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Effect of Storage Methods on Carbohydrate and Moisture of Cassava Planting Materials

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Abstract

Storage of cassava (*Manihot esculenta* Cruntz.) planting materials has been a challenge because of its properties of moisture and carbohydrates loss under storage. Two varieties of cassava cuttings 1 m long, stored for four months under four different storage methods in two locations Kabete and Kiboko. The storage methods were clamp under double shade (CUDS), horizontal under shade (HUS), vertical under shade (VUS) and the control horizontal under open ground (HOUG). In each storage method data loggers were installed to record temperature and RH. Percentage carbohydrate, moisture content (MC), 100% dry cuttings (DC) and cuttings dried to 25% or more of its stored length but not 100% were measured at intervals of 4 weeks. Data were subjected ANOVA and means separated using LSD. CUDS performed better than other storage methods in all parameters measured. The results showed cuttings stored under CUDS lost less moisture than those stored in HUOG. The moisture loss in CUDS was from 70.16%-56.69% while that of HUOG dropped from 70.16% to 27.26% within 8 weeks after storage. High rate of carbohydrate loss was observed in Kiboko than Kabete. Mean temperatures were 25 °C Kiboko and 22 °C Kabete. The results showed that temperature had effect on loss of carbohydrate. The results have proven that safe storage of cassava planting material is affected by plant related factors as well as environmental conditions.

Keywords: carbohydrate, cassava cuttings, cassava planting materials, moisture, storage methods

1. Introduction

Cassava contribute to food security and livelihood to majority of small scale farmers in semiarid areas. It is also a source of raw materials to more than 1000 microprocessors and traders around the world (Balagopalan, 2002). Cassava is a source of carbohydrate in Africa after maize and rice (Aerni, 2005). The ability of cassava to grow in marginal land as well as flexibility in harvest of tuber when needed make it the best crop of choice for most poor farmers. Worldwide cassava production increased from 163 MT in 1980 to 270 MT in 2013.A lot of effort has been put to increase cassava production to cater food, energy and animal feeds requirements in Africa but planting material has been a challenge to most farmers. Most farmers use planting materials from previous crop which, normally have diseases infection as well as low nutrients (Ogero et al., 2012).

Cassava planting materials require storage especially when climatic condition such floods, drought and low temperature or delayed land preparation and other factors. However, use of fresh planting materials is preferable than stored cuttings (Leihner, 1983; Lozano et al., 1977) as it has been observed that the longer the duration cassava planting materials are stored, deteriorate their sprouting. Sprouting ability depend on storage conditions (Oka et al., 1987) as well as other factors like temperature and moisture of field. Leihner (1986) reported that cassava stems lose carbohydrate reserves during storage mainly in form of total carbohydrate and reducing sugars. More lignified cuttings contain small amount of food reserved for shoots development during sprouting (Lozano et al., 1977). Despite good storage conditions, long storage durations bring about some losses in moisture, carbohydrates, and nutrients, which would partially account for reduced early vigour (Leihner, 1982). Cassava cuttings dehydrate when stored. The rate of moisture loss is high when the cuttings are stored in open air and exposed to sun (Leihner, 1982). Moisture loss on planting material are influenced by plant factors (level of lignification and moisture content at harvest) and environmental factors (radiation, humidity, temperature and wind speed) (Leihner, 1982).

When harvesting and planting are separated in time, a farmer can decide to leave some portion of crop as seed for next planting. But this can cause pests carryover and cause big loss to small scale farmers (Leihner, 1982). Also where land is unavailable, storage of planting materials is inevitable.

2. Materials and Methods

2.1 Description of Sites

The experiment was conducted in two sites namely University of Nairobi Kabete Campus and KARLO Kiboko. Kabete is situated about 15 km to the west of Nairobi city and lies at 1°15′S latitude and 36°44′E longitude and at altitude of 1930 m above sea level (masl) (Onyango et al., 2012). Kabete has a bimodal distribution of rainfall, with long rains from early March to late May and the short rains from October to December (Onyango et al., 2012). The mean annual temperature is 18 °C and total annual rainfall ranging between 700-1500 mm (Wasonga et al., 2015).

The second site was KARLO-Kiboko which lies within longitudes 37°.43212'E and latitudes 2°.12933'S, and 821.7 m above sea level in Makueni County, 187 km east of Nairobi, Kenya (Kivuva et al., 2015). The location receives between 545 mm and 629 mm of rainfall coming in two seasons. The long rains season is between April and May while the short rains season is between October and January. The mean annual temperature is 22.6 °C, where by the mean annual maximum temperature is 28.6 °C and mean annual minimum temperature is 16.5 °C (The Kenya Gazette, 2010).

2.2 Source of Cassava Stem Cuttings

The stem cuttings comprised varieties Karembo and KME4 were obtained from KARLO Thika. Planting and harvesting of planting materials was done at the same time as well as planting location to avoid the difference in accumulation of carbohydrate. The materials were selected on basis of the diseases free and high yielding of the varieties. KME4 has maturity of 8-10 months, fresh tuber yield is 38 t ha^{-1}, resistance to cassava mosaic virus and cassava brown streak. Karembo mature in 8 months and fresh tuber yield range from 50-70 t ha^{-1}, it has great tolerance to cassava mosaic virus and cassava brown streak virus (Kenfap Services Limited, 2013).

2.3 Experimental Design

The design was split plot in randomized complete block design (RCBD) (Petrenko, 2014). The main plot being storage methods (with 4 levels) sub plot being varieties (2 levels). The storage duration was in 5 terms (0, 4, 8, 12, and 16 weeks after storage (WAS)). Each main plot had 30 cuttings while the sub plot had 15 cassava cuttings from single variety each having 100 cm length with diameter range of 1.5 cm-3.4 cm. These 15 cuttings were tagged numbers 1-15 (Ravi & Suryakumari, 2005). Cassava cuttings were stored in four different storage methods namely; clamp under double shade (CUDS) (Plate 2), horizontal in open air under shade on the soil (HUS), vertical in open air under shade on soil (VUS) (Sales & Leihner, 1980; Plate 3) and horizontal under open ground with no shade on the soil (HUOG) (control or farmer's way of storing cassava cuttings when waiting transport or planting) (Plate 4). The shade was made by simple wooden poles and grass thatch (Plates 1 and 3). Three hitag 2 xsense loggers were installed to monitor temperature and relative humidity in clamp, under shade and under direct sun light. Two cuttings per storage method were sampled to form 6 cuttings. The 6 cuttings were cut into 20 cm cuttings after removing 10 cm from each end. The cuttings were mixed together and some were sampled for moisture and carbohydrate analysis.

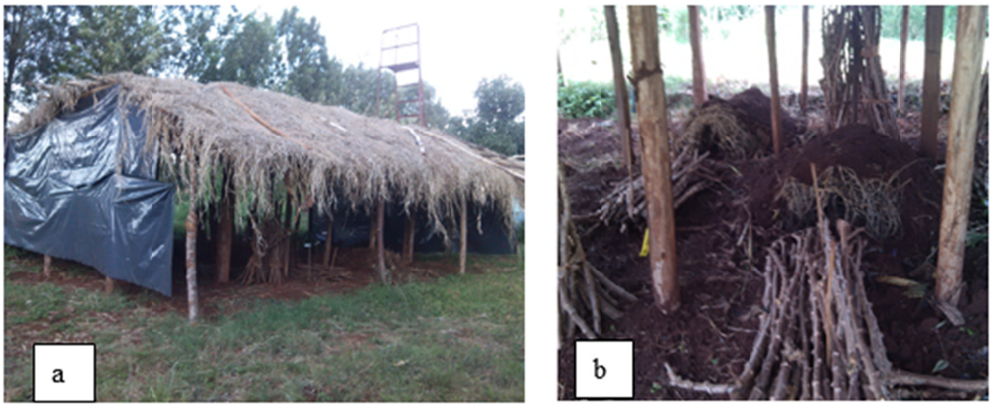

Plate 1. (a) Simple shade and (b) different storage methods under shade

2.4 Carbohydrate Determination

In each storage method six samples of 20 cm each were taken to the laboratory for carbohydrate tests. The sample cuttings ware cut at the middle and both sides of the cut were grated to obtain composite sample.

Plate 2. Clamp under double shade storage method

Note. (a) clamp structure frame, (b) arranged cuttings for storage (c) clamp storage method covered by grass then 0.06 m^3 of soil.

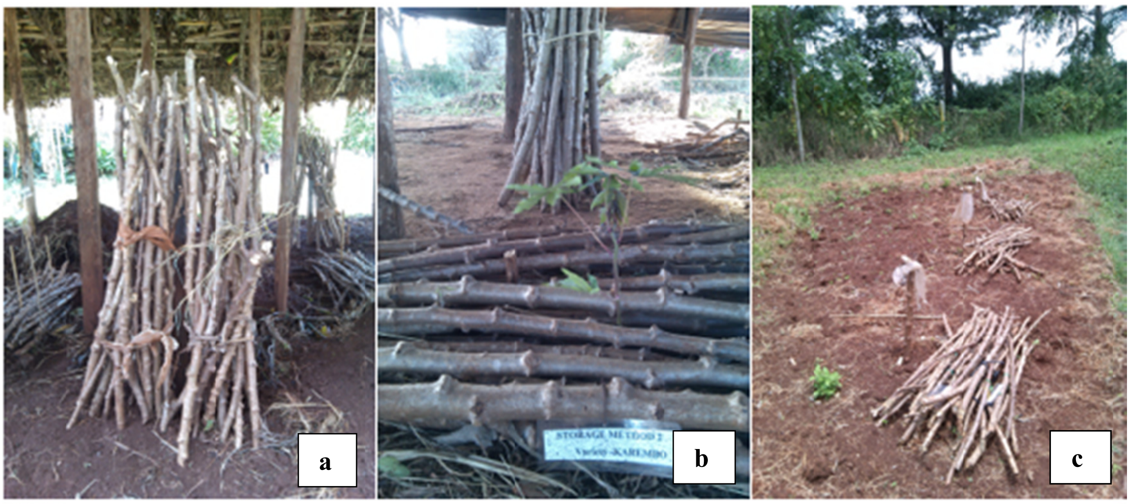

Plate 3. Different storage methods

Note. (a) Vertical under shade with lower end of cassava touching the soil, (b) horizontal under shade, (c) cuttings stored horizontal in open ground under direct sun light.

Total carbohydrate in dry samples was estimated by the anthrone method which is a simple calorimetric method with relative insensitivity to interference from other cellular components (Clegg, 1956; Ravi & Suryakumari, 2005). 1 gram from sample were taken in duplicate and transferred to graduated 100 ml beaker. Then 10 ml of distilled water were added and then stirred thoroughly to dispense the sample.

From 10 ml of sample suspensions 13 ml of 52% perchloric acid were added in order to solubilize starch in samples (Rose et al., 1991). The suspensions were stirred for 20 minutes and then diluted to 100 ml. Then the suspensions were filtered to 250 ml flask and the solution were diluted to the mark to form a stock solution (Clegg, 1956). From the stock solution 10 ml was drawn and diluted to 100 ml. 1 ml of the diluted sample, standard sample and blank were pipetted into individual test tubes, then in each test tube 5 ml of anthrone reagent in concentrated sulphuric acid was added. The reactions in this process were, concentrated H_2SO_4 catalyses the dehydration of sugars to form furfural (from pentose's) or hydroxy methyl furfural (from hexoses). Adding anthrone into the sample give condensation product with bluish or green coloured.

The test tubes then transferred to boiling water for exactly 12 minutes then cooled to room temperature. From the test tubes the solutions were transferred to glass cuvettes to read absorbance at 630 nm wave length (Clegg, 1956).

The formula used to calculate the concentration of carbohydrate in the samples was:

$$\frac{\text{Absabance of sample}}{\text{Concentration of sample}} = \frac{\text{Absabance of standard}}{\text{Concentration of standard}} \quad (1)$$

2.5 Determination of Moisture Loss from Stored Cassava Stem Cuttings

The moisture content was determined by constant temperature oven method (ISTA, 2015). From the composite sample, 2 g of sample were measured in duplicate into moisture dishes and put to oven at 103 °C for more than 17 hrs to obtain constant weight. Calculations and expression of results for each replicate in three decimal places using the following formula (ISTA, 2015):

$$\frac{\text{Loss of weight} \times 100}{\text{Intinial weight}} = \frac{M_2 - M_3 \times 100}{M_2 - M_1} \quad (2)$$

Where, M_1 is weight (in grams) of empty container; M_2 is weight (in grams) of container + sample before drying; M_3 is weight in grams of container + dry sample.

2.6 Data Analysis

The data were subjected to analysis of variance (ANOVA) (Kroonenberg & van Eeuwijk, 1998; Cohen & Brooke, 2004; Cheng & Shao, 2006; Smith, 2006) to determine the difference between storage methods and varieties. GenStat 15 edition were used. Means were separated using least significant difference (LSD) at $p \leq 0.05$ (Kivua et al., 2015). The assumptions were that the population was normally distributed, samples were independent, variance of population was equal and group of samples was equal.

Complete model used was (Kroonenberg & van Eeuwijk, 1998; Smith, 2006):

$$Y_{ijkl} = \mu + \alpha_i + \beta_j + \gamma_k + (\alpha\beta)_{ij} + (\alpha\gamma)_{ik} + (\beta\gamma)_{jk} + (\alpha\beta\gamma)_{ijk} + \varepsilon_{ijkl} \quad (3)$$

Where, μ is the general mean of the population α_I, β_j, γ_k is mean of storage methods, mean of varieties and mean of duration of storage, as main effects while $(\alpha\beta)_{ij}$, $(\alpha\gamma)_{ik}$, $(\beta\gamma)_{jk}$ are corresponding two-way interaction effect and $(\alpha\beta\gamma)_{ijk}$ three-way interaction effect. ε_{ijkl} represent the expected error (Kroonenberg & van Eeuwijk, 1998). The computed data composed percentage dry cuttings more than 25% of its storage length but not 100% (%DC > 25% SL), Percentage dry cuttings 100% of its storage length (%DC), percentage moisture of stored cuttings (%MC) and carbohydrate content of stored cuttings sampled at specific duration according to Equations 2, 4, 5 and 6.

$$\%DC > 25\%\ SL = \frac{DC > 25\ cm}{TNC} \times 100 \quad (4)$$

Where, %DC > 25% SL sampled cuttings with > 25 cm of its stored length dried but less than 100 cm; DC > 25 cm = sample cuttings with > 25 cm of its stored length dry; and TNC = total number of cuttings at a given time.

$$\%DC = \frac{DC}{TNC} \times 100 \quad (5)$$

Where, %DC = cuttings sample 100% of its stored length dried; DC = total dried cuttings samples; and TNC = total number of cuttings at a given time

$$\%\ Carbohydrate = \frac{25 \times b}{a \times w} \quad (6)$$

Where, b = absorbance of diluted sample; a = absorbance of dilute standard sample; and w = weight of sample (g).

3. Results

3.1 Weather Data during the Experiment Duration

The mean temperatures were 24.12 °C and 12.53 °C in Kiboko and Kabete respectively. Rainfall in Kiboko was negligible while in Kabete was around 5.67 mm. RH were around 82% and 65% in Kiboko and Kabete respectively. Data obtained from ICRISAT Kiboko and Kabete meteorological stations (Figure 1).

Data recorded by hitag 2 xsense data loggers (Table 1) were different from each storage methods. Minimum was recoded in CUDS and highest was under HUOG in both locations.

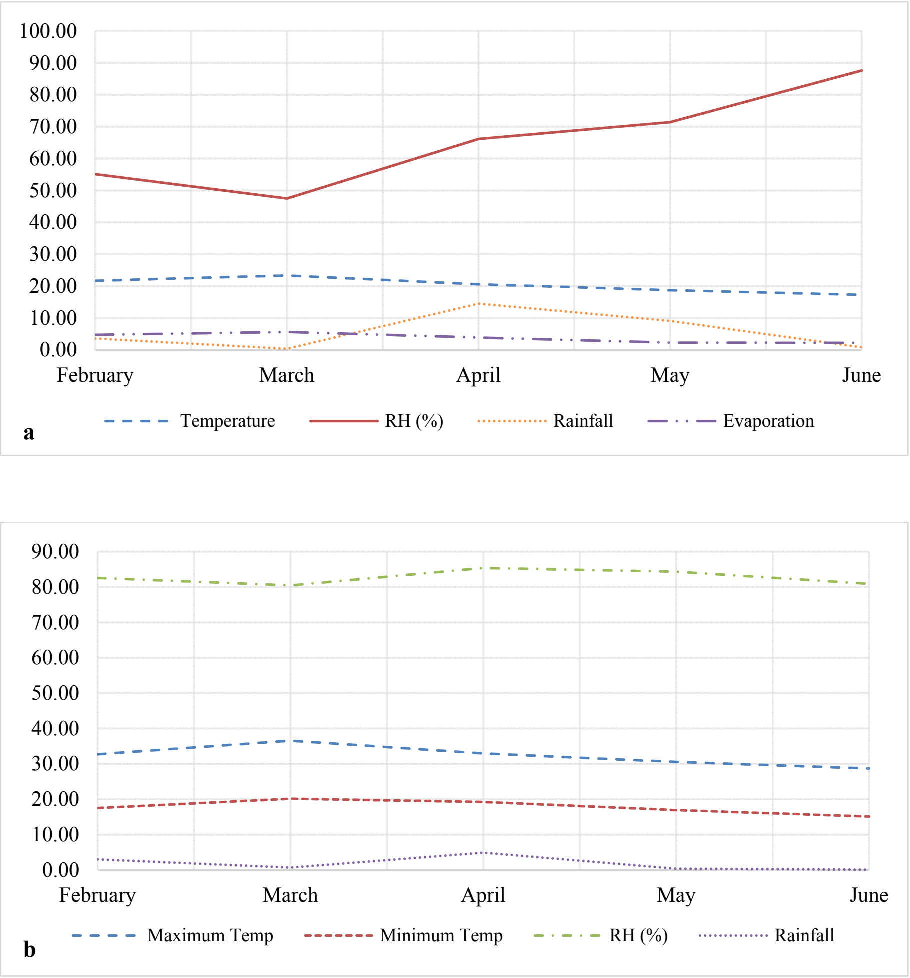

Figure 1. (a) Weather condition at Kiboko; (b) weather condition at Kabete in 2016

Table 1. Temperature and relative humidity in storage methods

Site	Storage method	Min T °C	Max T °C	Mean T °C	Min% RH	Max% RH	Mean% RH
Kabete	CUDS	12.25	24.5	18.78	38.00	100.00	72.05
Kabete	HUS &VUS	11.00	29.50	19.16	20.00	100.00	66.23
Kabete	HUOG	9.00	39.50	21.13	20.00	100.00	61.89
Kiboko	CUDS	17.50	32.75	24.99	20.00	92.00	60.13
Kiboko	HUS&VUS	14.50	40.00	25.42	20.00	100.00	56.66
Kiboko	HUOG	12.75	45.50	28.00	20.00	100.00	40.91

Note. T = temperature (°C), RH = relative humidity, Max = maximum, Min = minimum, CUDS = clamp under double shade, HUS = horizontal under shade, VUS = vertical under shade and HUOG = horizontal in under open ground.

3.2 The Percentage of Cuttings that Had Dried 25% of Its Storage Length but Less Than 100% (%DC > 25% SL)

The results showed highly significant difference ($p < 0.001$) among storage methods as well as varieties. The interaction between storage methods and varieties show significant difference ($p < 0.01$). Among storage methods, CUDS has the minimum increase of % DC > 25% SL, at 4 and 8 weeks after storage. Highest percentages (more than 50%) were found in horizontal under open ground with no shade on the soil only 4 weeks after storage.

CUDS performed better in all location and almost in all traits this can be explained by lowest mean temperature of 18.78 °C and 24.99 °C in Kabete and Kiboko respectively. Low mean temperature and medium RH reduce the desiccation of stored cuttings. The maximum temperature was recorded by temperature data logger's in horizontal under open ground on soil which was 45.50 °C in Kiboko. The maximum temperatures were recorded around 11:00 hours to 17 hours. Also the results shown that CUDS had high average of relative humidity of 72.05% and 60% in Kabete and Kiboko respectively while lowest mean relative humidity were recorded in HUOG 61.89% and 40.91% Kabete and Kiboko respectively. This justify why cuttings stored in HUOG lost more moisture than cuttings stored in CUDS. Low relative humidity means cuttings will loss water to surrounding. High evaporation of 5.62 mm was recorded at Kabete when average rainfall was 0.35 mm and also at the same time low RH was recorded. This mean that when there is low RH, cuttings loss more moisture content as evaporation become high. It also explains why cuttings stored in Kiboko dehydrated faster than that stored in Kabete.

The results also showed that the performance of HUS when the temperature was low was better than VUS. But under high temperature VUS lower end of cassava cuttings touching the soil did better than HUS. The mean temperature under shade was 19.16 °C and 25.42 °C, at Kabete and Kiboko respectively. While the maximum was 29.50 °C and 40.00 °C, Kabete and kiboko respectively. Relative humidity was 66.23% and 56.66% Kabete and Kiboko respectively. Thus Kabete site is good environment for cassava cuttings storage as compared to Kiboko because of low temperature and medium RH which is not triggering sprouting in storage or make stored cuttings to desiccate (Figure 2).

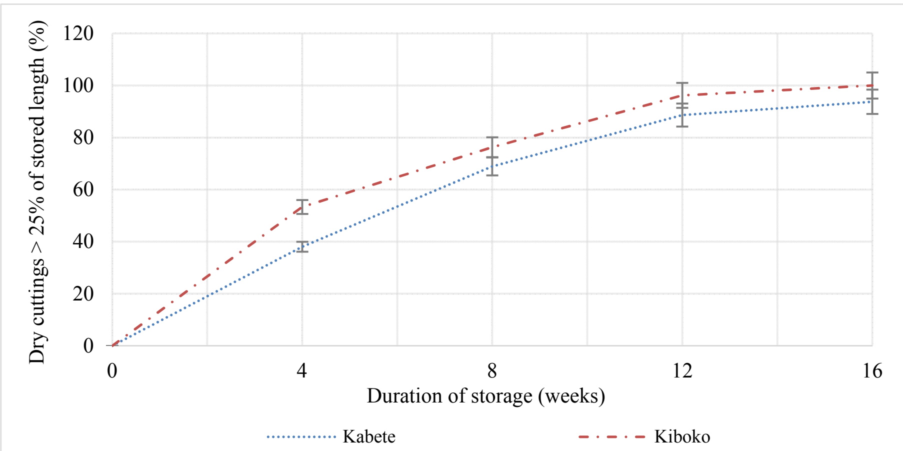

Figure 2. Rate of dehydration of cassava cuttings at Kabete and Kiboko for a duration of 16 weeks after storage

KME4 showed the best storability as compared to Karembo by having low% DC > 25% SL relative to that of Karembo.

3.3 Percentage Cuttings Dried 100% of Its Stored Length (%DC)

There was significant difference among storage methods at $p < 0.01$ as well as varieties (Figure 3). CUDS had lowest average dry cuttings of 34.40% as compared to other storage methods. The highest was under HUOG with 52.56% for whole period of storability test. Also KME4 had less dried cuttings 32.14% as compared to 47.15% of Karembo. Duration of storage was highly significant at $p < 0.001$ as results shown that the longer the storage percentage dried cuttings increased.

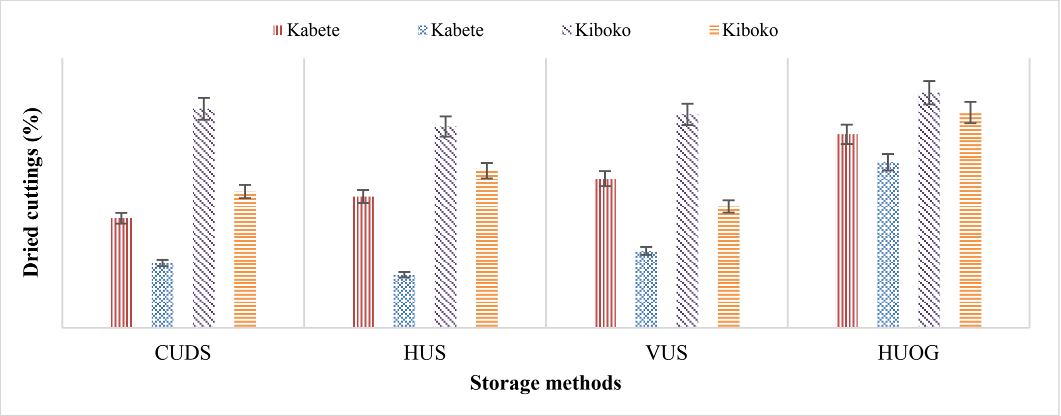

Figure 3. Effects of storage methods and variety on cassava cuttings drying in storage

Note. CUDS = clamp under double shade, HUS = horizontal under shade, VUS = vertical under shade and HUOG = horizontal in under open ground.

Storage was better in Kabete than in Kiboko due difference in RH, and temperature. Average relative humidity measured by Meteorology station Kabete was 60.04% and temperature was 23.54 °C as compared to average relative humidity measured by ICRISAT Kiboko field station of 83.91% and mean temperature of 33.18 °C. Variety KME4 performed better in both sites than Karembo. KME4 stored in Kiboko was performing better than Karembo stored in Kabete regardless of the difference in temperature and relative humidity.

3.4 Percentage Moisture of Stored Cuttings (MC%)

Moisture content of stored cuttings at different storage duration showed highly significant difference among sites ($p < 0.001$). The mean of moisture content of stored cuttings at 0 weeks of storage it was 70.16% both at Kabete and Kiboko. After 16 weeks of storage moisture content reduced to 14.23% at Kiboko and 39.70% at Kabete depending on methods of storage. Thus, the results shown that the rate of moisture content loss influenced by environmental conditions of particular location (Figure 4). The rate of dehydration in Kiboko was higher as compared to Kabete. Meaning that the moisture content of cuttings depends on weather conditions of locality of storage.

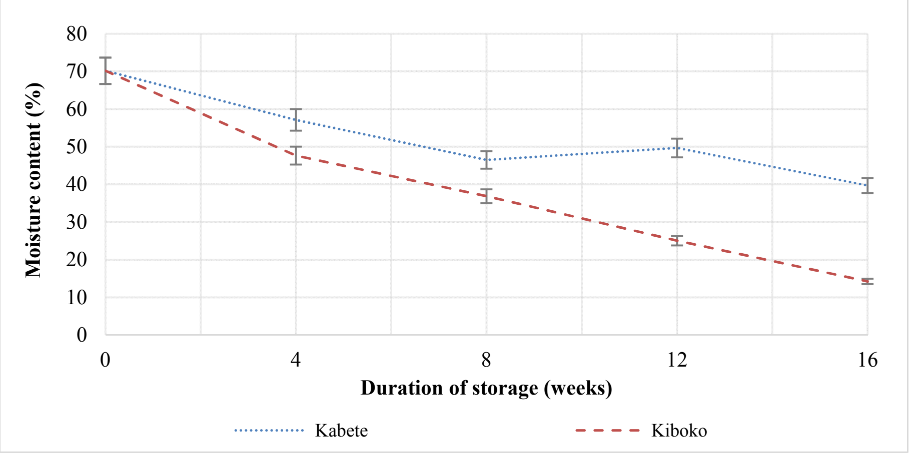

Figure 4. General percentage moisture content of cuttings with reference to duration of storage in two locations

Moisture reduction from stored cuttings in both Kabete and Kiboko site, dehydration of cuttings stored under CUDS was lower as compared to other storage methods while under HUOG dehydration of cuttings was highest. Thus, the best storage methods were CUDS followed by VUS and then HUS. Rate of dehydration of stored cuttings depends on varieties. Whereby, the rate of moisture loss of Karembo was higher compared to KME 4. CUDS performed better in all duration of storage from week 0 to week 16 after storage for stored cuttings.

3.5 Carbohydrate Content of Stored Cuttings

The amount of carbohydrate in cuttings during storage differed significantly among locations at $p < 0.001$. The results indicate that cuttings stored in Kiboko lost more carbohydrate than cuttings stored in Kabete (Figure 5). Duration of storage showed significant difference between weeks of storage at $p > 0.001$. The results showed that the more farmer store cuttings for long duration the more cuttings consume carbohydrate for maintenance. Also the results showed highly significant difference among varieties at $p < 0.001$. This mean the consumption of carbohydrate during storage differ with varieties. The interaction between duration of storage and variety was highly significant at $p < 0.001$ meaning that if the farmer store cassava planting material for a long time, it will lose more carbohydrate.

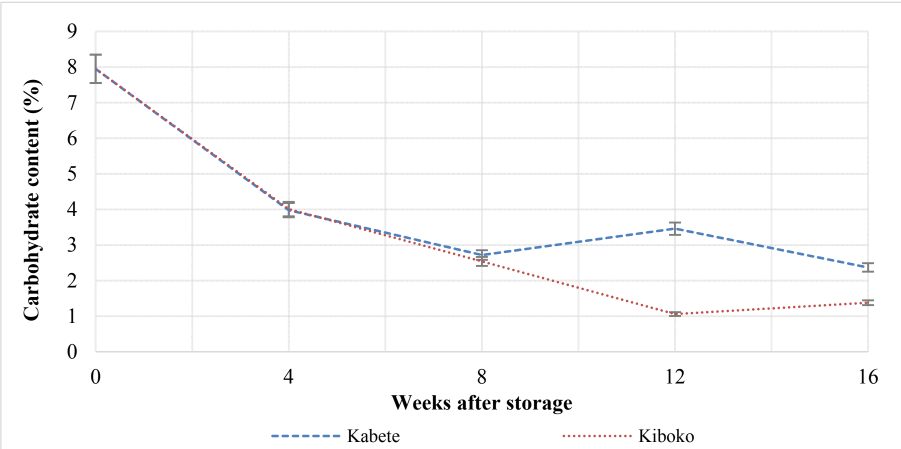

Figure 5. Average carbohydrate content reduction of cuttings with reference to duration of storage

4. Discussion

Cassava is vegetatively propagated and its cuttings are expensive as compared to true seed of other crops like maize and its establishment depends on quality planting materials. If 25% of original length of cassava dried during storage, then only 75% of stored cuttings is available for planting. Difference among the storage methods was observed in results as highly significant in stem dehydration and moisture loss. The carbohydrate loss was non-significant at $p < 5\%$ between storage methods but location of storage as well as varieties were significant among treatments. The rate of carbohydrate consumption in stored cuttings differed with location of experiment, Kiboko being hotter than Kabete had higher respiration rate than Kabete.

CUDS was shown to lose less moisture content than other methods. At 16 weeks after storage, the cuttings had an average of 53.54% moisture content as compared to control which had an average of 38.83%. This result may be attributed to difference in temperature and relative humidity among storage methods. Ratanawaraha et al. (2000) argued that storage under shade is better than under full sunlight. Direct sunlight containing heat energy which will accelerate the rate of moisture loss. The maximum temperature of 45 °C and 39.5 °C was recorded in the control at Kiboko and Kabete respectively. From the results it showed some increase in carbohydrate as well as moisture content of the stored cuttings at 12 WAS. This can be attributed by rainfall in March to April. The rainfall triggered some stored cuttings to sprout and form leaves which were contributing to photosynthesis. But general trend was decreasing in moisture and carbohydrate of stored cuttings. Similar results were obtained by Leihner, (2002) who showed that storing planting material under inadequate condition can cause cassava stake to loss 70% of sprouting ability if they were stored for 15 days at 24 °C. The difference in moisture loss is determined by cultivar, plant related factor such as degree of lignification at harvesting time and length of stored cuttings as well as environmental factors such as temperature, RH, radiation and air. Ravi and Suryakumari (2005) in their experiment of the novel technique to increase the shelf life of cassava planting materials they found similar factors affecting rate of moisture loss. The cuttings stored using HUOG in both sites lost moisture from 70.16% to 27.26% in just 8 weeks of storage probably due to be exposed full solar radiation and wind (Kinama et al., 2005). Kinama found that when soil doesn't have cover it loses more moisture through evaporation than when it contains cover crop or mulch. When there is high evaporation than rainfall results to high loss of moisture content of planting materials. It also explains why cuttings stored in Kiboko dehydrated faster than that stored in Kabete because evaporation in Kiboko is high than in Kabete. Pilbeam, Daamen, and Simmonds (1994) showed that evaporation in Kiboko is around 131.2 mm-224.9 mm from year 1991-1992. When stored cuttings are in open ground without cover or shade will lose more moisture content than when under shade and covered like in CUDS. According to Leihner (1982) cassava stored planting materials lose faster moisture in shorter stems than in long stems as the loss of moisture was recorded to start from two cut ends of stem cuttings increasing to the middle of the stem. This was resulting to some cuttings loss its viability from 25% of its length to 100%. It was recorded that only at 4 WAS the range loss of cuttings moisture were 31.11% to 58.33% depending on method of storage and location of storage. The loss of moisture was significantly different between varieties Karembo dehydrated more than KME4 stored in the same environment. Pérez et al. (2011) argued that cassava variety have difference capacity withstanding storage duration from harvesting to planting. This difference influences crop establishment and yield. The range of moisture content after 16 weeks of storage was 56.16%-43.27% for KME4 and 49.09%-34.30% for Karembo depending on site of experiment. Kiboko is a hot area with mean temperature of 25 °C and Kabete of 22 °C. This can explain the difference of moisture loss among the sites. In clamp storage in Kiboko the mean temperature recorded was almost similar (25.22 °C and 25.82 °C) perhaps due to hot air movement across the ventilation of clamp which was meant to reduce the RH in storage to control storage sprouting. This can explain the difference in performance of the clamp under double shade between Kabete and Kiboko. Thus Kabete site is good environment for cassava cuttings storage as compared to Kiboko because of low temperature and medium RH which is not triggering sprouting in storage or make stored cuttings to desiccate.

The results showed high significant differences among location and variety in carbohydrate loss of stored planting materials. The results showed significant loss during first 4 weeks after storage then after the rate of loss decreased. Ravi and Suryakumari (2005) found that carbohydrate content of stored cuttings decreases significantly in one month after storage. There after the change in content was less as compared to first four weeks. This rate can be due to reason during four weeks' moisture content of cuttings still high so even metabolic activities will be high. But other scenario can be due to stress of wounding of stored cuttings hence plant will be struggling to heal the wound caused in harvesting. The carbohydrate observed at 0 week of storage was 9.21% and 6.68% for Karembo and KME4 respectively. According to Kozlowsk (1991) carbohydrate consumption during storage can be due to maintenance respiration to keep planting material alive. Leihner (2002) reported that physiological deterioration of cassava planting materials linked with two main factors which are respiration and dehydration. He further said the respiration will be accelerated when cuttings are stored in hot environment than being stored in dry and cool environment. This can explain why the decrease in carbohydrate in Kiboko site was high as compared to Kabete. But also the results showed us that cuttings stored in HUOG lost less carbohydrate than other methods, it can be due to the fact that when cuttings lose high amount of moisture the maintenance respiration also will reduce or stop. Oka et al. (1987) found that respiration rate of stored cuttings increases soon after harvest of planting materials then after decrease before increase at slow rate again. This indicate that, variety and storage methods should be considered when a farmer wants to store the cassava cuttings with reference to a certain duration.

5. Conclusion

According to results obtained from this study storability of cassava depend on cultivar and environmental factors especially relative humidity, temperature, wind and radiation. It's better if cassava planting materials will be stored under shade and provide cover to insulate from high temperature and direct radiation. Where possible prolonged storage should be avoided since it contributes to carbohydrate loss during storage which has impact in crop establishment and vigour. High temperature has influence in carbohydrate loss as it increases respiration rate of stored cuttings Long term storage of cassava cuttings is possible under CUDS methods with temperature less than 20 °C.

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