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Evaluation of Appropriate Storage Technologies for Shelf-life Improvement of Cassava (*Manihot esculenta* Crantz) Roots for Marginal Upland Farmers

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ABSTRACT

Fast deterioration of roots after harvest is on of the major challenges in cassava production. This study was conducted to evaluate the effectiveness of simple cassava storage techniques in minimizing postharvest losses. Four storage techniques, namely: 1) box storage with moist sawdust as packing medium ; 2) box storage with moist river sand as packing medium; 3) packing in wet jute sack ; and 4) unpacked control were evaluated. Data on physical and chemical characteristics as well as sensory qualities of stored cassava roots were assessed. Cassava root var. 'Macan' deterioration in terms of vascular streaking and root decay and weight loss were minimized by packing the roots with moist river sand and sawdust. Moist river sand prolonged the shelf life of cassava roots for 30 days with very minimal degree of vascular streaking. Unpacked roots (control) lasted only for 6 days in storage due to severe vascular streaking and root decay while those packed in wet jute sacks lasted for 15 days. Sugar contents of cassava roots increased with time of storage while starch content decreased. Sensory qualities of the roots stored in boxes with moist river sand and sawdust for 30 to 60 days were as acceptable as or more acceptable than those of the freshly harvested roots when boiled.

Keywords: Box storage method, Physical and chemical parameters, Sensory Quality

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INTRODUCTION

Cassava (*Manihot esculenta* Crantz) is among the important root crops grown by many upland farmers in Inopacan, Leyte Philippines because of its ability to tolerate drought and to thrive in soils of low fertility. To these subsistence farmers, cassava serves as a reliable source of food when adverse climatic conditions limit the production of other food crops. The production advantages of cassava are, however, partly offset by the very short shelf life of the harvested roots due to rapid deterioration which can begin as quickly as 24 hours after harvest (Beeching *et al.*, 1998). Most varieties of cassava deteriorate within three to four days of harvest due to physiological processes which are initiated at sites of mechanical damage referred to as postharvest physiological deterioration (PPD) or vascular streaking (Ravi and Aked, 1996). PPD of cassava roots can lead to substantial quantitative and qualitative post-harvest losses causing high production and market risks.

To avoid the problem of rapid deterioration of the harvested cassava roots, farmers commonly leave cassava in the ground until it is needed and they only harvest few roots at a time. While the strategy somehow offered solution in preventing root deterioration, this resulted to underutilization of their small farm area as this leaves the land underused for quite some time. Moreover, when the roots are left in the ground longer, they often become fibrous and woody and their starch content decreases affecting their quality. Risk of crop loss from pests and diseases also increases if roots are left longer in the ground (Quevedo and Data, 1986).

Growing cassava in the uplands where the soils are generally of low fertility, acidic, and compact and where soil moisture fluctuation generally occurs can have adverse effect on the postharvest life of harvested roots (Aracena *et al.,* 1993). For example, Quevedo *et al.,* (1990) found that cassava var. Kadabao grown in loamy sand had significantly lower incidence of decay, and incidence and degree of vascular streaking than those grown in clay and clay loam soil after 9 days of storage at ambient condition. In addition, the same authors reported that cassava roots grown in soils with moisture at field capacity during pre-harvest pruning had significantly low incidence of vascular streaking than those grown in soils at 57 to 60% MC and in saturated soils. Aside from the growing environment, the degree of root injury, time lapse from harvest to storage (Nahdy and Odong, 1995), the cassava variety (Quevedo and Data, 1987) and storage techniques determine the postharvest life of harvested cassava roots.

Simple storage techniques reported to extend the shelf life of cassava roots for several days to weeks include pit storage, field clamps or in boxes with moist sawdust and packing in plastic bags (Crentsil *et al*., 1995, Quevedo, *et al*., 1985). The effectiveness of the above mentioned storage techniques in minimizing storage losses of cassava was, however, reported to vary depending on several factors mentioned above. Moreover, for a cassava root storage technique to be effective, it should not be expensive for the small farmers and should be easy to manage.

This study was conducted to evaluate the effectiveness of simple storage techniques of cassava roots in minimizing postharvest losses.

MATERIALS AND METHODS

A. Survey of existing postharvest handling and storage practices

A survey was conducted to determine some existing postharvest handling and storage practices for perishable and non-perishable crops used by farmers in upland barangays of Inopacan, Leyte. Using the prepared interview questionnaire, thirty-six (36) farmer respondents from barangay Linao, Sitio Batuan, Guinsanga-an, Tao-taon and Cabulisan, in Inopacan, Leyte Philippines were interviewed.

B. Design and evaluation of simple cassava storage experiment

Results of the survey (not shown) revealed that farmers do not store harvested cassava roots due to high perishability and instead practiced staggered harvesting. The practice resulted to underutilization of their small land areas as these are occupied by the standing crop longer. Moreover, leaving cassava roots in the ground after they matured will make them fibrous and woody with low starch content resulting to poor eating quality. Because of the disadvantages of staggered harvesting of cassava practiced by upland farmers in Inopacan, Leyte, the possibility of one time harvesting in combination with an efficient storage strategy was looked into. The storage techniques evaluated were based from literatures and those mentioned (but not practiced) by farmers.

1. Root sample preparation

Seven month old cassava var. 'Macan' roots were carefully harvested

from a farmer's field in Sitio Batuan, Brgy. Linao, Inopacan Leyte. These were placed in plastic crates lined with dried banana leaves and were immediately transported to the Philippine Rootcrops Crops Research and Training Center (PhilRootcrops), Visca, Baybay City, Leyte. Damage-free with more or less uniform size roots were selected and used as samples.

2. Preparation of storage boxes, jute sacks and packing media

Collapsible boxes measuring 47.6 x 63.8 x 30.5 cm made out of 1.27 cm (0.5 in) thick marine plywood were used. A box can contain approximately 20 kg of cassava roots when fully packed. Jute sacks used for packing copra were also tried in packing the roots because this was mentioned by one of the farmers interviewed. Sifted river sand and sawdust used as packing media were sundried for 3 days to partly sterilize them. Prior to use, the moisture contents of the two media were adjusted to 12% for river sand and 14% for sawdust. This was accomplished by gradual addition of water to the medium while continuously mixing. Medium moisture content was regularly monitored using soil moisture meter (EXTECH- MO750) until the desired MC was attained.

3. Experimental Design and Treatments

The experiment was laid out in simple CRD with three replications. The following storage methods were evaluated:

T_{0-} control (unpacked)
T_1 –box storage with moist sawdust as packing medium
T_2- box storage with moist river sand as packing medium
T_3 –packed in wet jute sack

4. Storage of roots

Roots intended for T_3 were placed inside jute sacks previously soaked in water until thoroughly wet. To keep the sacks wet throughout the experimental period, these were sprinkled with water whenever it appeared dry. Roots stored in boxes (T_1 and T_2), were placed in alternate layers of the medium with the medium occupying the bottom and the topmost layer of the box. Packing was done by first placing 3 cm thick packing medium at the bottom of the box (Fig. 1.). Twelve sample roots were placed on top of the medium and then were covered with the same

medium 1 cm thick just enough to cover the piled roots. The same procedure was followed for the next two layers. The topmost layer of roots was covered with 5 cm thick packing medium. All boxes were covered with plywood. The experiment was set up under ordinary room condition with temperature and RH ranging from 28-32 ^{0}C and 62.5 to 81%, respectively.

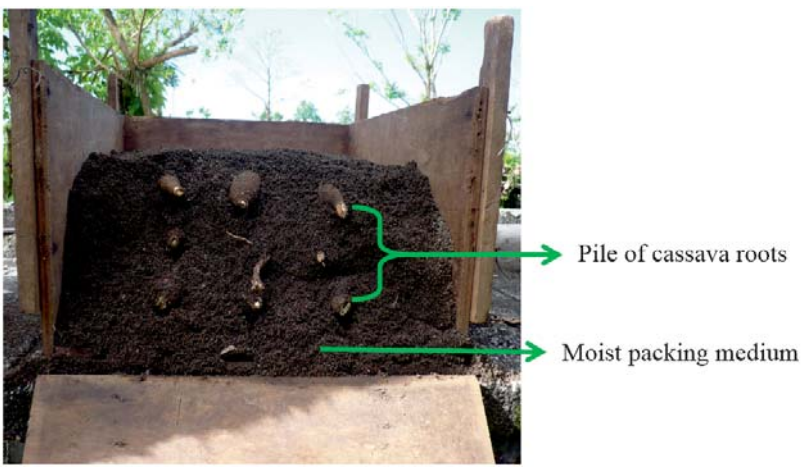

Fig. 1. Cassava roots stored in box with moist packing medium.

5. Measurement of Physical Changes

Weight Loss. Three roots from each of the upper, middle and lower layers (or a total of 9 sample roots in a box) were tagged and initially weighed. These tagged sample roots were weighed individually every sampling period to get the percentage change in weight. The percentage weight loss/gain was taken from the average of three replications per treatment.

Vascular streaking. Fifteen (15) root samples from each treatment (5 samples /replication) were cut into three sections: base, middle and tip and were examined for the presence of vascular streaks. The degree of vascular streaking was based on the cut area of each root and was rated using a scale of 1=No vascular streaking; 2=25% vascular streaking; 3=26-50% vascular streaking; 4=51-75% vascular streaking; and 5=76-100% vascular streaking.

Incidence and degree of root decay. Root samples used in monitoring

vascular streaking were also used in assessing incidence of decay. Samples that became brown and those that softened or appeared water soaked were declared rotten. The degree of decay was rated based on the rotten area/root using a scale of 0=No rotting; 1=less than 20% rotting; 2=21-40% rotting; 3=41-60% rotting; 4=61-80% rotting; and 5=81-100% rotting.

6. Measurement of Chemical Changes

Dry matter content (DMC). This was determined by oven-drying 100 grams sliced cassava root samples at 60°C until constant dry weight. DMC was calculated using the formula:

$$\text{DMC (\%)} = \frac{\text{Oven-dried weight}}{\text{Initial weight}} \text{ X } 100$$

Starch and total sugar contents. The starch and total sugar contents were also determined using Anthrone method (Cagampang and Rodriguez, 1980) and were analyzed at the Central Analytical Services Laboratory, PhilRootcrops, VSU, Visca, Baybay City, Leyte.

C. Sensory Evaluation

The stored and newly harvested roots were peeled and steamed for 2 hours or until totally cooked. Uniform slices were placed in plates and were evaluated by 15 untrained panelists composed of farmers from Sitio Batuan, Brgy. Linao, Inopacan, Leyte using Hedonic Rating Scale of 1-9 with 1 dislike extremely and 9 like extremely.

Statistical Analysis

Results were analyzed by performing analysis of variance (ANOVA). When ANOVA showed significant differences between treatments, comparison of treatment means was done by HSD (Honest Significant Difference) test. ANOVA and HSD were done using the Motorola Statistical Analysis Tool (MSTAT) program.

RESULTS AND DISCUSSION

Physical Characteristics

Weight Changes. Fig.2 shows that roots packed in wet jute sacks and unpacked roots had relatively higher weight loss compared to those stored in boxes with either moist river sand or sawdust packing medium.

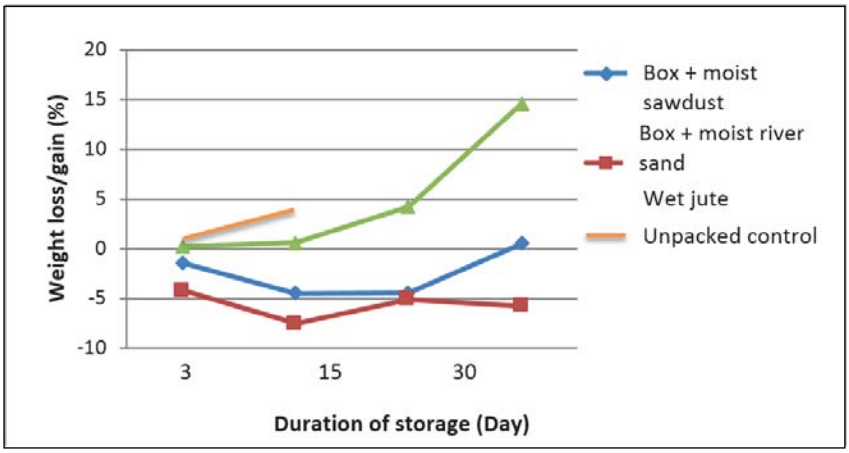

Fig. 2. Weight changes (%) of cassava roots var. 'Macan' subjected to different methods of storage recorded at 4 sampling periods.

Figure 2 also showed that while the unpacked roots (T_0) and those packed in wet jute sack (T_3)continued to lose weight during storage, those stored in boxes particularly with moist river sand packing medium (T_2) gained weight. Root absorption of water from the surrounding moist sand medium was believed to have caused the gain in root weight. Some roots developed root hairs which may have also partly contributed to the increase in weight.

Vascular streaking. The degree of vascular streaking of cassava roots sampled at 3, 15, 30 and 60 days of storage are shown in Tables 1-4 and Fig. 3. After 3 days of storage, roots stored in box with either moist sand or sawdust packing media had no incidence of vascular streaking while those packed with wet jute sack and the unpacked control had already slight streaking. After 15 days of storage the unpacked roots had already a rating of 3.0 or 26-50% of the cut surface having streaks, while those stored in boxes with moist sand and sawdust and those packed in wet jute sack had

only a rating of 1.2 (no streaking to 24% of cut surface area showing streaking). After storing for 30 days, the unpacked roots were all decayed but those stored in boxes with moist sand and moist sawdust and those packed in wet jute sacks all had very low degree of vascular streaking (rating of 1.2) After 60 days storage, roots stored in T_1 and T_2 had significantly lower degree of streaking than those stored in T_3. It is worth pointing out however that even after 60 days of storage, the degree of vascular streaking among roots from T_1, T_2 and T_3 were still very minimal (rating of 2.0 or 25% of the cut surface with streaks). Box storage using either moist sand or sawdust medium and packing with wet jute sack effectively slowed down the development of vascular streaking in stored cassava roots. The moist condition and the relatively high temperature of the medium (25-30^{0}C sand, 26-30^{0}C in sawdust, 26-30^{0}C in jute sack) have probably promoted curing of the roots.

Regardless of the method of storage used, streaking was more severe at the basal than both the tip and the middle portions of the roots after 60 days of storage (Table 4). The result suggested that the development of vascular streaking was enhanced by the damage/cuts inflicted during harvesting. The degree of damage during separation of roots from the cassava stalks affected the severity of vascular streaking (Quevedo *et al.,* 1985).

Table 1. Vascular streaking of cassava roots var. 'Macan' subjected to different methods of storage after 3 days of storage

Storage Methods	Sections of the roots			Mean
	Base	Middle	Tip	
Control	1.3	1.1	1.0	1.1
Box storage with moist sawdust	1.1	1.0	1.0	1.0
Box storage with moist river sand	1.0	1.0	1.0	1.0
Wet jute sacks	1.2	1.1	1.0	1.1
Mean	1.1	1.0	1.1	
CV (%) = 15.05				

No significant difference based on ANOVA. Vascular streaking indices: 1-No vascular streaking; 2-25% vascular streaking; 3-26-50% vascular streaking; 4-51-75% vascular streaking; 5-76-100% vascular streaking

stored in boxes with either moist sand or sawdust medium and those packed in wet jute sack had very low and comparable severity ratings (0.1 or 0-less than 20% of the whole root area having decay).

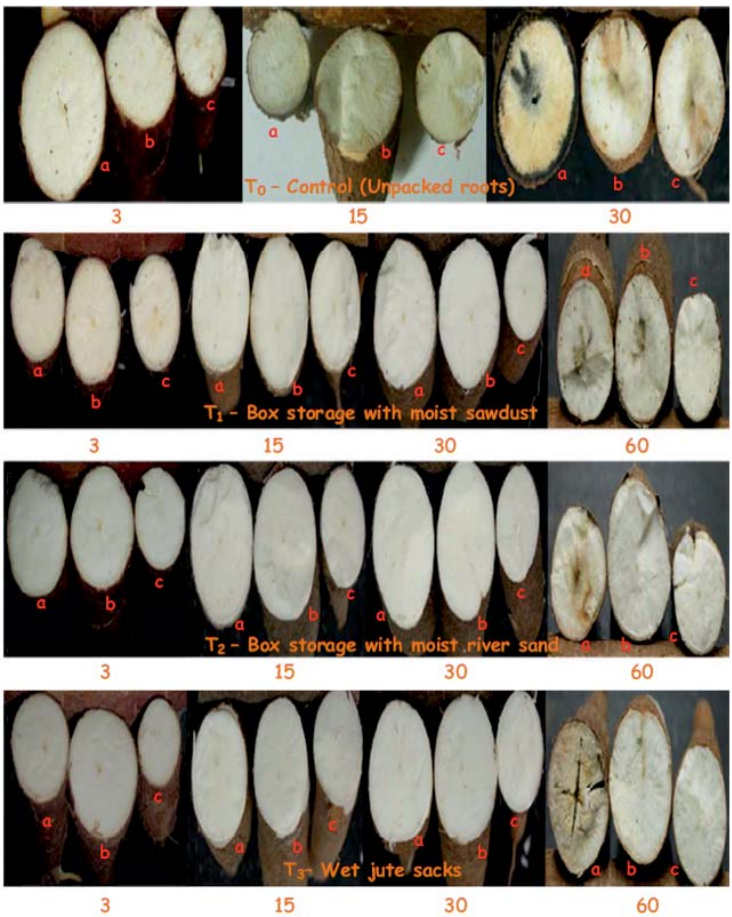

Fig. 3. Vascular streaking incidence of different sections (A – base, B – middle, C – tip) of cassava roots subjected to different methods of storage at 4 sampling periods.

The superiority of box storage with moist sand or sawdust packing medium over the other two storage techniques in minimizing decay of cassava roots was apparent as the duration of storage was extended to 60 days. After 60 days storage, roots stored in boxes with moist sand and sawdust media had only less than 10% decay with very low severity. With minimal streaking (Table 4), these roots could still be utilized for cooking

Table 2. Vascular streaking of cassava roots var. 'Macan' subjected to different methods of storage after15 days of storage

Storage Methods	Sections of the roots			Mean
	Base	Middle	Tip	
Control	3.0	2.6	2.3	2.6 a
Box storage with moist sawdust	1.1	1.1	1.1	1.1 b
Box storage with moist river sand	1.1	1.0	1.0	1.0 b
Wet jute sacks	1.2	1.2	1.2	1.2 b
Mean	1.6	1.4	1.4	
CV (%) = 24.43				

Storage method and root section means having a common letter or without letter designation are not significantly different from each other at 5% level, HSD.

Table 3. Vascular streaking of cassava roots var. 'Macan' subjected to different methods of storage after 30 days of storage

Storage Methods	Sections of the roots			Mean
	Base	Middle	Tip	
Box storage with moist sawdust	1.2	1.1	1.0	1.1
Box storage with moist river sand	1.1	1.0	1.0	1.0
Wet jute sacks	1.5	1.1	1.1	1.2
Mean	1.3	1.1	1.0	
CV (%) = 23.66				

No significant difference based on ANOVA.

Table 4. Vascular streaking of cassava roots var. 'Macan' subjected to different methods of storage after 60 days of storage

Storage Methods	Sections of the roots			Mean
	Base	Middle	Tip	
Box storage with moist sawdust	1.5	1.3	1.1	1.3 b
Box storage moist river sand	1.6	1.1	1.1	1.3 b
Wet jute sacks	2.1	1.5	1.4	1.7 a
Mean	1.7 a	1.3 b	1.2 b	
CV (%) = 15.20				

Storage method and root section means having a common letter or without letter designation are not significantly different from each other at 5% level, HSD.

Decay incidence and severity. The incidence of decay of the stored cassava roots was significantly reduced when stored in boxes with either moist sand or sawdust packing medium and in wet jute sack (Table 5).

After 15 days of storage the severity of decay of cassava roots stored in boxes with either moist sand or sawdust medium and those packed in wet jute sack were just statistically comparable and were significantly lower than the severity of decay suffered by the unpack roots (Table 5). Roots

stored in boxes with either moist sand or sawdust medium and those packed in wet jute sack had very low and comparable severity ratings (0.1 or 0-less than 20% of the whole root area having decay)

The superiority of box storage with moist sand or sawdust packing medium over the other two storage techniques in minimizing decay of cassava roots was apparent as the duration of storage was extended to 60 days. After 60 days storage, roots stored in boxes with moist sand and sawdust media had only less than 10% decay with very low severity. With minimal streaking (Table 4), these roots could still be utilized for cooking after the decayed portions are trimmed. Again, the conditions (moist and high temperature) in these three methods of storage which may have promoted the curing process have minimized infection of the roots by decay causing pathogens.

Table 5.Incidence (%) and severity decay of cassava roots var. 'Macan' subjected to different methods of storage after 60 days of storage.

Storage Methods	Root rot (%)		Severity Index	
	15	60	15	60
Control	83.4 a	-	0.6 a	-
Box storage with moist sawdust	3.7 b	7.1 b	0.2 ab	0.082
Box storage with moist river sand	0.0 b	3.3 b	0.0 b	0.028
Wet jute sacks	0.0 b	31.8 a	0.1 b	0.043
CV (%)	15.99	16.22	2.95	1.58

Means in the same column having a common letter or without letter designation are not significantly different from each other at 5% level, HSD. Root rot indices: 0-No rotting; 1-less than 20% rotting; 2-21-40% rotting; 3-41-60% rotting; 4-61-80% rotting; 5-81-100% rotting.

Chemical Characteristics

Root dry matter content. The dry matter contents of roots stored for 3, 15 and 30 days using the 4 methods of storage were just comparable (Table 6). A slight reduction in root dry matter contents was noted after 15 days of storage regardless of method of storage used. After 30 days of storage however, dry matter contents of roots from all 3 methods of storage slightly increased. After 60 days of storage, roots stored in boxes with moist sawdust had significantly higher dry matter contents than those stored in boxes with moist sand medium and those packed in wet jute sack. The loss of moisture or weight loss in roots packed with moist sawdust probably contributed to the increase in dry matter content.

Total sugar and starch contents. The sugar contents of roots stored at four methods of storage were just comparable and increased with time of storage (Table 7). Conversion of starch to sugar could explain the observed trend.

The starch contents of cassava roots were likewise not significantly influenced by the method of storage used (Table 8). Regardless of method of storage, starch content of cassava roots decreased with time of storage due to starch to sugar conversion mentioned earlier.

Table 6. Dry matter content (%) of cassava roots var. 'Macan' subjected to different methods of storage recorded at 4 sampling periods.

Storage Methods	Days of storage			
	3	15	30	60
Control	47.5	46.9	-	-
Box storage with moist sawdust	50.0	45.1	57.2	54.3 a
Box storage with moist river sand	49.0	45.0	51.0	49.2 b
Wet jute sacks	45.2	45.9	52.3	48.0 b
Freshly harvested	49.3			
CV (%)	5.91	19.98	6.10	4.53

Means in the same column having a common letter or without letter designation are not significantly different from each other at 5% level, HSD.

Table 7. Total sugar (%) of cassava roots var. 'Macan' subjected to different methods of storage recorded at 4 sampling periods.

Storage Methods	Days of storage			
	3	15	30	60
Control	0.2	0.7	-	-
Box storage with moist sawdust	0.4	1.3	2.1	3.0
Box storage with moist river sand	0.3	1.0	2.5	2.8
Wet jute sacks	0.2	1.6	3.4	-
Freshly harvested	0.3			
CV (%)		45.84	25.56	

No significant difference based on ANOVA.

Table 8. Starch content (%) of cassava roots var. 'Macan' subjected to different methods of storage recorded at 4 sampling periods.

Storage Methods	Days of storage			
	3	15	30	60
Control	68.2	86.0	-	-
Box storage with moist sawdust	82.5	89.1	71.7	58.0
Box storage with moist river sand	87.0	88.3	74.5	59.4
Wet jute sacks	90.7	83.8	68.6	-
Freshly harvested	78.2			
CV (%)		4.75	7.51	

No significant difference based on ANOVA.

Sensory Evaluation

Sensory quality attributes of steamed cassava roots sampled after 3, 15, 30 and 60 days storage are shown in Table 9. In all sampling periods, roots subjected to the four methods of storage got comparable scores with the freshly harvested roots in all 5 quality attributes. Steamed roots from those stored in boxes with moist sand or sawdust medium and those packed in wet jute sack for 60 days were still acceptable with comparable acceptability score with the freshly harvested ones. The result indicates that cassava roots could be stored for 60 days in boxes with moist sand or sawdust medium or packed in wet jute sack without adverse effect on the eating quality.

CONCLUSIONS

Box storage using either moist sand or sawdust packing medium effectively prolonged the shelf life of fresh cassava roots for 30-60 days by minimizing the incidence of vascular streaking, decay and weight loss and by preserving the desirable eating quality. Packing roots in wet jute sacks was only effective in keeping the roots in good quality for 10-15 days. For the three methods of storage to be effective, only good quality freshly harvested roots should be stored.

Table 9. Sensory quality rating of steamed cassava roots var. 'Macan' stored for 3, 15, 30and 60 days using different methods of storage.

Days of storage	Storage Methods	Quality Attributes				
		Appearance	Color	Flavor	Texture	Gen. Accept.
3	Control	5.8	5.7	5.9	5.8	5.8
	Box storage with moist sawdust	6.2	6.2	5.9	5.9	6.0
	Box storage with moist river sand	6.4	6.6	6.1	5.9	6.2
	Wet jute sacks	6.6	6.8	6.2	6.1	6.4
	Freshly harvested	5.6	6.0	5.9	6.5	6.1
	CV (%)	6.81	3.50	2.13	3.88	3.20
15	Control	6.7	6.5	6.4	6.6	6.80
	Box Storage with Moist sawdust	6.9	6.7	6.8	6.7	6.80
	Box Storage with Moist river sand	6.4	6.4	6.3	6.5	6.65
	Wet jute sacks	6.9	6.8	6.8	6.8	6.94
	Freshly harvested	6.3	6.6	6.0	6.3	6.40
	CV (%)	3.17	5.40	4.59	3.14	4.46

Table 9. Continuation

Days of storage	Storage Methods	Quality Attributes				
		Appearance	Color	Flavor	Texture	Gen. Accept.
30	Box Storage with Moist sawdust	5.1	4.7	5.7	5.2	5.5
	Box Storage with Moist river sand	5.3	5.1	5.0	4.7	5.3
	Wet jute sacks	5.6	5.3	5.0	5.2	5.6
	Freshly harvested	4.6	4.4	5.5	5.3	5.1
	CV (%)	31.77	13.41	14.30	10.07	6.70
60	Box Storage with Moist sawdust	5.3	5.3	5.8	6.3	6.0
	Box Storage with Moist river sand	5.1	5.1	5.9	5.9	5.1
	Wet jute sacks	5.1	5.7	5.7	5.3	4.9
	Freshly harvested	4.9	5.7	5.7	5.8	5.3
	CV (%)	20.52	16.19	10.70	5.31	12.89

No significant difference based on ANOVA.9-point hedonic scale:9-Like extremely; 8-Like very much; 7-Like moderately; 6 -Like slightly; 5-Neither like nor dislike; 4- Dislike slightly; 603-*Dislike moderately; 2- Dislike very much; 1-Dislike extremely*

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