pocket.

All 125 farmers engaged in the study belonged to a cooperative, and they all require solar dryer,

One of the notable impacts of this study arose from the practicality of the dryers to cutting PHLs during the COVID-19 lockdowns that necessitated the closure of markets and resulted in a backlog of stock of perishables. Among those engaged in the tests were market traders. During the COVID-19 period, while others were counting losses arising from the closure of markets, beneficiary communities accessed climate action solutions of solar dryers. They realized a reduction of pumpkin losses by 28%, enhanced earnings from high-quality dried cassava by $50 per farmer group while creating income for the youth who decentralized these dryers. The implications were that climate priorities were implemented, and at the same time, incomes were created to enhance livelihoods and the socioeconomic resilience of communities. These socioeconomic benefits provide market pull factors for the shift in local investment towards NDCs implementation. This data on impact is available for uptake to inform policies towards incentivizing such proven pathways of NDCs implementation that engage society.

MAJOR FACTORS AFFECTING SOLAR DRYING WEATHER CONDITION

The performance of a solar dryer is significantly dependent on the weather condition of the area where the solar dryer is installed. Both the heat and wind are required for removing the moisture content necessary for fast drying food on the tray; however, the location of the direct solar dryer is critical to position the blower or inlet towards the direction of the wind. In addition to the pre-treatment of the product, the weather conditions have the most significant influence on the capacity of the product that can be dried within a certain period.

According to observations during the dry season, sunny days products in the direct solar dryer dry faster most times temperature releasing to 40^{0}c to 59^{0}c this can happen during the hot afternoon of the day.

When it's raining, the solar dryer UV Polythene cannot be hit by the sun rays. This means that products will keep warm using the heat absorbed by the black iron sheet.

Advantages of solar drying crops in the solar dryer

- Solar dryers are more economical compared to dryers that run on conventional fuel/electricity.
- The drying process is completed in the most hygienic and eco-friendly way.
- Solar drying systems have low operation and maintenance costs.
- Solar dryers last longer/ durable

CONCLUSION

The feasibility study engaged 125 actors, predominantly small and medium scale farmers involved in cassava farming alongside other key value chains and who bear the brunt of PHLs. Although direct sun/air dryer is the predominant method used to preserve perishables, the longer drying times coupled with exposure of food to the elements and fluctuating drying efficiency dependent on prevailing weather have meant food items suffer quality losses. Be it through discolouration, mold/fungus attacks, dust and soiling from animals among other loss drivers. From the study, the average farmer loses up to 20,000 UGX due to post-harvest. This translate to losing about 80% of their product after every farming period.

These have laid bare the need for a better alternative. Pilot tests undertaken demonstrated the solar dryers' superiority in enhancing drying efficiency and covering other quality aspects critical to food safety, such as hygiene. The test community embraced the solar dryer climate action solutions to be taken up through the elaborate structure of accountability of their local cooperatives called VSLAs.

Among key success factors for the uptake of the dryer established, the population must believe that solar dryers can effectively add value to agricultural products compared to traditional open sun drying for more effective utilization. They must know how to use, operate, and maintain the solar dryer correctly and have an interest in alternative technology use. In addition, the construction materials and labour necessary for installation, operation, and maintenance must be locally available to ease the work.

NEXT STEPS

- Deployment of solar dryers to more solar dryer centres to operationalise a total of 5 solar dryer centres - to cover more farmers and enhance access among communities in Buganda.
- Data collection on the impact of the dryer centres in cutting PHLs, enhancing incomes, and driving the social, economic, and environmental dimension of the SDGs for uptake in implementing different sectorial policies – especially food safety standards.
- data feedback to inform SDGs policy implementation.

REFERENCES

Alonge, A. F., & Adeboye, O. A. (2012). Drying rates of some fruits and vegetables with passive solar dryers. *International Journal of Agricultural and Biological Engineering*, *5*(4). https://doi.org/10.3965/j.ijabe.20120504.00

Baysal, S. S., & Ülkü, M. A. (2021). *Food Loss and Waste*. *July*, 90–108. https://doi.org/10.4018/978-1-7998-8900-7.ch006

Jenkins, W., Tucker, M. E., & Grim, J. (2016). Routledge handbook of religion and ecology. In *Routledge Handbook of Religion and Ecology*. https://doi.org/10.4324/9781315764788

MAAIF. (2017). *THE REPUBLIC OF UGANDA MINISTRY OF AGRICULTURE , Performance Review Report*. https://www.agriculture.go.ug/wp-content/uploads/2019/09/MAAIF-Performance-Report-2016-2017.pdf

Matavel, C., Hoffmann, H., Rybak, C., Sieber, S., Müller, K., Brüntrup, M., & Salavessa, J. (2021). Passive solar dryers as sustainable alternatives for drying agricultural produce in sub-Saharan Africa: advances and challenges. *Discover Sustainability*, *2*(1). https://doi.org/10.1007/s43621-021-00049-4

NPHC. (2016). *The National Population and Housing Census 2014 – Main Report, Kampala, Uganda*. https://www.ubos.org/wp-content/uploads/publications/03_20182014_National_Census_Main_Report.pdf

Saleh, U. A., Onuigbo, F. I., Abdulrahman, S., & Ayodeji, A. E. (2017). Consruction of a Direct Solar Dryer for Perishable Farm Products. *International Journal of Scientific Research Engineering & Technology (IJSRET)*, *6*(2), 108–116.

Udomkun, P. et al. (2020). Review of solar dryers for agricultural products in Asia and Africa: An innovation landscape approach. *Journal of Environmental Management*, *Volume 268*, 1. https://doi.org/https://doi.org/10.1016/j.jenvman.2020.110730

ANNEX

ANNEXE 1: DETAILS OF COMMUNITY MEMBERS INTERVIEWED FOR DATA COLLECTION

The table below indicates the different farmers interviewed from 5 VSLAs in Buganda kingdom, central Uganda.

	Nsonga VSLA members		
1	Birungi Agnes	Female	0756751213/0774901104
2	Nolla Male		0751898731
3	Ssekamatte Ronald	Male	0751543150
4	Wanyale Abdulatif	Male	0756660661
5	Nabayego Annet	Female	
6	Namutebi Oliver	Female	0755029071
7	Akia Sarah	Female	
8	wanbowa Tracy	Female	
9	nakafu Trinity	Female	
10	mbekeka Josephine	Female	
11	Nakame Mariam	Female	0759122948
12	Katerega Mastula	Female	0752417285
13	Katerega Faridah	Female	0753139898
14	Nakate Daisy	Female	0702154814
15	Nakiyinji Catherine	Female	
16	Mirembe Gertrude	Female	
17	Nantongo Florence	Female	
18	Nakazzi Madinah	Female	
19	Nakityo Eve	Female	
20	Namutoosi Jalia	Female	
21	Namuswe	Female	

22	Ndagire Lukwago	Female	
23	Nakasagga Victoria	Female	
24	Lule Agnes	Female	
25	Nakafu Edith	Female	
26	Nampeera Jacinta	Female	
Ggera Village savings and loans association located Buikwe district – Ggera village			
27	Nakabogo Betty	Female	770571132
28	Bakanansa Keti	Female	703492047
29	Alibakiriza Recheal	Female	
30	Nasanga Goretti	Female	701758366
31	Nabulime Catherine	Female	706667483
32	Nakonde Priscila	Female	
33	Nanyonga Annet	Female	774479730
34	Kayiga Geofrey	Male	751370746
35	Bengo Moses	Male	706977294
36	Nansubuga Betty	Female	
37	Namiya Harriet	Female	
38	Luutu David	Male	
39	Namutebi Justine	Female	
40	Namuddu Mariam	Female	
41	Ssempebwa Julius	Male	
42	Nakandi Lydia	Female	
Sugu Agalyawamu Women Group located in Buikwe district – Sugu village			
43	Nambi Ruth	Female	756331123
44	Nansubuga Milly	Female	788374582
46	Rwantare Sarah	Female	788242184
47	Nakinsige Nuulu	Female	758836279
48	Naiga Nuayati	Female	703950369

49	Namuli Faridah	Female	785460993
50	Nabuma Sawuda	Female	704313742
51	Najjemba Nuulu	Female	701234847
52	Mutesi Nuulu	Female	708023157
53	Najjemba Azzena	Female	774307712
54	Mutesi Jowelia	Female	754135663
55	Nabatanzi Fatina	Female	758636711
56	Nankanja Safina	Female	781936295
57	Namubilu Madinah	Female	753221764
58	Nalwoga Abiba	Female	788127774
59	Nazziwa Annet	Female	759125361
60	Namusisi Beatrice	Female	774504187
61	Bagara Aiddah	Female	778109210
62	Kayya Derick	Male	779644339
63	Nayima Molini	Female	751911137
64	Ssebadduka Ibrah	Male	753362261
65	Namwanje Jalia	Female	
66	Bisaso Hakim	Male	
67	Muwanika Kalimu	Male	
68	Nakalyowa Faridah	Female	
69	Namutebi Jane	Female	
70	Naantogo Jalia	Female	
71	Namugenji Shadia	Female	
72	Nakafu Sophia	Female	
Mukama Mulungi VSLA located in Luwero district – Kalungu village			
73	Segujja Geoffrey	Male	778454361
74	Sebuliba Paul	Female	780783856
75	Kiyeya Patrick	Male	782101577

76	Sauya Najjuma	Male	774953903
77	Lubega Steven	Female	784539348
78	Edward Gitta	Female	772461570
79	Bettu Gitta	Female	789108624
80	Semakula Irine	Male	778186785
81	Harriet Kakiryo	Female	774252900
82	Fredrick Kakiryo	Male	777800233
83	Ndawula Nuruh	Female	776758163
84	Anold Sembuuze	Female	772040037
85	Nakawesa Allen	Male	781381624
86	Nanjobe Christine	Female	708137514
87	Sentumbwe patrence	Female	782567787
88	Nassezi Joweria	Female	708208575
89	Namitala Sarah	Female	788242635
90	Mbaizi Gerald	Female	776932518
91	Mubiru Rechard	Female	752607713
92	Muwonge Aida	Female	774799210
93	Namagembe spe	Female	751619541
94	Mwinike Rhona	Female	782786821
95	Naglunga Pheobe	Female	789108624
96	Kyando Salm	Male	788303579
98	Naggayi Margaret	Female	
99	Sewinabo Micheal	Male	
100	Senwagi Saul	Male	708816214
Twekembe Kakoma Men and Women Group			
101	Kyazze Simon Peter	Male	0702147203
102	Kabunga Herbert	Male	

103	Sebunya Fred	Male	0750983131
104	Kawesi Godfrey	Male	0751059305
105	Ssekawanga Yudaya	Male	0704673561
106	Kawooya Penegiliwo	Male	0753266171
107	Njita Hadija	Female	0787948161
108	Nakabugo Taatu	Female	0775618151
109	Babirye Firida	Female	0753713200
110	Namyalo Gaudensia	Female	0782179333
111	Komugisha Joniva	Female	0773512457
112	Mwanje Edirisa	Male	0773520648
113	Namirembe Jaliya	Female	0779303986
114	Nabbale Annet	Female	0775826209
115	Magale Hassah	Male	
116	Nakawuki Fatuma	Female	
117	Namutebi Malusi	Female	
118	Kayongo J	Male	
119	Mukliti Ali	Male	
120	Nabatessa Angie	Female	
121	Nabasumba Joweria	Female	
122	Kiyimba Richard	Male	
123	Nakirijja Aidah	Female	
124	Male Livinstone	Male	
125	Eribu Martin	Male	

ANNEX 2: INTERVIEW GUIDE / DATA COLLECTION TOOL USED DURING THE FEASIBILITY STUDY

INTERVIEW GUIDE

iv. The subject identifies themselves – just the name;

v. Specifies the Village Savings and Loans Association (Vsla) they are members of, how many members are in that VSLA and how many of them use the solar dryer center;

vi. Specifies the value chains they farm;

vii. Specifies whether they farm for subsistence use of sale or both;

viii. Specifies the level of postharvest losses they used to suffer that are now being reversed;

ix. Specifies this level of losses in incomes that have now been recovered from using the solar dryers;

x. Specifies if the dried product is getting increased market opportunities,

xi. The drying rates of the produce when it uses a dryer compared to open sun drying and how fast the dryer is compared to open sun drying,

xii. Speak on the hygiene of solar dryer compared to open sun drying,

xiii. Speak generally on the benefits they have from the dryer centre and if they intend to continue using it in the future,

DATA COLLECTION TOOL USED DURING THE FEASIBILITY STUDY

QUESTIONNAIRE GUIDE TO VSLAS UNEP-EBAFOSA IS WORKING WITH IN BUGANDA KINGDOM

UNEP-EBAFOSA Uganda is closely working with CBS-PEWOSA SACCO in Uganda, Buganda Kingdom to co-operate around the solution of the solar dryer to reduce post-harvest losses, briquettes to drive climate action, EBA-Cassava growing to grow cassava organically and supply it to processors like cassava flour processors. The essence is to increase income and improve livelihoods of VSLAs and to action nationally determined contribution (NDCs). This work is under the UNEP-EBAFOSA Innovative volunteerism logic and co-operating around the solutions.

(The reason for this tool is to guide the program, understand the VSLAs we are working with)

Questions / Discussion Points

1. How long has your VSLA existed? Where is it located?

2. How many members?

3. which value chains do members engage in?

3b. can these value chains be preserved through drying?

3c. which markets do you sell your produce?

3d. if a solar dryer was provided, will members be willing to use it communally with counterparts of the VSLA and others?

3e. will members be willing to pay a small fee of about UGX100 per kg or produce dried, to use the dryer services sharing with other members of the VSLA & community?

4. how much post-harvest losses are experienced for each value chain?

6. apart from farming which other income activities do members engage in?

14. Are members involved in agriculture as businesses?

15. What products do members sell/cultivate?

16. Do members make profit?

17. how do members preserve their harvests?

18. Do members have bookkeeping / record keeping skills?

22. Are you already involved in UNEP-EBAFOSA Uganda program on post-harvest handling using solar dryer, Planting cassava? If yes when did you become involved?

23. Which climate action solutions have you acquired so far as a VSLA (solar dryer centre, fuel briquettes, cassava cuttings)?

24. If you acquired a solar dryer how many Kilograms of cassava can you dry?

25. How many kilograms of cassava where you losing before acquiring a solar dryer?

26. How much money have you got after selling cassava chipped from the dryer?

27. Would you be interested in Joining PEWOSA SACCO to save.

THE STUDY QUESTIONNAIRE OF THE SOLAR DRYER FEASIBILITY STUDY

Questionnaire for the VSLA members saving with CBS-PEWOSA SACCO in selected VSLAs in the Buganda Kingdom

Introduction

UNEP-EBAFOSA Uganda, CBS-PEWOSA SACCO are conducting a baseline to understand CBS-PEWOSA Village Savings and Loans Association enterprise performance and Agri-financing activities conducted by the members

Your VSLA/ SACCO has been selected as a key stakeholder in the CBS-PEWOSA saving activity. The purpose of this study is to use the results to develop strategies and policies that can facilitate the growth of agriculture enterprises and promote local enterprise competitiveness in the cassava business development and other crop enterprise for value addition purpose.

Please spare a few minutes of your time and respond to the questions in this questionnaire.

Your responses will be treated with confidentiality. Kindly consent that you are responding to this questionnaire freely.

Your Name please.....

Gender.....

Name of a VSLA/SACCO.....

Nature of Business / enterprises (agriculture enterprise, Value addition dealer,)

1. In which area are you located/based in?

2. What is the name of the VSLA / SACCO you belong and when did you join that VSLA? 2b. is the chairpersons post rotational 2c. how many official posts are in your VSLA and are they rotational? 2d. would you prefer that posts are rotational? 3. How much do you save with CBS-PEWOSA? (Inform the respondent that this information will be kept confidential) 3b. which income generating activities are you engaged in that enable you get income to save?
4. For how long have you been saving with this VSLA/SAACO?
5. How many members are in the VSLA?
6. Do you plant / farm cassava if yes continue with the questions below / if not go to the next part?

7. Which other agriculture crops are you engaged in? Please list them **7b. which markets do you take your harvest?** **7c. how much do you earn from each of these value chains?** **7d. which other income generating activities are you engaged in?** **7e. how much do you earn from each of these activities?**
If the respondent has ever planted cassava or has cassava on his farm or has interest in cassava product, farming, value addition and marketing of cassava products please continue with the following question
8. For how long have you been in cassava farming?
9. Please names some of the cassava varieties you have been planting in your garden?
10. What acreage of your land can you dedicate to cassava farming?
11. In what season do you plant cassava in your area / district and why?

12. What post-harvest handling techniques/ methods are you using in your community? (List them below)

13. In What form do you sell your cassava to buyer on the market and at what price?

Answers (tick the answers)

A. Cassava roots

B. Cassava flour

C. Cassava chips

14. How much cassava do you have now in your in (Kilograms)?

A. Garden

B. Store

C. Milling machine

15. How much cassava do you lose; in Kilograms

A. On the farm during harvest

B. During drying

C. At storage time

D. During milling into cassava flour

16. What ecosystem-based adaptation (EBA) approaches do you on your farm? (Explain to the respondent what is EBA)

17. What challenges do you face in growing cassava? Please list them below

18. If you are given clean cassava cutting by UNEP-EBAFOSA Uganda are you / members able to collect it in our farm?

A. YES

B. NO

If no why?

19. What is the number of acreages dedicated to cassava by farmers in your VSLA

VALUE CHAIN / ENTERPRISE DEVELOPMENT/ POST-HARVEST HANDLING

1. Have you ever had of solar drying technology, its usage and price?

A. YES

B. NO

(Explain the solar dryer to the respondent)

2. Which crops do you have in your reach and can be added value on using a solar dryer? (List them Below)

2b. if a solar dryer was provided, will you be willing to use it communally with members of your VSLA and others?

2c. will you be willing to pay a small fee of about UGX100 per kg or produce dried, to use the dryer services sharing with other members of your VSLA & community?

3. When you are supported as a VSLA with a solar dryer are you able to use it if you are trained? (Define to the respondent what is a solar dryer)

A. YES

B. NO

C. I don't know

4. What other agriculture crop/enterprise can you add value using a solar dryer. (List them)

5. Mention and explain the local methods used for drying cassava in your community
6. Are VSLA members the right people to learn value addition making
THANK YOU FOR YOU TIME

ANNEX 3

First day Google drive photos of the moisture meter reading include the following

https://drive.google.com/drive/folders/11oZwnsemzMl24uLjB7kVwdIoEWAbRA8I?usp=sharing

Second day Google drive photos to show evidence of the reading of samples using moisture meter

https://drive.google.com/drive/folders/1teinrPy_sgnvP8dez1lGoRFbKz1hs2RX?usp=sharing

EBAFOSA
Ecosystem Based Adaptation for Food Security Assembly

info@ebafosa.org

P.O Box 30552 00100
Nairobi
Kenya

WWW.EBAFOSA.ORG