Environmentally-Controlled Sweetpotato Storage Unit

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Introduction

Sweetpotato (*Ipomoea batatas* Lam) roots are rich in carbohydrates and can produce more edible energy per hectare than wheat, rice or cassava (Lebot 2009). In addition, sweetpotatoes contain substantial amounts of proteins, vitamins and minerals, playing a key role in famine relief (Loebenstein, Thottappilly 2009).

The roots can be stored for up to one year if the right procedures and storing conditions are followed (Woolfe 1992). Immediately after harvest the roots should be cured (Edmunds et al. 2008), allowing cuts, bruises and skinned areas on the roots to heal (Lebot 2009). If curing is not done properly sweetpotato will not store well (Stathers et al. 2005). The speed of the healing process is driven by temperature, humidity and aeration. For optimum curing, roots should be at a ventilated environment with temperature between 26 °C and 30 °C, and relative humidity between 80% and 90%. The curing period should be as short as possible, not exceeding 7 days, that is because curing conditions also promotes respiratory activity, that leads to weight loss. After curing, the roots should be stored at a temperature between 14 °C and 16 °C and relative humidity between 80% and 90% (Lebot 2009). During storage, a reduction in sweetpotato mass is expected. This reduction can be as high as 2% a month, but is marginal when roots are kept under ideal storage conditions (Estes 2009).

In many regions of sub-Saharan Africa agricultural production is confined to the rainy season. In those areas, sweetpotatoes are only produced during part of the year (Low et al. 2009). The possibility to store the crop, would allow farmers to harvest as soon as the roots are mature so that the fields are available for other crops, or for fallow, still during the rainy season. Particularly in sub-Saharan Africa the crops must be harvested before the dry season to avoid damages to the roots by sweetpotato weevils. In addition, stored roots can be sold later in the season when fresh roots are not available, bringing additional income (Stathers et al. 2005). However, the ideal curing and storing conditions can only be achieved using an environmentally-controlled facility (Estes 2009) where air temperature, humidity and ventilation can be adjusted (Lebot 2009). The objective of this project is to develop an environmentally-controlled sweetpotato storage unit, suitable to be used by village-based enterprises in sub-Saharan Africa.

Environmentally-controlled sweetpotato storage unit

The environmentally-controlled sweetpotato storage unit will be able to cure up to 5000 kg of roots at a temperature of 28 °C and relative humidity of 85%. For storage, the unit will be able to maintain the temperature at 15 °C and relative humidity at 85%. The system will be built using a 6-m intermodal dry freight container. It has been design in a way to be affordable, durable and easy to operate. Components were selected so that the unit can be manufactured and repaired locally without the need of special imported items.

Intermodal dry shipping containers are standardized steel rectangular closed boxes, 6 m long, 2.4 m wide and 2.6 m high. They are built with corrugated weathering steel and are fitted with doors at one end, as shown in Figure 1.

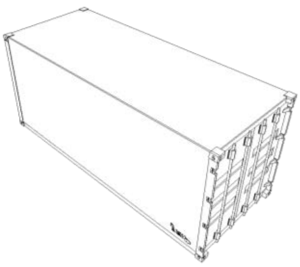

Figure 1 *Dry shipping container will be used for the storage unit.*

A shipping container was chosen because of its wide availability and sturdiness. Furthermore, its standard size facilitates replicating the system in other locations. In addition, containers can be easily locked, safeguarding the contents, and can be moved to another site, if necessary.

For thermal insulation, the container walls, roof, floor and doors will be covered a with a layer of extruded polystyrene foam and a layer of sprayed-on expanded polyurethane foam. This combination was chosen considering cost, thermal resistance, durability and ease of installation. The insulation on the walls and doors will be shielded with aluminium sheets, while the floor will be shielded with a wooden board and a rubber mat. At the entrance a strip curtain will be installed (Figure 2).

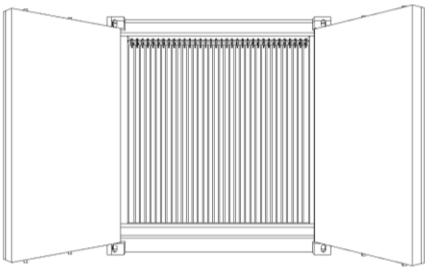

Figure 2 *Containers walls, doors, floor and roof will be insulated with polystyrene foam and a polyurethane foam.*

A vapor-compression refrigeration system will be used to cool and heat the air. Suitable, locally available equipment will be used. Attention will be given to select a system with a large cooling coil. In the absence of such equipment, a standard air conditioning unit will be used, and the necessary modifications will be made to assure that the intended temperature and humidity is reached (Figure 3).

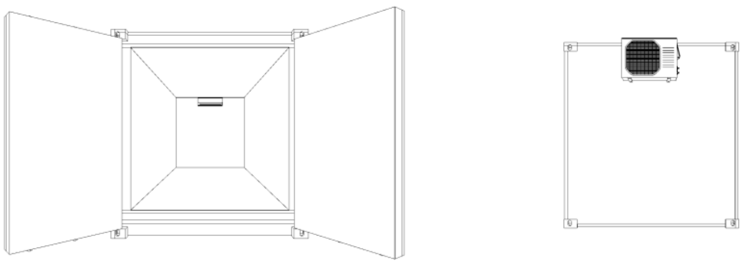

Figure 3 *A vapor-compression refrigeration system will be used to control air temperature.*

A vapor-compression refrigeration system was chosen because of its wide use, making it easier to find spare parts and qualified technicians for servicing. Absorption refrigeration system as well as systems powered by direct current (DC) were considered, but discarded because of the need for more specialized personnel for their maintenance.

Ventilation was designed based on the system described by Edmunds et al. (2008). It uses two axial fans, assuring that the cooled and moisture air pass consistently through the sweetpotatoes (Figure 4). The airflow distribution has been evaluated using computational fluid dynamics.

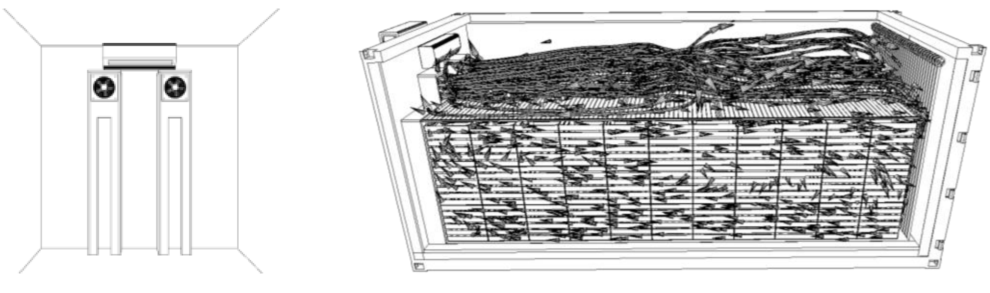

Figure 4 *Ventilation system uses axial fans to create a negative pressure, forcing the air to pass through the roots.*

Humidification of the air will be achieved using an irrigation sprinkler (Figure 5). The system produces water droplets larger than ideal, but was chosen because of its low cost, easy maintenance and widespread availability. Systems using high pressure or ultrasound were considered, as they produce smaller water droplets and thus more suitable for air humidification. However, those system, require water free from solid particles, thus, for using with untreated ground water, additional water filters would be needed.

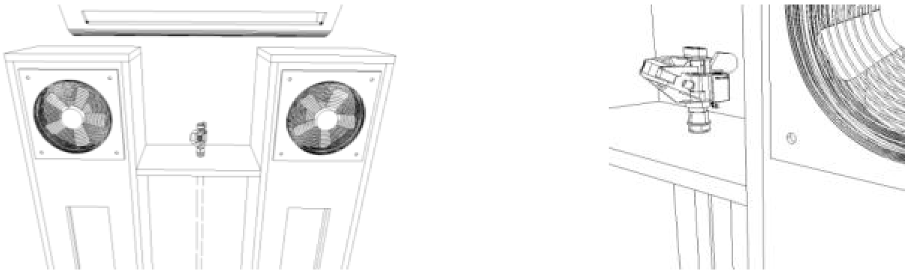

Figure 5 *An irrigation sprinkler will be used to humidify the air.*

Wooden crates (56 cm × 45 cm × 45 cm) will be used (Figure 6a), arranged in 3 rows with 3 crates stacked atop each other. The storage unit will fit a total of 99 crates (Figure 6b).

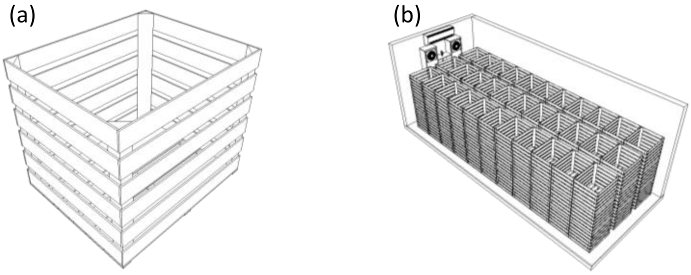

Figure 6 *Illustrations showing (a) wooden crate and (b) how it will be arranged inside the storage unit.*

After loading, the crates will be roofed with a sliding cover. The cover will protect the roots from becoming wet and guide the airflow to the other end of the container (Figure 7).

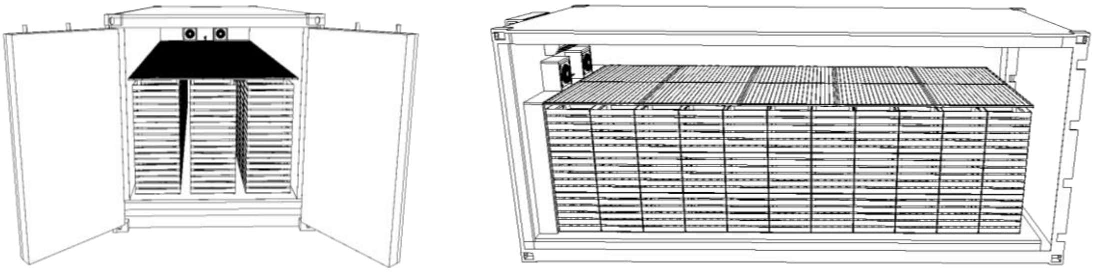

Figure 7 *Interior of the container showing the cover that protect the roots from the sprayed water.*

To guide the air and assure its uniform distribution across all roots, wooden air deflectors will be placed at the end of rows, between the crates, as shown in Figure 8.

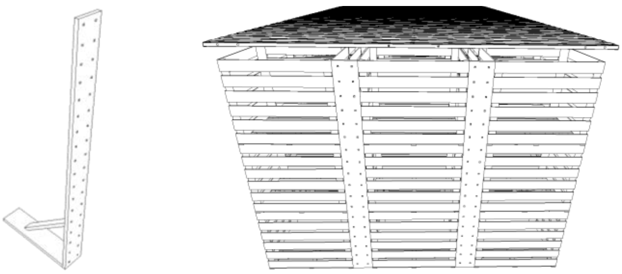

Figure 8 *Wooden deflector used to guide the air and assure uniform airflow distribution.*

Two weatherproof LED floodlights will be installed inside the unit to provide proper illumination for inspection and cleaning (Figure 9).

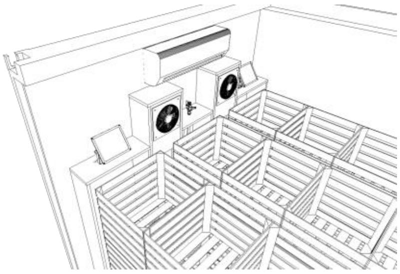

Figure 9 *Interior of the storage showing placement of LED floodlights.*

The entire system will be powered by solar energy using a rooftop photovoltaic system (Figure 10). To assure non-stop operation, even in the event of consecutive cloudy days, the exact specifications of the system will be only determined after all electric components have been installed and tested.

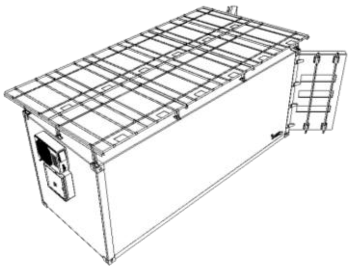

Figure 10 *Solar panels will, provide electricity supply and protect the unit from direct solar radiation.*

The unit will be fully automated, user will have only to choose between curing or storing functions and inspect the roots periodically.

Activities and schedule

The first step will be to purchase a 6-m long container and have it delivered to a workshop in Kisumu. There, the unit will be washed, sandpapered, coated with a primer and repainted. Once repainted insulation will be added, followed by the shields. After that the refrigeration system will be installed and the ventilation system constructed. Next, the humidification system will be assembled and the floodlights mounted. Concomitantly the construction of the cover will be commissioned and the sliding rails fixed on the interior walls of the unit. Finally, a control box will be assembled and the system will be tested using power from the grid. Tests will be done with empty crates and power consumption will be evaluated. The unit will then be transported to its final site, before having the photovoltaic system installed. Meanwhile, at Organi site the foundation base to place the container will be constructed and the pipe system prepared to supply water to the unit. When the unit is delivered at the Organi site, it will have the painting repaired on spots that were scratched during transport, the water pipes will be connected and the photovoltaic system installed. Finally, the unit will be tested with empty crates and the users will be trained on how to operate it. Table 1 shows the scheduled activities.

Table 1 *Scheduled activities for installing the environmentally-controlled sweetpotato storage unit at Organi site.*

Activity	Location	May, 2017				June, 2017			
Acquiring container	Kisumu	/	■			/	/		
Cleaning and repainting	Kisumu	/	■			/	/		
Fitting thermal insulation, shield, curtain and sliding rail for the cover	Kisumu	/		■		/	/		
Commissioning cover and air deflectors	Kisumu	/		■		/	/		
Installing refrigeration, ventilation, humidification and lighting systems	Kisumu	/		■		/	/		
Assembling control box	Kisumu	/			■	/	/		
Testing with empty crates (powered from grid)	Kisumu	/			■	/	/		
Despatching to Organi	Kisumu	/			■	/	/		
Building foundation base	Organi	/	■			/	/		
Preparing water supply	Organi	/	■			/	/		
Repainting scratches	Organi	/				/	/	■	
Connecting water supply	Organi	/				/	/	■	
Installing photovoltaic system	Organi	/				/	/	■	
Testing with empty crates (powered from photovoltaic system)	Organi	/				/	/		■
Training operators	Organi	/				/	/		■

Budget

Personnel costs includes 30 commissioning days at NRI rate (cost band H), travel, visa, subsistence, accommodation and transport. Additionally, a local assistant should be hired to be trained on how to build the unit. Material and services costs are shown in Table 2.

***Table 2** Material and service cost projection*

Material and services	Cost (USD)
6-m freight container and transport	2,237
Cleaning, sandpapering and painting	447
Insulation and shield	782
Strip curtain	112
Refrigeration system	1,000 ± 200*
Ventilation system	238
Humidification system	340
Lighting system	96
Photovoltaic system	4,000 ± 500*
Cover and air deflectors	336
Control box	217
Foundation base and hydraulic connections	188
Total	**9,993 ± 700***

*exact specifications still need to be defined, affecting price

Expected results

It is expected that the development of a curing and storing unit suitable to be used by village-based enterprises in sub-Saharan Africa reduces postharvest losses and allows more efficient use of the fields during the rainy season, fostering food security and improving livelihood of rural populations.

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