Journal of Food Science and Engineering 6 (2016) 227-236
doi: 10.17265/2159-5828/2016.04.005

Sand Storage, Extending the Shelf-Life of Fresh Sweetpotato Roots for Home Consumption and Market Sales

Putri Ernawati Abidin[1], John Kazembe[2], Richard A. Atuna[3], Francis Kwaku Amagloh[3], Kwabena Asare[1], Eric Kuuna Dery[1] and Edward Ewing Carey[1]

1. International Potato Center (CIP), c/o CSIR Savanna Agricultural Research Institute (SARI), P.O. Box 3785, Kumasi, Ghana

2. CIP, P.O. Box 31600, Lilongwe 3, Malawi

3. University for Development Studies (UDS), P.O. Box TL 1350, Tamale, Ghana

Abstract: Uni-modal rainfall pattern has long dry spell wherein sweetpotato is scarce, expensive but cheap at harvest. The crop is mostly consumed, processed or sold. Extending shelf-life of roots is crucial for Malawi and Northern Ghana as the crop has high value. Trials were conducted in the countries at the community level. In the dry season, temperature is cool in Malawi while warm in Ghana, but thru harmattan, the night is cool with low relative humidity. In Malawi, orange-fleshed sweetpotato Zondeni var., white and yellow types were assessed in three types of storage, Afghan ventilated pit store, storage in dry sand of pit-steps, and of a granary. In Ghana, local moistened heap and sandbox were compared. In Malawi, weight losses were calculated relative to the quantity stored at start, it was not cumulative. At 1.5 months no significant difference was among treatments. By 3.5 months the pit-steps method emerged to be superior and continued to 6.5 months. Losses in granary were due to shriveling, in the pit-stepsdue to termites and rats, and in ventilated pit due to termites, rats and Java black rot. Sprouting was high in pit-steps, but it was simply removed and roots returned to storage. At 6.5 months, the beta-carotene of Zondeni roots was traceable. Farmers gained high price when selling them as roots were scarce. Women favored the pit-steps because it was manageable. In Ghana, the sandbox was superior to local moistened heap. Methods designed were suitable for home consumption, but will require modification for commercialization.

Key words: Sand storage, sweetpotato, orange-fleshed sweetpotato, local knowledge, shelf-life of storage roots, beta-carotene.

1. Introduction

The sweetpotato is widely grown in tropical, subtropical, and temperate areas between 40° North and 32° South. A wide range of cultivars is suitable for different soils and climates [1-3]. The crop is mostly grown in small plots by subsistence farmers in low-input agricultural systems [4, 5]. In Malawi, sweetpotato is an important crop after maize and cassava [6, 7] and it is increasingly becoming an important crop among other root and tuber crops in Ghana since the last few years [8]. A uni-modal rainfall distribution pattern is typically having a long dry season and causes a fairly short harvest season. With respect to sweetpotato cropping system, farmers normally treat sweetpotato as a rain-fed crop for storage root production, consequently, during the harvest season, abundant roots are found at the farms' gates and in markets. By that time, the sweetpotato is mostly consumed, processed, or sold quickly by farmers, due to the fact that the sweetpotato storage roots have a short shelf-life. This condition becomes a major constraint for sweetpotato farmers in Sub-Sahara Africa. Considerably, the price of the storage roots is significantly cheap. In contrast, at out

Corresponding author: Putri Ernawati Abidin, Ph.D., research fields: sweetpotato seed systems, sweetpotato value chains, linking agriculture, nutrition, health and wealth using orange-fleshed sweetpotato, postharvest handling for sweetpotato for food security and nutrition security.

of the harvest season, the sweetpotato becomes scarce and expensive.

In tropical environments, where refrigerated storage is not economically feasible, roots will generally keep for only a few weeks. This happens mostly in developing countries. When subjected to normal marketing practices, it is clearly having a negative impact on reduced marketing opportunity to a few week staking part in the sweetpotato value chains. This means that fresh roots can be eaten only for 2-3 months of a year. Extending the shelf-life would allow people to sell and eat fresh sweetpotato for a longer period of time, and would make the crop more attractive and market orientation. Hence it will be improving incomes of many resource-poor farmers. Farmers have developed various methods to extend sweetpotato shelf-life, i.e. storage in soil, grass or ash, storage in pits like in Malawi [6] or other countries in the South and Eastern Africa, or simply left in the ground and harvested piecemeal as required such as in Uganda [4, 9] or other countries in East Africa, or processed into sun-dried chips such as in Northeastern Uganda [4] as well as in many more countries in Sub-Sahara Africa. Normally these indigenous storage methods are only effective for a month or two, after which quality declines due to rots, infestations by pests and physiological deterioration. Recently the “Triple-S” (Storage in Sand and Sprouting) method [10] has been developed as a way of storing the non-marketable clean roots at room temperature for subsequent use in producing the planting material for the next planting season. Since this method has shown an effective technique of storing the sweetpotato roots for a few months, we therefore reasoned that the storage in sand method can be realistic for keeping the fresh marketable size of storage roots in the sand store for a longer period of time. Furthermore, we have also considered in a number of literatures knowing the impact of getting beta-carotene-rich orange-fleshed sweetpotato (OFSP) varieties into the diets of rural and urban consumers, especially on young children in Sub-Sahara Africa [11-13]. Therefore, we inspired ourselves to include the OFSP varieties into our postharvest trials. It is well recorded that Malawi and Ghana have a high number of the children below five of age living with malnutrition and vitamin A deficiency (VAD). At present, the local sweetpotato varieties predominantly found are white and yellow flesh. The objective of the experiments was to develop and evaluate the indigenous postharvest methods commonly used by farmers in Sub-Sahara Africa and bringing the knowledge of farmers in Afghanistan who are successfully using a ventilated pit to store their Solanum potato for a few months. This method was introduced by a scientist of Catholic Relief Services (CRS) to Solanum potato farmers in Sub-Sahara Africa. The trials were conducted at the community level in Northern Malawi and Northern Ghana. Both countries have a similar rainfall distribution pattern, i.e. uni-modal rainfall distribution pattern.

2. Materials and Methods

2.1 Geographical Area of Trials

2.1.1 Malawi

Three communities with a total of 90 households were chosen, one community in Mzimba District of Northern Region and two in Kasungu District of Central Region. The trials were situated at the 13° South and its mid-elevations of ~1,200 m above sea level (masl). One introduced orange-fleshed sweetpotato (OFSP) Zondeni variety, one white and one yellow locally grown varieties were investigated in the three types of storage, Afghan ventilated pit store, storage in dry sand of pit-steps, and of a granary. If there was more than one local variety, these were bulked together in each of the storage treatments at each location. Each store was replicated thrice in every community. The storage trials were initiated in May 2014, during the harvest period. Assessments of weight loss and taste were done at 6 weeks or 1.5

months after stored (MAS), 3.5 MAS, and 6.5 MAS. Taste was also assessed prior to initiation of storage and it was conducted in May 2014. This taste assessment was consistently done at each storage's observation interval. Another notably important assessment was also made, it was an evaluation on the market value of roots after being stored for a certain period of time. The market assessment was done at 1.5 MAS, i.e. in June 2014 during the peak harvest, and at 6.5 MAS, i.e. in Nov. 2014 when roots were normally scarce or not found at all.

Good agricultural practices (GAP) for sweetpotato and careful handling during harvesting were introduced to farmers to minimize mechanical damage on sweetpotato storage roots prior to be stored and investigated throughout the postharvest trial. The farmer participants in this trial were trained on sweetpotato production, multiplication, pest and disease management, drip irrigation, postharvest handling, and OFSP utilization and processing. Since the β-carotene rich orange-fleshed sweetpotato was unknown by farmers in that area, we needed to sensitize farmers on the benefit of having the vitamin A rich OFSP in their daily diet. They also needed to know its processing and utilization. Traditional curing was practiced, farmers kept the roots in their house-yards under the sun for 3 days and then in a storeroom for another 3 days. In this way, farmers in Malawi believed that sweetpotato became sweeter. In fact, the farmers like sweetpotato to be sweeter. Baseline and Endline survey were done to accomplish the trial results to be more meaningful.

2.1.2 Ghana

The results from Ghana were treated as a complimentary result for the Malawi's storage trial. More details from Ghana could be found in another publication elsewhere. Five communities with a total of 100 households were selected in Bawku, Upper East Region. The trials were recorded at 11° North and its mid-elevation of ~220 masl. The temperature was hotter compared to Malawi, whereas during harmattan, the night temperature was relatively cool. Although Ghana has a similar uni-modal rainfall pattern with Malawi, but rainfall was more erratic than the rainfall was being experienced in Malawi. Two OFSPs and one white variety were assessed in the two types of storage, local moistened heap and sandbox. Farmer participants were trained on sweetpotato production, multiplication, pest and disease management, postharvest handling and OFSP utilization and processing. Traditional curing was practiced. Baseline and Endline survey were also done.

2.2 Storage

The Afghanistan pit namely Afghan pit, is a ventilated pit storage adapted from the method successfully used for Solanum potato storage by Catholic Relief Services in Afghanistan. Two indigenous methods from Malawi are pit storage and traditional raised granary. The pit storage was modified with steps also called as pit ladder to allow easy access to lower levels. Inside of the traditional raised granary structure was plastered with clay-cement. The dry sand was used in both pit-steps and granary. The dry sand covered layer-by-layer on the arrays of storage roots. The roots should not touch on each other while being stored. One indigenous method from Ghana, the moistened heap was compared to a newly introduced sandbox. The sandbox was a box made from a concrete and plastered by cement. The sweetpotato storage roots were stored in such away on an array, then the dry sand was added on this array layer-by-layer as it is similarly described in the methods for pit-steps and raised granary structure from Malawi. The room wherein the sandbox was built was roofed with the grass-thatched.

2.3 Data Collection

Weight loss measurement in the storage trials was indicated to be a significant attribution in order to determine the quality of sweetpotato fresh roots and its shelf-life. The weight loss included shriveling, rots and pest damage were measured. In Malawi, data of weight loss, taste test, RH and temperature were collected, at regular intervals up to 6.5 MAS. At each storage interval, losses were calculated relative to the quantity stored at the beginning of the period, and thus were not cumulative. Furthermore, the market assessment and β-carotene analysis were done at 1.5 (June 2014) and at 6.5 MAS (November 2014). In Ghana, losses in stores were monitored at 6, 12, and 18 weeks of storage. Genstat [14] A and STATA program were used for the statistical analyses.

3. Results and Discussion

3.1 Malawi

Baseline survey has revealed that farmers already shifted to grow sweetpotato as a cash crop in the last few years. The northern region farmers used to be the commercial tobacco producers. There was a case that the tobacco crop was banned in the world markets of agricultural commodity, and Malawi was among the countries which got this negative effect on the economic importance of this crop especially for farmers in this region. Hitherto, the OFSP was not chosen to be commercial crop but the white and yellow flesh sweetpotato were among the cash crops in this particular region. Farmers believed that the OFSP could easily rot because of its short lifespan, therefore this orange type had no value for them. But farmers still liked it that was a reason why they continued growing the orange type of sweetpotato in the garden. They mostly used it only for home-consumption. After completing the trials, it was noticed from the Endline survey that a change occurred at the opinion of these farmers. Farmers have chosen the orange type varieties (OFSP) to be included in their commercialized commodity after participating in the postharvest trial. This was due to the noble performance of the OFSP throughout the trials along with recognizing its health benefit importance as the Vitamin A powerhouse.

Fig. 1 presents the results of weight loss in the storage trials. Further details and statistical significance are provided in Table 1. At 1.5 MAS there were not striking differences among treatments, but by 3.5 MAS the pit-steps (sand pit) method was starting to emerge as consistently superior, a trend that continued through 6.5 MAS. Losses in granaries were

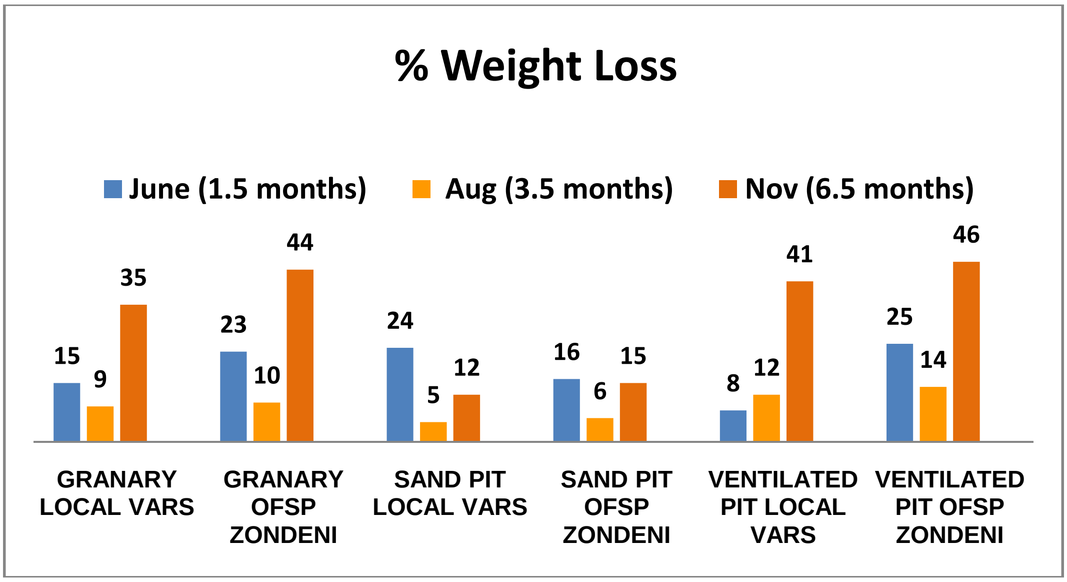

Fig. 1 Percentage weight loss observed after 1.5 MAS, 3.5 MAS, and 6.5 MAS during the dry/winter season of 2014 across the three types of storage (*p* value < 0.01 and LSD 5% = 9.6; MAS *p* value < 0.001 and LSD 5% = 9.6; sites *p* value < 0.1 and LSD 10% = 8.2; varietal differences: ns).

Table 1 Averaged percent weight loss by sweetpotato roots according to type of storage, sweetpotato varieties, sites and months of observation in 2014.

Items	% weight lost per unit
Type of storage	
Granary with dry sand	22.8
Pit ladder storage with dry sand	12.9
Ventilated Afghan pit storage	27.6
P-value	**
LSD 5%	9.6
Varieties	
Local	20.1
OFSP—Zondeni variety	22.1
P-value	ns
LSD	-
Site	
ZombeAlaki (Kasungu District)	23.8
Chizerema (IKasungu District)	24.5
Champira (Mzimba District)	15.1
P-value	(*)
(LSD 10%)	(8.2)
Months after stored (MAS)	
June (after 1.5 months)	18.5
August (after 3.5 months)	9.2
November (after 6.5 months)	35.6
P-value	**
LSD5%	9.6
MAS across type of storage	
Granary in June_1.5 months	19.2
Granary in Aug_3.5 months	9.5
Granary in Nov_6.5 months	39.8
Pit-steps storage in June_1.5 months	19.9
Pit-steps storage in Aug_3.5 months	5.2
Pit-steps storage in Nov_6.5 months	13.7
Afghan in June_1.5 months	16.5
Afghan in Aug_3.5 months	12.9
Afghan in Nov_6.5 months	53.3
P-value	**
LSD5%	16.7
Grand mean	21.1
cv%	24.9

largely due to shriveling, while in the ladder pits were due to termites, and rats (if sand cover was not thick). Losses in ventilated pits were due to termites, rats, and Java black rot. Sprouting was consistently high in the pit-steps, but sprouts were simply removed at assessments and roots returned to storage. Farmers believed that by removing the sprouts and returning the roots to storage did not give any effects on losses.

Unfortunately, temperature and humidity in stores were not logged constantly during experiments. However, they were measured at sampling times, at which point relative humidity was observed to be consistently lower in granaries and open air, compared with the pit storage methods. This would explain the shriveling that occurred in granaries (Fig. 2). Moreover, as seen from Fig. 2, the weight loss is less when the percentage of relative humidity is relatively high, between 60% and 70% while the temperature is constantly at average of 26 °C. According to Ref. [15], the temperatures above 15 °C lead to more rapid sprouting and weight loss. Strikingly, we have found that the weight loss was reduced when the relative humidity was high, although the temperature above 15 °C. Furthermore, Cantwell [15] gave an example on commonly being practiced by sweetpotato farmers in the USA. They noticed that the optimal keeping storage roots in the dry box or bins or keeping them loose is at 12.5 °C to 15 °C with 95 percent relative humidity (RH). Moreover, the farmers never put the storage roots in the refrigerator up to selling to the market or bedding for vines production. In this way, the sweetpotato farmers can keep their roots up to 10 months [15]. Regulating the relative humidity to be relatively high in the granary and in the dry sand pit-steps can be an important indicator to reduce the weight loss of storage roots in these types of storage, with the assumption of keeping the temperature in the storage not above 26 °C and so. It is not easy to get this temperature in the hot tropical areas. Nevertheless, the temperature of the dry sand covering the storage roots, in principle, can be mechanically regulated to reach this point.

The ambience of the storage causing the fluctuation of the percentage of the relative humidity could be significantly influenced by the physiological activity of the storage roots, such as respiration and metabolism, of which its mechanism will be ending up

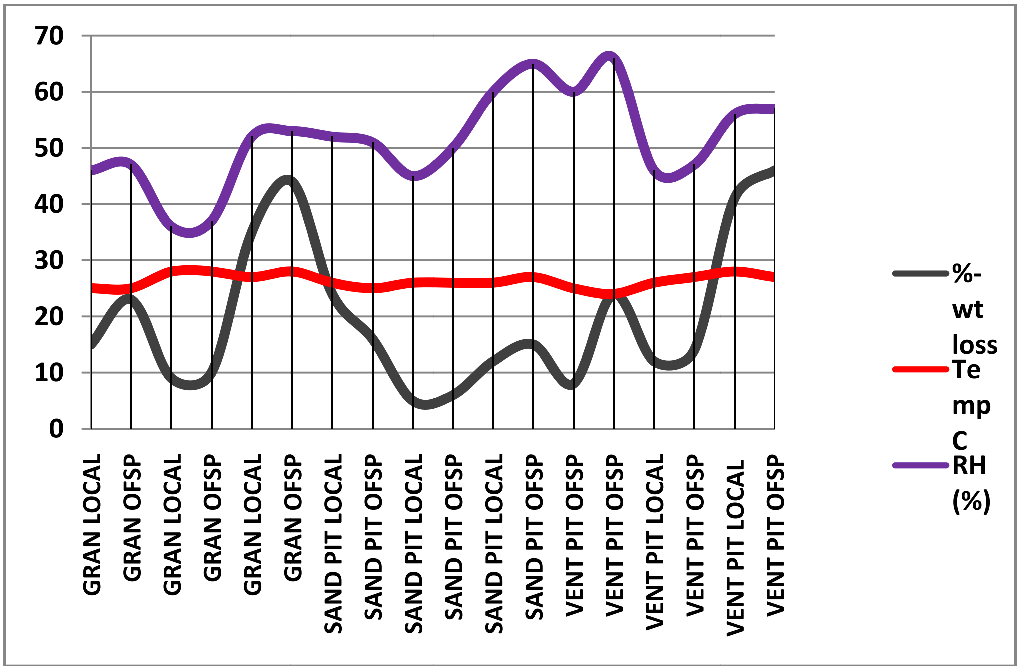

Fig. 2 Correlation between Temperature (°C) and Relative Humidity (%) towards the weight loss.

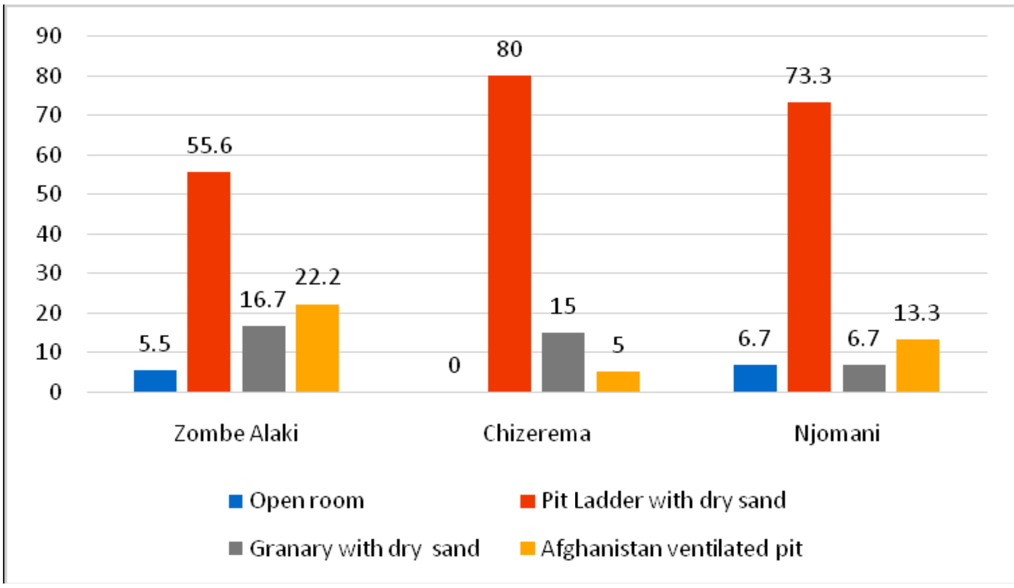

Fig. 3 Results from collecting farmers' opinion during the Endline Survey (source: DADHU Agro-enterprise, Lilongwe, Malawi, June 2015).

of producing water [16]. This might contribute to the humid ambience in the storage trial. It most likely depends on the sweetpotato varieties, as well. Nonetheless, a well thought-of investigation is suggested to follow up the findings.

Fig. 3 reveals the results of the Endline survey reported by a consultant group in Malawi (DADHU Agro-enterprise, Lilongwe, Malawi, June 2015, unpublished). They concluded that the pit-steps with dry sand was the most preferred method because it is easy to collect the sweetpotato roots at any point even by women when they wanted to use the roots either for consumption or marketing. The top was just covered with sand unlike Afghanistan method. Additionally, they were able to access the sweetpotato roots in the first step without tampering with other roots being stored in the subsequent steps, unlike the Granary. It was easy to construct and used by both men and women. The low adoption or low preference by farmer participants was the Afghanistan method. Farmers said that because it was less effective in keeping the roots be fresh, and they experienced high percentage of rotting. They recommended that pit-steps and granary storage facilities were socially inclusive technologies as perceived by respondents.

An interesting—but possibly instructive—inconsistency was introduced to the experiments at storage initiation, when roots of OFSP "Zondeni" variety were "cured" at all locations, whereas the roots of the local varieties were not subjected to the same treatment as they were not deemed ready for harvest. While the cure method may contribute to sweetness, it is not the correct way to cure the sweetpotato—a process that allows for wound healing under high temperature and humid conditions [17]. Whether the "curing" treatments contributed to differences in weight losses of local varieties and "Zondeni" among storage methods may be worthy of further investigation.

Taste tests conducted at storage initiation and after each storage interval indicated that farmers or consumers by and large appreciated the appearance and taste of the OFSP "Zondeni" variety over the local non-OFSP varieties. These preferences held up at 1.5 MAS, 3.5 MAS, and 6.5 MAS. Although some consumers rated the boiled "Zondeni" as too sweet, they still largely preferred it (data not shown). The main observations from farmer assessments of retail prices from the beginning of the experiment to the end was that by the end, prices were higher and they were distinguishing prices for OFSP and local varieties (Tables 2 and 3).

Moreover, from the Endline survey report, the gross margin analysis revealed that with sand pit-steps (pit ladder) storage technology, farmers could realize an increase in gross margin as storage period increases. With other storage technologies, farmers are better off selling at harvest time in the month of May than when they sell at 1.5 MAS or 3.5 MAS. The worst case was when using the ventilated Afghan-pit store, the gross margin was minus or below 0 (data not shown).

Results from the beta-carotene analyses in June and November 2014 are shown in Table 4. OFSP "Zondeni" variety was still within the range of moderate beta-carotene, it was between 40-129 μg/g based on the β-carotene content that was grouped and categorized by Simonne [18]. ß-carotene is the carotenoid with the highest pro-vitamin A activity (100%) because it can be entirely converted into two molecules of vitamin A (retinol) [19]. From 100 g of "Zondeni" there are 9,180 μg of beta-carotene, equivalent to 765 μg of retinol activity equivalents (RAE), which is more than 150% of the recommended daily allowance for a child under 5.

3.2 Ghana

Parts of the study from Ghana as a complimentary result towards Malawi's results are also written in this paper. Fig. 4 shows that in the course of time, the weight loss significantly increased, however, the incidence of weight loss in the traditional heap was much higher compared to sandbox at 6 weeks of being stored but slightly increased in the direction of the traditional heap at 18 weeks after being stored.

Table 2 The first market assessment done at the peak harvest (June 2014).

District	EPA/Sites	Description of roots	Price (Malawi Kwacha)
Kasungu	ZombeAlaki	10 small roots (< 100 g)	100
		4 big roots (> 100 g)	150
Kasungu	Chizerema	17 small roots (< 100 g)	100
		5 big roots (> 100 g)	100
Mzimba	Champira	5 small roots (< 100 g)	100
		3 big roots (> 100 g)	150

Table 3 The second market assessment done when sweetpotato roots were scarce (Nov 2014).

Site	Group type	Variety	Description of roots	# of roots per heap	Weight of roots (kg)	Price/heap (Malawi kwacha)
1.Zombealaki (Kasungu)	Women	Zondeni	Small roots (< 100 g)	8	1	200
			Big roots (> 100 g)	4	1.75	200
		Local	Small roots (< 100 g)	6	1	100
			Big roots (> 100 g)	6	1	200
	Men	Zondeni	Small roots (< 100 g)	5	1.5	150
			Big roots (> 100 g)	5	2	250
		Local	Small roots (< 100 g)	6	1	150
			Big roots (> 100 g)	5	1	200
2. Chizerema (Kasungu)	Women	Zondeni	Medium roots (> 100 g)	8	1	250
		Local	Medium roots (> 100 g)	11	1	300
	Men	Zondeni	Medium roots (> 100 g)	8	1.5	300
		Local	Medium roots (> 100 g)	7	1	250
3. Champhira (Mzimba)	Women	Zondeni	Small roots (< 100 g)	8	1	250
			Big roots (> 100 g)	4	1.5	350
		Local	Small roots (< 100 g)	14	1.5	300
			Big roots (> 100 g)	9	2.5	400

Table 4 β-carotene ((μg/g) status for each variety at 1.5 and 6.5 MAS.

Varieties	B-carotene (μg/g)	
	June (1.5 MAS)	Nov (6.5 MAS)
Local (Kenya & Zimbabwe)	10.7	7.4
OFSP, Zondeni	83.9	91.8

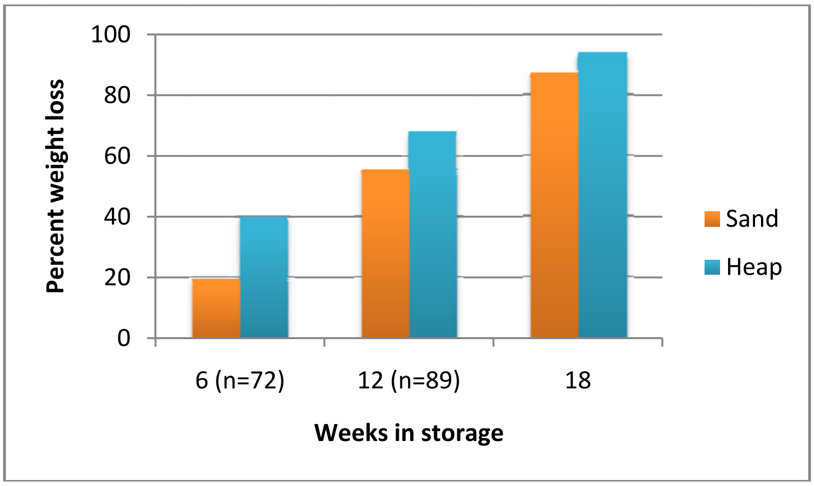

Fig. 4 Weight loss from sweetpotato during 18 weeks of storage at households in 4 communities, Bawku.

Tables 5 and 6 have given detailed information based on each sweetpotato variety regarding varietal storability and market demand. It was found an improvement in the length of storage root being stored. Using the sandbox method could increase the length of sweetpotato fresh roots to be stored for home consumption as well as for market orientation. At least, the OFSP Apomuden variety, which was anticipated to have poor storage characteristic, could be stored in the sandbox up to 4.5 months in the two communities being observed. Furthermore, there was no market for Apomuden recorded during the baseline, but after the trial, people started marketing it.

Table 5 Varietal storability and market demand at Buya-Natinga/Old Ninkongo.

Variety/Cultivar	Max. storage length (before the project) in months	Max. current length of storage in months	Comments
Kuffour	1 month	4 months	Good when produced early
Obaari White	3 months	7 months	Best market demand
Asankunaboro	3 months	-	-
Awaal	3 months	-	-
Asaamadek	2 months maximum	5 months	Better market
Apomuden	Anticipate poor storage	4.5 months	Poor market demand, mainly for HH consumption

Table 6 Varietal storability and market demand at New Ninkongo.

Variety/Cultivar	Max. storage length (before the project) in months	Max. current length of storage in months	Comments
Asaankasnaabbogor	Good storage	-	Good market
Asaamadek	Stores well (2 months)	-	Good market—white fleshed Sweetpotato
Obaari	Good storage	6.5months	Best market
Kuffour	Poor storage	4months	Early market
Awaal	Good storage	-	Good market
Apomuden (“NasaraDankali”)	Storage probably poor. Yet to observe how it stores as it has just been introduced	4.5 months	No market baseline, but now people market it

4. Conclusion

Sand storage has shown a great potential to be promoted to the sweetpotato farmers in Malawi, Ghana and may be elsewhere in the future. In Malawi, the OFSP fresh storage roots could be obtained from the sand storage at 6.5 months after being stored. Meanwhile, in Ghana, having more harsh environment than Malawi, farmers could still enjoy eating the fresh roots up to 4.5 months for the OFSP Apomuden variety. Both countries showed a good prospect on the marketing opportunity of the OFSP roots. This is because the result has revealed that the shelf-life of sweetpotato storage roots could be extended up to the period of which the sweetpotato storage roots were usually scarce in the locality. It is suggested the findings can be scaled out with a slight modification based on the local condition and its circumstances so that more resource-poor farmers can gain out of it.

The improvement of local knowledge on the storage methods on sweetpotato can contribute to reducing hunger, improving nutrition status and strengthening the household income to reduce the poverty. It is certainly having its significance in combating the effect of climate change.

Acknowledgement

USAID-OFDA, Irish Aid through CIP-led project “Rooting out Hunger in Malawi with Nutritious Orange-Fleshed Sweetpotato”, Ministry of Agriculture partners in Ghana and Malawi, CIP-Malawi & Ghana; CRS-Malawi & Ghana; Mzuzu-CADECOM, and Dr. Michael Pots (CRS, New Zealand).

References

[1] Purseglove, J. W. 1991. *Tropical Crops. Dicotyledons. Longman Scientific and Technical*. NY, USA: John Wiley and Sons, Inc.

[2] Woolfe, J. A. 1992. *Sweetpotato: An Untapped Food Resource*. Cambridge Univ. Press and the International Potato Center (CIP). Cambridge, UK.

[3] Ann, P. M. 1993. *Tropical Soils and Fertilizer Use. Intermediate Trop*. Agric. Series. Longman Scientific and Tech., Ltd. UK.

[4] Abidin, P. E. 2004. “Sweetpotato Breeding for Northeastern Uganda: Farmer Varieties, Farmer-Participatory Selection, and Stability of Performance.” Ph.D. Thesis, Wageningen University, the Netherlands, 152.

[5] Ebregt, E., Struik, P. C., Abidin, P. E., and Odongo, B. 2004. "Farmers' Information on Sweetpotato Production and Millipede Infestation in North-Eastern Uganda. II. Pest Incidence and Indigenous Control Strategies." *NJAS—Wageningen Journal of Life Sciences* 52-1: 69-84.

[6] Abidin, P. E., Nyekanyeka, T., Heck, S., McLean, S., Mnjengezulu, G., Chipungu, F., Chimsale, R., and Botha, B. 2013. "Less Hunger, Better Health and More Wealth: The Benefits of Knowledge Sharing in Malawi's Orange-Fleshed Sweet Potato Project." In *Hunger-Nutrition-Climate Justice. A New Dialogue: Putting People at the Heart of Global Development,* edited by Annom. Conference papers, 15-16 April 2013, pp. 55-58, Irish Presidency of the Council of the European Union, Irish Aid, Mary Robinson Foundation Climate Justice, CGIAR-Climate Change, Agriculture and Food Security (CCAFS), World Food Programme (WFP), Dublin, Ireland. http://cgspace.cgiar.org/handle/10568/27890.

[7] Sindi, K., Kiria, C., Low, J. W., Sopo, O., and Abidin, P. E. 2013. *Rooting out Hunger in Malawi with Nutritious Orange-Fleshed Sweetpotato: A Baseline Survey Report*. Blantyre, Malawi. International Potato Center (CIP), 98.

[8] Obiukwu, O. 2015. "Why Dumping Local Diet for Foreign Cuisine Is Dangerous for Africa." Ventures, Business Policy Innovation Life + Innovators 2016. Accessed 4 July, 2016. http://venturesafrica.com/food/.

[9] Ebregt, E., Struik, P. C., Odongo, B., and Abidin, P. E. 2007. "Piecemeal Versus One-Time Harvesting of Sweet Potato in North-Eastern Uganda with Special Reference to Pest Damage NJAS-Wageningen" *Journal of Life Sciences* 55: 75-92.

[10] Stathers, T., Low, J., Mwanga, R., Carey, T., David, S., Gibson, R., Namanda, S., McEwan, M., Bechoff, A., Malinga, J., Benjamin, M., Katcher, H., Blakenship, J., Andrade, M., Agili, S., Njoku, J., Sindi, K., Mulongo, G., Tumwegamire, S., Njoku, A., Abidin, E., and Mbabu, A. 2013. "Everything You Ever Wanted to Know about Sweetpotato: Reaching Agents of Change ToT Manual." International Potato Center, Nairobi, Kenya, 390. Accessed 4 July, 2016. http://cipotato.org/wp-content/uploads/2014/11/006194.pdf).

[11] Low, J. W., Arimond, M., Osman, N., Cunguara, B., Zano, F., and Tschirley, D. 2007. "A Food-Based Approach Introducing Orange-Fleshed Sweet Potatoes Increased Vitamin A Intake and Retinol Concentrations in Young Children in Rural Mozambique." *Journal of Nutrition* 137: 1320-7.

[12] Haskell, M. J., Jamil, K. M., Hassan, F., Peerson, J. M., Hossain, M. I., Fuchs, G. J., and Brown, K. H. 2004. "Daily Consumption of Indian Spinach (Basellaalba) or Sweet Potatoes Has a Positive Total Body Vitamin A Stores in Bangladeshi Men." *American Journal of Clinical Nutrition*: 705-14.

[13] Bouis, H. 2002. "A New Tool for Fighting Micronutrient Malnutrition." *Journal of Nutrition* 132 (Symposium: Plant breeding): 491S-4S.

[14] Anonymous. 2005. "Genstat Release 8." Lawes Agricultural Trust, Rothamsted, Harpenden, 92.

[15] Cantwell, M., and Suslow, T. 2012. "Sweet Potato: Recommendations for Maintaining Postharvest Quality." Source: Perishables Handling #107, August 2001. Dept of Plant Science, Univ. of California, Davis. http://postharvest.ucdavis.edu/pfvegetable/SweetPotato/.

[16] Galston, A. W., Davies, P. J., and Sotter, R. L. 1980. *The Life of the Green Plant*. 3rd ed. New Jersey. USA: Prentice-Hall, INC.

[17] Anonymous. 2016. "Sweet Potato (Ipomoaebatatas)." World Crops for Northern United State. Accessed 12 July, 2016. http://worldcrops.org/crops/sweet-potato.

[18] Simonne, A. H., Kays, S. J., Koehler, P. E., and Eitenmiller, R. R. 1993. "Assessment of β-carotene Content in Sweetpotato Breeding Lines in Relation to Dietary Requirements." *Journal of Food Composition and Analysis* 6: 336-45.

[19] Bechoff, A. 2010. "Investigating Carotenoid Loss after Drying and Storage of Orange-Fleshed Sweetpotato." Ph.D. thesis. University of Greenwich, UK.