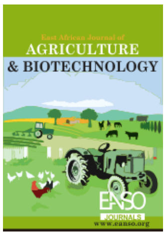

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Original Article

Performance Evaluation of Different Storage Technologies on Storage Stability of White-Coloured Sweet Potato Roots Under Farmers' Conditions in Tanzania

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Sweet Potato Storage, Beta-Carotene Content, Colour, Hardness, Total Soluble Solids, Weight Loss.

ABSTRACT

Sweet potatoes' high perishability after harvesting is one of the major factors limiting their potential. This is exacerbated by the lack of appropriate storage methods. This study aimed to evaluate different storage technologies for the storage stability of white-coloured sweet potato roots under farmers' conditions in Tanzania. The study was carried out at the Crop Science laboratory at Sokoine University of Agriculture (SUA) for 77 days in a completely randomized experimental design. The experiment included four treatments: improved traditional raised, woven Polypropylene Bags, bamboo buckets, and ventilated bags. Each treatment was replicated three times. Physiological loss in weight, hardness, total soluble solids, colour, and beta-carotene content were measured at the Food Science laboratory at SUA during the experiment storage period. Analysis of variance and comparison of means for the sample collection was performed using GenStat® Executable release 16 Statistical Analysis Software. White-coloured sweet potato roots stored in ventilated bags and the improved traditional raised platform resulted in a weight loss of 49.4% and 68.7%, respectively. It was also observed that the improved traditional raised platform had a significantly high total soluble content /concentration, with a value of 21.27% while Ventilated bags resulted in a Total soluble solid content of 17.02 %, which was significantly low. Furthermore, results show that Ventilated bags had the lowest beta carotene content (8.72 µg/g) compared to other treatments. The findings of this study strongly suggest that storing white-coloured sweet potato roots in ventilated bags is an appropriate method. In the context of the current study, further research on different sweet potato roots packaging materials is recommended.

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INTRODUCTION

Sweet potato (*Ipomoea batatas* L.Lam.) is a dicotyledonous root crop that originated from tropical America (Coop, 2010). In Tanzania, the crop is mainly cultivated around the Lake zone, Eastern zone, Southern highlands, and Northern parts (URT, 2016). It is cultivated by 771,257 households during short rainy and long rainy seasons, with an estimated annual production of 504,346 tonnes (NBS, 2012). Sweet potato roots contribute to food security and income generation (Ahmad *et a*l., 2014). There are several varieties of sweet potatoes, including white-coloured flesh, cream-coloured flesh, yellow, red, and purple (Rahman *et al.,* 2003). White-coloured sweet potato roots are a great source of nutrients including Calories, Fat, Carbohydrates, Protein, Fiber, and Vitamins (De Albuquerque *et al.*, 2019). Consuming white-coloured sweet potato roots enhances healthier eyes, reproductive system and heart and kidney functions (Johnson & Pace, 2010).

Despite its importance, white-coloured sweet potato roots production in Tanzania is still facing some challenges. The major challenge is the high post-harvest losses that both suppliers and consumers experience due to the poor storage methods. Inappropriate storage facilities have contributed to considerable post-harvest white-coloured sweet potato roots losses in many developing countries. The losses are estimated to range between 25 and 50% of the total production of the world (Robert *et al.,* 2014). Inappropriate storage facilities lead to qualitative, quantitative, and economic losses (Singh *et al.*, 2007). Despite the need to improve the production of white-coloured sweet potato roots in Tanzania, insufficient information concerning efficient storage technology limits farmers and traders to choose the best technology to reduce post-harvest losses.

The research by Teye *et al.* (2011) compared two storage technologies, which were the Purpose-Built Evaporative Cooling Barn and Modified Pit Storage under Ghana conditions, neglecting other sweet potato storage technologies such as indoor storage, clamp storage and zero energy. The results showed that the Purpose-Built Evaporative Cooling Barn stored sweet potatoes better than the Modified Pit Storage. Furthermore, research by Mpagalile *et al.* (2007) used the traditional pit, improved open pit, improved housed pit (*mjinge*), and raised woven structure (*kihenge*) to evaluate the storability of sweet potato roots, neglecting indoor storage, clamp storage, and zero energy technology storage. The results showed that improved housed pit (*mjinge*) storage performed comparatively well whereas the traditional pit method was the poorest in all attributes.

The Purpose Built Evaporative Cooling Barn and housed pit storage are used for the storage of sweet potato roots to attain optimum temperature and relative humidity of 12.5 °C – 15 °C and 85% - 90%, respectively (Teye *et al.*, 2011). Nevertheless, their adaptability to small-scale farmers and traders in developing countries like Tanzania is limited due to their high initial capital and high running costs, prompting the choice of temporary storage measures including burying the sweet potato roots in the ground and the use of bamboo baskets which have low storage performance. This situation calls for high demand

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by small-scale farmers and traders for storage technology with low capital and running costs.

Indoor storage technologies can be used to maintain proper storage temperature and relative humidity through ventilation in hot and arid areas (Baimey *et al*., 2017). In using these technologies, white-coloured sweet potato roots can be stored with minimum changes in colour, weight, and firmness and minimum rotting (Gopala Rao, 2015). This study assessed the storability of white-coloured sweet potato roots using indoor storage technologies, including the improved traditional raised platforms, Woven Polypropylene Bags, and ventilated bags. The intention was to obtain results that will give the users confidence and allow them to choose the best-performing storage technology for white-coloured sweet potato roots as a strategy to increase shelf life and hence reduce post-harvest losses and also guide policymakers in promoting indoor storage technologies.

MATERIALS AND METHODS

Site Description

The experiment was conducted in the Entomology Laboratory, Department of Crop Science, at Sokoine University of Agriculture in Morogoro, Tanzania (6° 72' 56" S, 37° 32' 14" E). The experimental site was selected based on the research materials availability. The experiment was conducted under indoor conditions for 77 days, from July 2022 to September 2022, during which temperature and relative humidity were 20 to 29 °C and 53-99%, respectively.

Sourcing of Raw Materials and Treatment

Freshly harvested sweet potato roots were collected from eight villages in the Gairo district and delivered to the experimental site on the same day. At the site, the roots were sorted and cleaned before applying the storage methods. The injured roots were discarded.

Experimental Layout

White sweet potato roots were stored using the four storage treatments adopted for this study: the improved traditional raised platforms, the Woven Polypropylene Bags, ventilated bags, and bamboo baskets. The use of bamboo baskets posed as the control experiment due to being widely used by both farmers and traders. In each treatment, 50 kg of white-coloured sweet potato roots was used in a completely randomized design, with three replications.

Sampling and Data Collection

After every 5 days, samples of ten white-coloured sweet potato root pieces were selected randomly from each experimental trial. The data collected were in-storage temperature and humidity, Weight, Hardness, TSS, Colour, and Beta carotene content as outlined.

Temperature and Humidity

After every 10 minutes for the period of 77 days, data on temperature and humidity in each treatment was collected by using a data logger (Model - DHT22, Power supply - 3.3-6V DC, Output signal - digital signal via single-bus, Sensing element - Polymer capacitor, Operating range - humidity 0-100%RH; temperature - 40~80Celsius, Accuracy - humidity +-2%RH (Max +-5%RH); temperature <+-0.5Celsius, Resolution or sensitivity - humidity 0.1%RH; temperature 0.1Celsius, Repeatability - humidity +-1%RH; temperature +-0.2Celsius, Humidity hysteresis - +-0.3%RH, Long-term Stability - +-0.5%RH/year, Sensing period Average: 2s, Interchangeability - fully interchangeable, Dimensions - small size 14*18*5.5mm; big size 22*28*5mm).

Physiological Loss in Weight (%).

During the 77 days of storage, the physiological loss in weight (PLW) was evaluated at 5-day intervals. The initial root weight was determined using an analytical balance and recorded at the start of the storage period. The roots were weighed, and the value recorded was referred to as the final weight on the date of observation. For each observation day, the PLW was calculated as follows (Prathiksha & Ramachandra, 2017):

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$$\text{Physiological loss in weight (\%)} = \frac{(\text{Initial Weight} - \text{Final weight})\text{g}}{\text{Initial Weight (g)}} * 100$$

Hardness

A texture analyser (Model, CT3 10K), was used to analyse the hardness qualities (internal and external) of raw sweet potato root flesh. The sample was cleaned with a piece of cloth after being washed with clean tap water to eliminate any dust. Using the procedure described in Prathiksha and Ramachandra (2017), a two-bite compression test with 10.0 mm deformation was performed using a cylinder probe (2 g trigger), at a test speed of 10.0 mm/s, and the results were shown and recorded.

Total Soluble Solids (TSS).

Total soluble solids (TSS) of the sweet potato roots were estimated by using a Refractometer on the different days of observation. A small amount of the flesh of the roots was crushed using a mortar and pestle and the obtained slurry was filtered using multiple layers of muslin cloth. The obtained clear juice was applied in drops on the prism of the calibrated refractometer and the values were read (Prathiksha & Ramachandra, 2017).

Colour

Colour was analysed by the calorimetric method (Sherwood calorimeter model 260, voltage 12V DC 300 mA, weight 2.2 kgs, RS 232 Printer).

Beta-Carotene Content /Vitamin A (mg/100g)

To measure Beta-carotene content, the petroleum ether method was used in the different treatments for the different roots. In each treatment, Beta carotene determination was done according to Delia and Mieko (2004), with slight modifications, where a 2.0g homogenized sample was taken into a Polytron bottle followed by extraction using 50 ml of cold acetone. Then a portion of the extract was transferred into a separating funnel containing 25 ml of petroleum ether (40^0C-60^0C Bp) for partitioning, followed by washing with about 125 ml of distilled water until the extract was acetone free. The washed sample was then passed through anhydrous sodium sulphate to make it free from any trace of water. The dried carotene extract was collected into a clean and dry volumetric flask in which it was subjected to measurements by the UV-Visible Spectrophotometer at 450 nm ((Double beam UV-3000 model X-ma3000 spectrophotometer Human Corporation, England).

Beta carotene standard solution with 110 mg/ml concentration was prepared by taking 0.0110 g of β-carotene standard powder obtained from Sigma-Aldrich into a 100 ml volumetric flask. 10 ml petroleum ether was added and swirled to dissolve and finally petroleum ether was added until the volume made to 100 ml mark of the volumetric flask. Serial dilutions of 0 mg/ml, 0.1 mg/ml, 0.2 mg/ml, 0.4 mg/ml, and 0.6 mg/ml were prepared by taking 0 ml, 0.2 ml, 0.4 ml, 0.8 ml, and 1.0 ml of the stock standard solution (110 mg/ml) into 25 ml volumetric flask. Petroleum ether was added to complete volumes (25 ml). Absorbencies of the diluted standards were read and a standard calibration plot was constructed and the linear regression equation obtained, which was used to calculate the Beta carotene content of the samples (Rasaki, 2009).

Data Analysis

Analysis of variance and comparison of means for Temperature and Humidity, Weight, Hardness, TSS, Colour, and Beta carotene content was performed using GenStat® Executable release 16 Statistical Analysis Software. The means were compared by Tukey Honest Significance Difference (HSD) test at 5% probability. Analysis of variance (ANOVA) was used to validate the variability of all collected data based on storage treatments and time of data collection. Regression (R^2) and Pearson correlation (r) relationships between all numeric variables were done using R-software to determine their relationships between all variables (Barret *et al*., 2021; Wickham, 2016).

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RESULTS

Physiological Loss in Weight (%).

The mean per cent weight loss of sweet potatoes stored using different storage methods for 77 days is shown in *Table 1*. There were significant differences among treatments for physiological weight loss (p<0.05). Ventilated bags registered significantly low (49.4%) weight losses compared to all other treatments consistently followed by Woven Polypropylene Bags (50.1%), Bamboo buckets (62.4%) and improved traditional raised platforms (68.7%), the highest during storage.

Table 1: Weight loss (%) in White coloured sweet potato roots stored for 77 days in indoor technologies

Storage methods	Initial weight (grams)	2 weeks (grams)	4 weeks (grams)	6 weeks (grams)	8 weeks (grams)	10 weeks (grams)	PLW (%)
Woven polypropylene bags	310.8a	36.38ab	43.26a	60a	79ab	98.4ab	50.1ab
Ventilated bags	340.5a	16.93a	27.85a	42.7a	59.9a	78.6a	49.4a
Bamboo buckets	373.6a	88.33ab	123.37ab	142.4ab	178.6ab	224.3c	62.4ab
Improved traditional raised platform	449.9a	137.02b	151.52b	169.5b	197.4b	211.8bc	68.7b
Grand mean	369	70	87	104	129	153	57.7
Se	48.4	31.3	29.2	29.3	37.5	36.1	5.83
LSD	118.4	76.6	71.5	71.6	91.7	88.3	13.45
Cv	23.1	21.3	24.3	22.2	26.5	33	12.4
P	0.113	0.031	0.014	0.012	0.023	0.013	0.027

Key: FWL=Physical final weight loss, PLW=Physiological final weight loss

Hardness

Aspects of textural parameters of white-coloured sweet potato roots were observed in all treatments as the most important factor in determining consumer acceptance of sweet potato root products (Delia, 2004).The results on hardness of white-coloured sweet potato roots are the indicators of firmness of the roots.

External Hardness

Treatments, duration, and their interactions have shown significant differences in external Hardness (p<0.05) (*Tables 2*). It is also shown that the four different treatments resulted in different external hardness; with the highest value (10909(g)) for the improved traditional raised platform, followed by Bamboo buckets (7405(g)), Woven Polypropylene Bags (7281(g)), and Ventilated bags (7194(g)).

Internal Hardness

The results on internal hardness 2 are in *Table 2*. The four storage treatments have shown a significant influence on the internal hardness of white-coloured sweet potato roots (p<0.001). Results obtained indicate that the traditional raised platform achieved a significantly higher hardness of 7360(g), followed by Bamboo buckets (7283(g)), Woven Polypropylene Bags (6965(g)) and Ventilated bags resulted (6920(g)), the lowest in the list.

Total soluble solids (TSS).

Total soluble solids (TSS) were highly significantly influenced by the storage treatments and storage (p<0.001). In this study, TSS in sweet potato roots stored in the improved traditional raised platform, Bamboo buckets, Woven Polypropylene Bags and Ventilated bags were 21.27%, 17.91%, 17.74% and 17.02%, respectively.

Colour

Storage methods have shown to affect sweet potato root colour significantly (p<0.001) (*Table 2*). Storage in Ventilated bags resulted in the lowest colour value (11.2 (E10.), RYB) compared to other treatments while the colour value recorded on Woven Polypropylene Bags was 16.82 (E10.), RYB. The Colour value recorded due to storage in the Bamboo buckets was 16.92 (E10.), RYB while the Improved traditional raised platform storage resulted in the highest (17.13 (E10.), RYB) colour value (*Table 2*).

Beta Carotene Content

Beta carotene content (µg/g) was highly significantly influenced by the treatments and storage duration ($p<0.001$) (*Table 2*). Beta carotene content in sweet potato roots stored in Ventilated bags was 8.72 (µg/g), which was the lowest. The highest Beta carotene content was 12.53 (µg/g), recorded in sweet potato roots stored in Bamboo buckets. Beta carotene content in sweet potatoes stored in the Woven Polypropylene Bags and the improved traditional raised platform was 11.46(µg/g) and 10.881(µg/g), respectively.

Table 2: Hardness (g), Total soluble solids (%), Beta Carotene (µg/g) and Colour value (E10.), RYB in White coloured sweet potato roots stored for 77 days in indoor technologies

Storage methods	Hardness		Total soluble solids (%)	Beta Carotene (µg/g)	Colour value (E10.), RYB
	External (g)	Internal (g)			
Woven Polypropylene Bags	7281a	6965a	17.74a	11.46b	16.82a
Ventilated bags	7194a	6920a	17.02a	8.72a	11.2a
Bamboo buckets	7405a	7283a	17.91a	12.53c	16.92a
Improved traditional raised platform	10909a	7360a	21.27b	10.82b	17.13a
Grand	8197	7132	18.48	10.881	15.52
se(+/-)	1847.3	206.8	0.35	0.3166	3.029
CV	17	1.9	3.1	2.7	93.4
P-Value	0.132	0.082	<.001	<.001	0.162

Correlation and Regression Analysis

A significant relationship was observed between the following parameters; hardness 1 and 2 ($p<0.001$, $r=0.78$, $R^2=0.6$), cohesiveness and weight ($p<0.001$, $r=0.63$, $R^2=0.39$), springiness and weight ($p<0.05$, $r=0.32$, $R^2=0.089$), beta carotene and weight ($p<0.05$, $r=0.32$, $R^2=0.09$), springiness and hardness 2 ($p<0.05$, $r=0.36$, $R^2=0.12$), cohesiveness and springiness ($p<0.05$, $r=0.33$, $R^2=0.09$), beta carotene and cohesiveness ($p<0.001$, $r=-0.53$, $R^2=0.27$), color and cohesiveness ($p<0.05$, $r=0.32$, $R^2=0.084$),

Table 3: Correlation and regression analysis in White coloured sweet potato roots stored for 77 days in indoor technologies

	Hardness1	Hardness2	Cohesiveness	Springiness	Beta Carotene	Colour value
Weight	p=0.052, r=0.25, R2=0.046	p=0.24, r=0.15, R^2=0.007	p<0.001, r=0.39, R^2=0.63	p=0.0.012, r=0.32, R^2=0.089	p=0.011, r=0.32, R^2=0.09	p=0.48, r=0.092, R^2=-0.0088
External Hardness		p<0.001, r=0.78, R^2=0.6	p<=0.66, r=0.059, R^2=0.014	p=0.52, r=0.086, R^2=0.0098	p=0.4, r=0.11, R^2=0.0046	p=0.98, r=0.0.0028, R^2=-0.017
External internal			p=0.53, r=0.082, R^2=0.011	p=0.0042, r=0.36, R^2=0.12	p=0.73, r=0.53, R^2=-0.015	p=0.69, r=0.052, R^2=0-0.015
Beta Carotene						p=0.12, r=-0.2, R^2=0.025

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DISCUSSION

Physiological Loss in Weight (%).

The experiment was carried out indoors to imitate the sweet potato storage requirements of farmers and traders. The weight loss (%) after 77 days of storage at indoor conditions was substantially lower than the weight loss without storage. The major cause of weight loss was the evaporation of moisture, implying that the none-stored roots incurred higher moisture loss. Storage in Ventilated bags incurred less weight loss than Polypropylene Bags, improved traditional raised platforms and Woven Bamboo buckets. The higher and lower PLW of the roots imply the respective higher and lower rates of moisture evaporation during storage, reflecting the quality of the storage system used. These findings are consistent with the results by Edun *et a*l.,(2019) who revealed that moisture reduction correspondingly results in weight loss and hence the roots can be easily damaged. The results also concur with those by Sugri *et a*l.,(2017) who revealed that the lowest percentage of weight loss after storage occurred due to low moisture reduction. Furthermore, Degras (2003) observed that increased temperature in storage might have enhanced the rate of moisture reduction, resulting in weight loss.

Hardness

Food acceptance is significantly influenced by texture. For sweet potato roots, their textural properties depend upon their structure and composition. As some experiment treatments led to high hardness while others displayed low values, it implies that the hardness of the sweet potato roots was significantly influenced by the storage. These observations are similar to the previous findings by Fuentes *et al.* (2014) in potatoes, in which an extreme reduction in the textural hardness of potatoes during storage was obtained. Zhang *et al*. (2002) also reported that during storage and prior to the processing of sweet potatoes, the firmness of the roots was significantly reduced. Also, similar findings by Song *et al*.(2011) show that storage time increased hardness of sweet potato roots and decreased water loss and respiration rate, which resulted in better storability with minimized weight loss.

Total Soluble Solids (%).

In the current study, total soluble solids (%) was significantly affected by the treatments and storage period ($p<0.001$). In a similar study by Sugri *et al.* (2019), moisture reduction in sweet potato roots resulted in the increase of total soluble solids. TSS content is an essential quality parameter that indicates the quality of a food product. This is directly related to the availability of starch, which can be converted to sugars (sucrose, glucose, and fructose). The breakdown of starch into sugars might have resulted in the increase in total sugar content, which is directly responsible for the increase of TSS during storage. Similar results were obtained by Thriveni *et al.*(2019) and Rosero *et al*. (2020), who observed that moisture reduction resulted in the increase of total sugar content, which is directly responsible for high TSS during storage.

Colour

One of the most important appearances that contribute to customers' acceptability is colour. In the food industry, the colorimetric method is commonly used to monitor and control product quality. The common qualitative values associated with colour analysis are colour value (E10) and RYB. The R-values used to characterize the samples' reddish colour gradually decreased with storage time. This change could be attributed to increased respiratory activity during storage (Hernandez *et al*., 2014). The reddish colour is usually associated with water-soluble anthocyanin. The results indicate that there was a decreasing trend in redness during storage, corresponding to reduced moisture content. The decrease in the redness values in the samples was probably attributed to the degradation of red anthocyanin pigments.

Tani *et al*., 2019 discovered that storage time significantly affected the colour value of sweet potatoes. The Y-value is a measurement for yellowish colour. The yellowish colour is related

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to the carotenoids and flavonoids pigments. The results from this study are similar to the findings by Kim *et al.* (2021), which indicated that in the stored roots of sweet potato, colour varied greatly between the different varieties of sweet potato, which ranged from white to light yellow and deep yellow. The parameter B-values is used to indicate the blue colour. Blue colour is related to anthocyanins, which is responsible for the coloration of tissues (Yang *et al.*, 2020).The results of this study concurs with the findings by Pankomera (2015) and Lee *et al*. (2013), which indicated Anthocyanins were present in sweet potato roots during storage.

Beta Carotene Content

Beta carotene concentration of sweet potato roots varied during storage, similar to the findings by Zhang *et al.*(2019) that carotene concentration is caused by variations in storage time. As a consequence, it is unlikely that the variation in carotene content between the four treatments in the current study was caused by a change in storage conditions. Weather data collected during storage revealed that Woven Polypropylene Bags had higher average humidity (64%), followed by other treatments during the storage period. In a similar study by Faber *et al.* (2013), differences in weather conditions might have led to the variation in beta carotene content. Furthermore, comparable results were found by Siregar (2022), showing that changes in storage conditions might have led to the variance in beta carotene concentration.

CONCLUSION AND RECOMMENDATIONS

Storage is a critical component of the sweet potato post-harvest value chain, and it has been identified as the most critical point in minimizing losses. The vast majority of sweet potato losses among farmers and traders are due to inadequate storage facilities. To reduce such losses, farmers and traders should be encouraged to use effective sweet potato post-harvest storage technology. The findings of this study strongly suggest that storing white-coloured sweet potato roots in ventilated bags is an appropriate method. Furthermore, the use of ventilated bags can also be effective when storing undamaged sweet potato roots. Farmers and traders are advised to sort and grade their roots before storage. In the context of the current study, additional research in other types of packaging materials is recommended.

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