RESEARCH PROGRAM ON Roots, Tubers and Bananas

CGIAR

Technical Report:
Postharvest Physiological Deterioration (PPD) Tolerance of Selected Ugandan Cassava Varieties

Extending the shelf-life of fresh cassava roots for increased incomes and postharvest losses reduction

Expanding Utilization of Roots, Tubers and Bananas and Reducing Their Postharvest Losses

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RTB ENDURE

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NARO

IITA Research to Nourish Africa

IIRR

Kyambogo University knowlegde and skills for service

cirad AGRICULTURAL RESEARCH FOR DEVELOPMENT

Centro Internacional de la Papa CIP

Bioversity International

CIAT Centro Internacional de Agricultura Tropical International Center for Tropical Agriculture

IITA Research to Nourish Africa

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The CGIAR Research Program on Roots, Tubers and Bananas (RTB) is a broad alliance led by the International Potato Center (CIP) jointly with Bioversity International, the International Center for Tropical Agriculture (CIAT), the International Institute for Tropical Agriculture (IITA) and CIRAD in collaboration with research and development partners. Our shared purpose is to tap the underutilized potential of root, tuber and banana crops for improving nutrition and food security, increasing incomes and fostering greater gender equity, especially among the world's poorest and most vulnerable populations.

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ACRONYMS AND ABBREVIATIONS

CIAT	International Centre for Tropical Agriculture
CIP	International Potato Center
DSIP	Agriculture Sector Development Strategy and Investment Plan
IFAD	International Fund for Agricultural Development
IIRR	International Institute of Rural Reconstruction
IITA	International Institute ofTropical Agriculture
NARL	National Agricultural Research Laboratories
NARO	National Agricultural Research Organization
PPD	Postharvest Physiological Deterioration
ROS	Reactive Oxygen Species
RTB	CGIAR Research Program on Roots, Tubers, and Bananas

SUMMARY

Postharvest Physiological Deterioration (PPD) is one of the leading causes of postharvest losses in fresh cassava in Uganda. This food loss factor is a result of scopoletin and esculin compounds which are produced when roots are harvested and detached from the parent plant. This phenomenon is also called primary postharvest deterioration or more generally vascular streaking, due to the development of dark bluish or brownish radial veins or streaks that occur four days after harvest. This renders the roots unpalatable. Losses are estimated to be as high as 40-60% within the first seven days after harvest and can reach 100% within the next 2-5 days if the roots are not consumed or processed into other more stable products. It results into losses for farmers, traders and consumers along the food supply chain in terms of reduced food security and incomes. It also limits access to more distant markets.

Therefore, there is a potential for expanding the utilization of and incomes from fresh cassava by addressing PPD. PPD varies with varieties. But information on the levels of PPD for Ugandan varieties was not available. In addition, the effect of other agronomic practices such as pruning on PPD levels in cassava varieties and their acceptability was also unknown.

Thus the purpose of this study was to screen cassava varieties for their level of tolerance or susceptibility to PPD. Specifically, it aimed at collecting varieties of fresh cassava roots preferred by consumers in Ugandan. The study targeted the two major fresh cassava supply axes, i.e., Masindi/Kiryandongo and Kyenjojo/Kabarole. Fresh cassava roots were screened for tolerance or susceptibility to PPD. The study also aimed at determining the effect of pruning on the deterioration of cassava roots over time and the changes in root biochemistry during storage of both pruned and non-pruned cassava varieties.

Eight Ugandan varieties (Bufumbo, Njule, Kirimumpale, Hoima, Kigita, TME14, Nyaraboke, and NASE14) were used for the study. Fresh roots of each of these varieties were harvested, cleaned and scored for PPD, reducing sugar, starch content, cyanide content and dry matter (DM) content. The effect of leaf pruning on PPD was assessed for all the varieties and their acceptability investigated. To do this, leaves of seven mature plants of each variety were removed (pruned) and another seven plants were left intact (control). After 7 days, roots from pruned and control plants were harvested and assessed for changes in the rate of PPD, reducing sugar and dry matter (DM) content. Results showed differences in levels of PPD among the eight varieties.

Varieties with low levels of PPD (values below 20%) included Hoima, Njule, NASE14 and TIM TIM. Those with moderate levels of deterioration (30-40%) after seven days included Kirimumpale, Kigita and Nyaraboke. Bufumbo showed high level of susceptibility to PPD (above 40%) after 7 days.

Pruning reduced the level of PPD by 43.9%. Pruning caused slight changes in sugars and carbohydrate composition of roots but these were not significant. Under ambient temperatures, both pruned and unpruned root storage resulted in significant reduction in cyanogenic potential of cassava after 7 days of storage but lower level of cyanogenic compounds were found in pruned roots (possibly due to remobilization of nitrogen that probably took place after pruning). In some varieties, pruning increased the acceptability level of stored roots by up to 3 points and in none of the varieties it led to reduced acceptability.

Therefore, pruning is a potential valuable technology for extending cassava roots shelf-life and reducing postharvest losses along the value chain. Furthermore, it improves the acceptability of the fresh roots which can be marketed for longer periods. However, inconsistent varietal responses to pruning were observed. These call for proper assessment of each variety to find out the ones that better respond to pruning and other shelf-life extension treatments that can contribute to increased farmers and traders' incomes as well as food security at household level. Preliminary results indicate that varieties such as Nyaraboke, Njule, TME14 and Hoima are the most suitable to pruning. Since all of them, apart from TME14, are local varieties that are susceptible to viral diseases such as cassava mosaic disease and cassava brown streak disease, the development of a seed system to enhance the delivery of clean planting materials of these varieties to farmers is recommended.

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1. INTRODUCTION

Cassava is an important source of food and income in Uganda, providing about 20% of the calorific needs and constituting about two-thirds of per capita food production. It is one of the ten commodities that have been prioritized by the Ugandan Government in its Agriculture Sector Development Strategy and Investment Plan (DSIP). Uganda is the eighth largest producer of the crop in Africa, with an estimated 3.0 million tons in 2014 (FAOSTAT, accessed on October2015). It is estimated that in some parts of Uganda nearly 60% of households grow cassava and nearly 90% of the population consume cassava in different forms at least once a day (EAAPP, 2011). Fresh cassava is widely consumed both in urban and rural areas as a snack and main meal. Fresh cassava marketing is currently an important source of income (Scoping study, 2014). Uganda has a policy of releasing “sweet varieties”, i.e., varieties with low levels of cyanogens. These varieties are popular, with consumer demand increasing especially in urban areas, thereby providing incomes to both women and men farmers and traders. Retailing of fresh cassava is dominated by women.

Despite the growth in demand and markets for fresh cassava in all areas of Uganda and especially in urban areas, there are limitations to increased utilization and income generation due to the high perishability resulting from the rapid Postharvest Physiological Deterioration (PPD). PPD is initiated as soon the roots are harvested.

PPD is a purely physiological process, involving production of reactive oxygen species (ROS), which initiates a programmed cell death (Venturini et al., 2015). In plants, ROS are continuously produced as by-products of aerobic respiration (Zidenga et al., 2012). Under normal conditions, the plant has several mechanisms to scavenge ROS, preventing or amending their toxicity (Apostol et al., 1989). Under conditions of stress (after harvest), however, the equilibrium between the production and scavenging of ROS is disturbed, resulting in a rapid increase in the build-up of ROS known as an oxidative burst (Zidenga et al., 2012).In cassava roots, an oxidative burst occurs within 15 minutes of harvest characterized by increased activity of enzymes that modulate ROS levels, such as catalase, peroxidase and superoxide dismutase (Zidenga et al., 2012). Symptoms developed by PPD are displayed by a dark blue striped vascular tissue and brown occlusionsin the parenchyma of the cassava root (Ofor, 2011). Chemical deposits (oxidized phenolics) in the root xylem cause discoloration of storage parenchyma, accompanied by an unpleasant taste and odour (Onyenwoke & Simonyan, 2014). These features are accompanied by fluorescent compounds called hydroxycoumarins that are observed when the parenchyma root is subjected under ultraviolet light (Reilly et al., 2001). Hydroxycoumarins such as scopoletin and its glucoside, scopolin play roles in plant defense and have pharmacological activities (Blagbrough et al., 2010). Scopoletin synthesis has been found to increase in fresh roots after harvest and reach maximum levels around day 3 or 4 of storage (Sánchez et al., 2013). The tubers, when damaged, normally respond with a healing mechanism which involves release of coumaric acid, 15 minutes after damage. However they fail to switch it off in harvested tubers (Sánchez et al., 2010). Scopoletin accumulation is more pronounced in cassava cultivars with high susceptibility to deterioration (Blagbrough et al., 2010). The rate of development and the intensity, pattern and distribution of PPD varies between cultivars and roots. This calls for further studies to identify the level of this deterioration among Ugandan varieties.

As a result of PPD there is a significant level of postharvest losses in fresh cassava roots which translates in reduced food security and incomes especially for smallholder farmers and traders. Other effects are largely related to the unnecessary sell off of stock at

lowerprices, an increased need for consumers to undertake a number of repeated purchases, limitation in reaching distant markets, poor industrial processing prospects and the general reduction in the value of cassava as a crop for smallholder farmers.

There is limited information about the level of deterioration of different cassava varieties due to PPD susceptibility, even among tolerant genotypes. Availability of such information would guide specific interventions in selection of cassava varieties that are suitable for marketing and utilization in enterprises requiring fresh cassava roots such as those that process snacks and other products.

Thus the overall objective of this study was to screen cassava varieties for their levels of tolerance or susceptibility to PPD and provide science-based information about the most suitable varieties for application of shelf-life extension technologies such as pruning, waxing and high relative humidity storage.

The specific objectives of the study were to:

1. Identify popular varieties of cassava from Masindi and Kabarole axes that are commonly sold in Ugandan markets for home consumption

2. Screen the varieties for tolerance or susceptibility to PPD

3. Assess the influence of pruning of cassava plants on biochemical changes and rate of deterioration of the roots stored in ambient conditions.

2. MATERIALS AND METHODS

2.1. Varietal collection and selection

The study targeted varieties of cassava most marketed and consumed in Masindi/ Kiryandongo and Kyenjojo/Kabarole axes. These are presented in Table 1 below.

Table 1: Cassava varieties preferred by farmers and traders in the study area

Kyenjonjo area	Kabarole area	Kiryadongo area
Nyaraboke	Kibonange	Nyaraboke
Kirimumpale	Mpagi	Hoima
Bufumbo	Kajahi	NASE14
Njule		TIM TIM
Kijita		Nyamigyera
		NAROCAS1
		Bao
		TME14

The varieties are preferred because of their sweet taste, low cyanogenic content and comparatively low rates of PPD. Apart from NAROCAS1and NASE14, which are varieties from research stations, all the others are indigenous local landraces.

The roots were harvested 12 months after planting (Figures 1 and 2). Care was taken during harvesting to avoid injuries to the roots since root injury accelerates the onset of PPD (Venturini et al., 2015). Pruning is one way of reducing PPD (CIAT et al., 2012). Removal of leaves on the cassava plants (pruning) was conducted 7 days prior to root harvesting. Roots were obtained from pruned and non-pruned cassava plants of each variety.

Figure 1: Pruning of cassava plants

Figure 2: A careful harvesting of roots

The cassava roots were transported in plastic crates to the National Agricultural Research Laboratories (NARL), Kawanda for analyses.

2.2. Scoring for Postharvest Physiological Deterioration

Cassava roots were treated according to the method described by CIAT (2012).Roots of each cultivar with a minimum length of 18 cm, without mechanical damage or pre-harvest rot were selected. The roots were washed with potable water using a soft bristled brush to remove adhering soil and allowed to drip dry for 10 minutes at room temperature. The distal and proximal ends were cut off with a stainless steel knife, so that the remaining root section is about 15 cm long. Crosswise sections 2, 4, 6, 8, 10, 12 and 14 cm from the proximal end were cut. A total of 7 sections were evaluated. The roots were scored for PPD according to the method described by Wheatley et al. (1985). Numerical values were assigned according to a scale of 0-10 on the proximal surface of each cut slice (Appendix 1). The scale values correspond from 0-100% PPD. The average of the numerical values in each of the 7 evaluated sections was obtained and expressed as "Percent of deterioration"(see Figure 3).

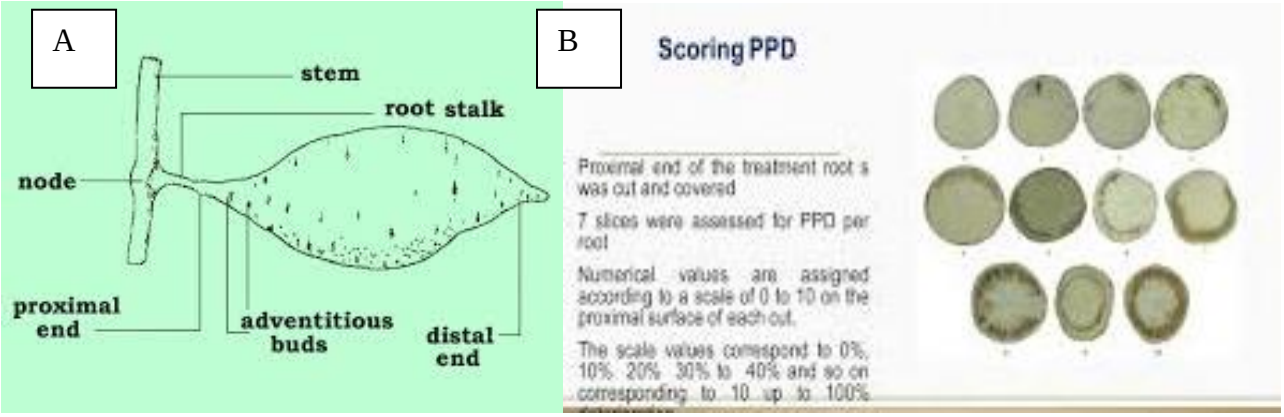

Figure 3: Cassava root attached to stem showing the distal and proximal ends of root (A) and pictorial showing the method used for scoring the cassava root for PPD (B).

Figure 4: A researcher labels roots

Figure 5: Scoring for PPD on research station

Figure 6: One of the roots prepared for PPD scoring

2.3. Determination of dry matter

The dry matter content was determined using the method by Uarrota et al. (2016). Roots of each cultivar were randomly selected. The selected roots were cut into 2cm slices using a stainless steel knife, and mixed thoroughly. Triplicates of 100g samples (W_1) were dried at 60°C for 48 hours in an oven drier (Leader, Leader Engineering Widnes, United Kingdom) or until a constant weight (W_2) was obtained. Percent dry matter content (DM %) was calculated as follows:

Dry matter content = 100 * (W_2/W_1)

2.4. Determination of starch yield

Cassava starch was extracted by a modified method described by Nuwamanya et al. (2009). Roots were peeled and cleaned with distilled water. Roots were then blended with distilled water (500g of tubers in 1000ml of water) using a blender (Waring® Commercial Blender, HBB2WTG4, USA). The pulp was stirred for 2 minutes and filtered using a triple cheese cloth. The filtrate was allowed to stand until the starch sedimentedand the top liquid decanted and discarded. The starch sediment was again washed with distilled water, and the top liquid discarded. The starch produced was oven-dried on aluminum pans at 60°C for 18-48hours or until a constant dry weight was obtained and then stored in dry plastic air tight containers at room temperature.

The starch yield was calculated as follows:

Starch yield = (WDS/WFTR) x 100

Where:

WDS = weight of dried starch

WFTR = weight of fresh roots

2.5. Determination of digestible starch

Distilled water (0.1ml; blank), standard corn starch (98%; 0.1g) for making standard curve and cassava starch (100mg), as a sample, were transferred to a clean test tube and 10% sulphuric acid(5ml; Lobachemie® Reagents and Fine Chemicals, 1830, India) added. The test tube was placed in a water bath (Grant Instruments Ltd, TXF200, England) at 80˚C for 30 min. The supernatant (0.5ml) was transferred into a clean dry test tube as well as 5 serial dilutions for the standard solution. Distilled water (1ml), phenol (0.5ml, 5%; VWR® Chemicals, France) were added to the contents in the test tube and vortexed (Labonet® International, 50200, United Kingdom) for 5s. Concentrated sulphuric acid (1ml) was added to the contents in the test tube, shaken for 5s, and allowed to cool at room temperature for 15min and then absorbance was measuredwith a spectrophotometer (WPA Biowave II+, England) at a wavelength of 490nm.The spectrophotometer was zeroed by reading absorbance of the blank then the absorbance of the prepared sample. The standard sample and serial dilutions of known concentrations were also measured. A graph of the data obtained from the readings got from the standard samplewas plotted with the solution concentration on the x-axis and the absorbance on the y-axis**.**The equation of the "best-fit" straight line was determined using MS Excel© 2013. This equation gave the mathematical relationship between solute concentration and absorbance.Finally, the equation was used to derive the concentration of digestible starch in the cassava starch samples.

2.6. Determination of amylose content of cassava starch

Cassava starch (100mg) was transferred into a volumetric flask, wetted with ethanol (95%, 1ml;VWR® Chemicals, UN1170, France) and distilled water (10ml), followed by NaOH solution (10%, 2ml; Lobachemie® Reagents and Fine Chemicals, 0589800500, India). The contents were heated in a water bath (Grant Instruments) at 60˚C until a clear solution was formed. The flask with its contents was cooled at room temperature and diluted to the mark (100ml) with distilled water. A portion of distilled water (5ml) was added and acidified slightly with HCl (6M, 0.3mLs; Sigma-Aldrich®, UN1789, Germany). The contents were mixed thoroughly by shaking for 5s and Iodine solution (10%, 5ml) was added. Absorbance of the solution was read at 640nm against standard potato amylose and amylose content quantified.

2.7. Determination of reducing sugar content

Cassava flour (500mg) was mixed with ethanol (1ml, 95%) and distilled water (2ml) in a centrifuge tube. Hot ethanol at 60°C (10ml, 95%) was added to the resultant solution. It was vortexed for 5min and centrifuged (Labofuge 400R, Thermo Electron Corporation, Germany) for 10min. The supernatant was decanted into a volumetric flask and made up to 100ml with distilled water. This solution (10ml) was used for quantification of reducing sugars. The supernatant, distilled water (blank) and serial dilutions of 99% glucose (standard) (0.5ml each) were pipetted into separate clean dry test tubes. Distilled water(1ml) and 5ml phenol (5%; UNILAB®, 1159, Ajax Finechem, Australia) were added to the contents in each of the test tubes and vortexed for 3-5s. Concentrated sulphuric acid (1ml) was added to the contents in the test tubes, shaken for 3-5s and allowed to cool for 15min and then the reducing sugar content was quantified at 490nm (Nuwamanya et al., 2015)

2.8. Determination of total cyanide content

Linamarase enzyme solution was prepared according to a modified method described by Haque & Bradbury (1999).Sap (1ml) was squeezed from the end of the petiole (stalk) of cassava leaves and mixed with orthophosporicacid (0.1M, 10ml; Unilab® 372-2.5L GL, Ajax Finechem, Australia) to give a solution of enzyme. This solution was stored at room temperature for 1hour until it was utilized. The peeled cassava root (50g) was added to orthophosphoric acid (160ml, 0.1M) and finely ground in a blender. The mixture was centrifuged at 129000RCF for 30min at 4˚C. Triplicate samples (0.1ml) of the supernatant were added to separate clean dry test tubes. Standard solutions of Potassium Cyanide (1 g/ml) as well as its serial dilutions and 1ml of distilled water (blank) were also added to the test tubes. To each of these test-tubes, orthophosphoric acid (0.1M, 0.4ml, pH 7.0) and linamarase enzyme solution (0.1ml) were added and incubated at 30^0C for 15min. Sodium hydroxide (0.2M, 0.6ml) was added to the above sample and incubated at room temperature (25±5ºC) for 5min. Orthophosphoric acid (2.8ml, pH 6) and of *N*-chlorotosylamide (Chloramine-T, (0.1ml) were added to the sample, shaken for 5s and incubated for 5min at room temperature. Pyridine-barbituric acid (color reagent; 0.6ml) was added to the sample, shaken for 3-5s and left for 10min at room temperature after which absorbance was read at 605nm (Bradbury, 1999).

2.9. Sensory analysis

Rating was done on a 9-point hedonic scale with anchors ranging from 1 (dislike extremely) to 9 (like extremely) according to Ubbor & Akobundu (2009). Sensory analysis of all steamed cassava samples involved the participation of 20 panelists who comprised of staff at National Agricultural Research Laboratories, Kawanda. Panelists consisted of 7 males and 13 females and their age ranged from 24 to 50 years. Availability, willingness and familiarity with steamed cassava were some of the factors considered for selection of the panelists. Each panelist evaluated five sensory characteristics (appearance, taste, aroma, texture and mouth-feel) which were consequently averaged as overall acceptability.

Upon arrival at the sensory laboratory, each panelist read an explanation of the study and gave their informed consent. Steamed cassava samples were placed onto disposable plastic plates and labeled with randomly selected three digit numbers. The samples were steamed for 30min and served 15min later. The coded samples were presented under normal lighting conditions, in a randomized manner across panelists to ensure that the order did not introduce bias into the results. Each individual evaluated the five aforementioned sensory characteristics. Each panelist was presented with the test sample and a bottle of drinking water to rinse out their mouths before and after each taste. The panelists were asked to evaluate the product and record their perception of each sensory characteristic using a nine-point hedonic scale (Appendix 2). The ratings on the 9-point hedonic scale used were: 9=“like extremely”; 8=“like very much”; 7=“like moderately”; 6=“like slightly”; 5=“neither like nor dislike”; 4= “dislike slightly”; 3=“dislike moderately”; 2=“dislike very much”; 1=“dislike extremely”.

3. RESULTS AND DISCUSSION

3.1. Variation in levels of PPD

There was variation in rates of PPD both within and across varieties. Roots from pruned cassava plants exhibited a lower PPD rate than the roots from non-pruned ones (Table 2).

Among the control varieties, low PPD values (below 20%) were observed for varieties of Hoima, Njule, NASE14 and TME 14. On the other hand, varieties with moderate PPD (30-40%) after seven days included Kirimumpale, Kigita and Nyaraboke. The PPD of such varieties maybe improved through other shelf-life extension treatments. Varieties with high PPD values (40% and above) after seven days such as Bufumbo are likely to spoil very fast if left at room temperature and should be utilized or processed immediately although data is not shown.

As shown in Table 2, NASE 14 and TME14 had PPD score of 10% or lower, suggesting that these varieties could be classified as 'naturally resistant' to PPD. All the other varieties, except for Bufumbo, have PPD scores of 11-40% and may be classified as 'naturally tolerant' to PPD. Bufumbo, with >41% PPD score, could be classified as susceptible to PPD as shown in Figure 7 below. After pruning, roots of many cassava varieties had lower PPD scores with mean reduction of 43.9% between the pruned and unpruned roots of the same variety after 7 days of storage. Largest change in PPD was observed in varieties including Hoima, Bufumbo and Njule. Thus when pruned, varieties such as Hoima, Nyaraboke, Njule, TME14 had PPD at less than 10% after 7 days of storage. Pruning therefore had an overall effect of lowering PPD across all the tested varieties (apart from NASE14) and therefore it is highly recommended for extending the shelf-life of the harvested roots.

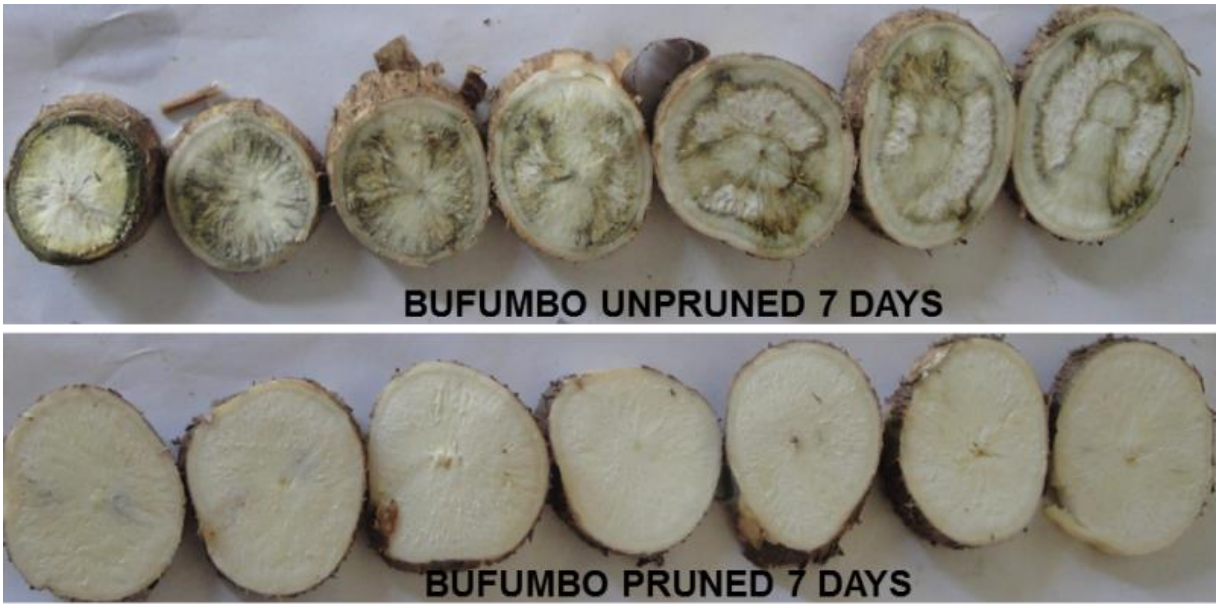

Figure 7: Representative picture on the effect of pruning on PPD reduction in cassava roots.

Table 2: Variation in PPD of selected varieties at day 7

Variety	% PPD Non-pruned	% PPD Pruned	% difference
Bufumbo	52.6±1.85	18.5 ±0.32	- 64.82
Hoima	14.6±0.53	5.1 ±0.64	- 65.07
Kirimumpale	31.5±2.14	18.5±0.54	- 41.37
Kigita	30.2±2.19	20.5±0.32	- 32.12
Nyaraboke	36.8±4.76	6.0±1.33	- 83.7
Njule	11.0±1.01	5.0±1.43	- 54.54
NASE14	10.0±0.34	10.8±1.54	+0.8
TME14	5.3±0.71	5.2 ±1.45	- 1.8
Mean	**24**	**11.2**	**43.9**

3.2. Variation in root biochemistry of varieties with normal storage time of seven days

Varieties which showed a higher level of tolerance to PPD and enjoyed a higher preference in the market were considered for further evaluation. They were evaluated for key changes in biochemical properties, namely reducing sugars, hydrogen cyanide, dry matter content, starch yield and starch content. These properties are indices of the physiological stability of the roots during marketing and therefore influence acceptability of cassava varieties among users (Kawuki et al., 2015).

The results revealed that there were some changes in the biochemical properties of the cassava roots during storage.

Changes in reducing sugar values

Table 3 shows the reducing sugar content of flour obtained from roots from pruned and non-pruned plants of sampled cassava varieties. No significant differences (at 95% confidence level or $p<0.05$) were observed in the average reducing sugar content of cassava flour obtained from stored cassava roots of pruned and non-pruned plants. Reducing sugar content of cassava harvested from pruned cassava plants ranged from 7.79% in Hoima to 9.22% in Bufumbo after 7 days of storage. Non-pruned cassava plants yielded roots with reducing sugar content varying between 9.76% in Bufumbo to 12.68% in TME14 after 7 days of storage. Much as pruning did not have a significant effect on the reducing sugar content of the cassava roots, all cassava varieties showed an increase in reducing sugar content over time. The increase is an indicator of increase in acceptability of the cassava root or products from the roots, such as flour.

Table 3: Reducing sugar content of flour from roots of pruned and non-pruned plants of selected cassava varieties at zero (0) and seven (7) days of storage

	Pruned; Ambient storage			Non-pruned; Ambient storage		
	0day	7days	Difference	0day	7days	Difference
Bufumbo	5.64±0.08	9.22±0.12	3.58	5.22±0.43	9.76±0.34	4.54
Hoima	5.49±0.13	7.79±0.21	2.30	4.28±0.18	9.82±0.25	5.55
Kigita	5.34 ±0.12	8.29±0.32	2.95	5.00±0.72	12.31±0.54	7.31
Kirimumpale	4.90 ±0.17	7.91 ±0.19	3.01	3.80±0.18	9.86±0.38	6.06
NASE14	6.18 ±0.09	9.07±0.31	2.89	5.90±0.47	12.01 ±0.37	6.11
Njule	5.93 ±0.13	8.90±0.12	2.96	5.43±0.17	10.45±0.62	5.02
Nyaraboke	5.43±0.11	8.19±0.34	2.76	5.18±0.28	12.03±0.51	6.85
TME14	3.14 ±0.23	7.93±0.27	4.79	4.78±0.15	12.68±0.12	7.9
Mean	**5.26**	**8.41**	**3.16**	**4.95**	**11.12**	**6.17**

Changes in the cyanogenic potential after treatment

There were significant differences ($P<0.05$) in the cyanogenic potentials (measure as HCN content) of cassava varieties and between the roots from pruned and non-pruned plants (Table 4). A general decrease in cyanogenic potential was observed with pruning, which could be attributed to remobilization events (for nitrogen) that probably took place after pruning. The minor reductions in the cyanogenic potentials of the roots seven days after harvest could be attributed to volatility of free cyanide and prolonged interaction between the enzyme linamarase and the cyanogenic glucosides in the roots (Padmaja, 1995). Njule had slightly higher level of cyanogenic potential than the other varieties which still fell within the recommended range of allowable cyanogenic potentials for varieties that are used for fresh consumption, which is 50ppm according to Cereda & Mattos (1996). Results seem to suggest that pruning before root harvesting can reduce the cyanogenic potential of cassava roots.

Table 4: Cyanogenic potential of roots from pruned and non-pruned plants of selected cassava varieties at zero (0) and seven (7) days of storage

	HCN (ppm) average, Non-pruned			HCN (ppm) average, Pruned		
Variety	0	7	Reduction	0	7	Reduction
Bufumbo	50.41±1.54	44.23±0.54	6.18	49.65±0.81	43.57±2.43	6.08
Hoima	27.84±2.85	26.51±0.71	1.33	28.42±1.86	26.12±3.45	2.3
Kigita	47.89±3.86	41.27±2.39	6.62	47.17±3.31	41.65±3.21	5.52
Kirimumpale	44.86±6.94	42.19±2.84	2.67	44.19±0.87	41.56±2.53	2.63
NASE14	31.01±9.54	30.23±3.25	0.78	30.76±0.24	29.53±0.22	1.23
Njule	53.20±3.45	46.49±2.36	6.71	52.40±1.75	46.79±0.53	5.61
Nyaraboke	36.79±4.32	31.45±3.34	5.34	36.23±2.56	32.98±1.87	3.25
TME14	32.61±0.75	30.23±2.84	2.38	32.12±3.28	28.78±3.12	3.34
Mean	**40.6**	**36.6**	**4.0**	**40.1**	**36.4**	**3.7**

Starch yield from pruned and non-pruned cassava plants

From the results obtained, there were no major differences in starch yields for pruned and non-pruned plants at harvest (Table 5). After 7 day storage the starch yields of roots harvested from non-pruned cassava plants ranged between 14.6% in Bufumbo and 17.9% in TME14 while for pruned cassava it ranged between 18.6% in Bufumbo and 23.0% in NASE14. An average reduction of 1.34 percentage points was observed in starch yield of roots from pruned cassava plants after 7 day storage while for non-pruned cassava plants the average reduction was 6.33 percentage points. Therefore, pruning contributed to contain the natural starch yield reduction of cassava roots occurring during storage under ambient conditions (Table 5).

Table 5: Starch yield from roots of pruned and non-pruned plants of selected cassava varieties at zero (0) and seven (7) days of storage

Variety	Mean starch yield					
	Pruned			Non-pruned		
	0	7	Reduction	0	7	Reduction
Bufumbo	19.8±0.12	18.6±0.23	1.2	19.9±0.14	14.6±0.18	5.3
Hoima	22.5±0.04	19.2±0.17	3.3	21.3±0.08	15.9±0.12	5.4
Kigita	22.0±0.11	21.8±0.17	0.2	21.8±0.23	14.7±0.22	6.1
Kirimumpale	24.1±0.01	22.9±0.31	1.2	24.41±0.26	17.4±0.31	7.01
NASE14	24.3±0.29	23.0±0.22	1.3	23.4±0.21	14.9±0.21	8.5
Njule	22.1±0.42	20.7±0.37	1.4	21.9±0.41	16.3±0.37	5.6
Nyaraboke	21.7±0.52	21.2±0.37	0.5	22.2±0.35	14.8±0.21	7.4
TME14	21.1±0.28	19.5±0.64	0.6	22.2±0.14	17.9±0.27	4.3
Mean	**22.2**	**20.86**	**1.34**	**22.14**	**15.81**	**6.33**

Variation in root dry matter content

Both pruned and unpruned cassava roots showed a reduction in dry matter content after 7 days of storage (Table 6). The reduction was more pronounced for unpruned cassava roots but not at significant level. Reduction in dry matter during storage are likely due to biochemical changes in the root including starch hydrolysis and these changes may have been affected by pruning.

Table 6: Variation in percentage dry matter of varieties after 7 days of storage

	% dry matter with increasing days				
Variety	**Pruned**		**Non-pruned**		**Difference in % DM at 7 days for pruned and non-pruned**
	0	7	0	7	
Bufumbo	34.76±0.56	32.57±0.85	34.68±0.74	31.82±0.29	0.08
Hoima	34.87±0.28	33.34±0.74	35.6±0.75	32.96±0.57	0.73
Kigita	34.38±0.22	30.22±0.36	36.29±0.23	30.52±0.64	1.91
Kirimumpale	35.24±0.29	30.56±0.46	38.69±1.18	31.86±0.35	3.45
NASE14	32.66±0.32	31.12±0.46	37.9±1.64	31.38±0.47	5.24
Njule	33.57±0.31	31.29±0.69	35.79±1.73	31.3±0.55	2.22
Nyaraboke	34.85±0.29	32.79±0.92	41.62±1.32	31.95±0.54	6.77
TME14	35.12±0.52	34.55±0.26	37.12±0.54	33.31±0.65	2.00
Mean	**34.43**	**32.06**	**37.21**	**31.89**	**2.8**

3.3. Overall sensory acceptability of selected pruned and non-pruned cassava varieties

Sensory acceptability scores of steamed cassava roots are shown in Table 7.Before root storage, overall sensory acceptability for steamed roots from pruned plants did not differ from the roots from non-pruned plants. However, pruning increased acceptability of the roots after 7 days of storage in some varieties like (Hoima) by up to 3 points. In varieties such as Nyaraboke and TME 14, no improvements in acceptability were observed.Varieties Hoima and Bufumbo were the most preferred at harvest although this acceptability reduced after 7 days of storage. This shows that some cassava varieties with roots that lose their palatability (Ofor, 2011) within 7 days of storage can maintain good palatability with pruning. The least favored cultivar for freshly harvested cassava was Kigita, primarily due to its low score for texture (4) (hence its name that means *ghee* in the local Western Uganda dialect). This is an indicator that very soft cassava is not liked by most consumers.

Table 7: Acceptability of the quality attributes of steamed roots from pruned and non-pruned plants of cassava varieties at harvest and after 7 days of storage

Variety	Pruned		Non-pruned		Acceptability improvement due to pruning	
	0day	7days	0day	7days	Acceptability improvement at day 0	Acceptability improvement at day 7 storage
Bufumbo	8	4	8	3	0	1
Hoima	8	5	8	2	0	3
Kigita	6	5	6	3	0	2
Kirimumpale	7	5	7	4	0	1
NASE14	7	4	7	3	0	1
Njule	6	4	6	3	0	1
Nyaraboke	7	5	7	3	0	0
TME14	7	5	7	3	0	0

4. IMPLICATIONS OF FINDINGS

In this study varietal differences in their tolerance to PPD were evaluated. Changes in cassava root biochemical compounds as a result of root storage in ambient conditions (room temperature of 22-30^{0}C for most Ugandan locations) were also studied. The cassava varieties showed variable shelf-life of their roots, which can be improved with pruning of the plants before harvesting. All the varieties in the study had low cyanide levels and are thus classified as sweet cassava varieties according to Cereda & Mattos (1996) who reported that low cyanide cassava has a cyanide level below 50 ppm. Nevertheless pruning induced a significant reduction in cyanogenic potential which is an advatage in cases where environemtal and soil factors lead to higher cyanogenic content.

Therefore, future research could aim to investigate the effect of varying agro-ecological conditions on levels of PPD and cyanide contents in Uganda cassava varieties. It is also important to note that temperature variations across the season could affect biochemical composition of cassava roots during storage. This could also be evaluated further to target the right season or time of harvest for reduced PPD. Enhanced acceptablitiy of the roots with pruning means that this technology can be advanced in Uganda and all regions where fresh and unfermented cassava is consumed. It can result in icreased marketability of roots and create opportunities for businesses involving cassava diversification into snack foods and other fresh root based products. Thus pruning could be synergised with other shelf-life extension technologies that do not compromise postharvest quality in terms of starch properties and caloric value of the roots. However, farmers' preferences of some sensory attributes on the roots including mealiness, flavour and taste also need to be taken into consideration.

Thus multiple factors need to be taken into consideration when selecting the ideal variety for use in fresh root processing and marketing.

5. CONCLUSIONS

From the study, it can be concluded that pruning is very useful for extending the roots shelf-life but varietal differences may be observed. Pruning caused slight changes in sugars and carbohydrate composition of roots but his effect was not significant. Under ambient temperatures, both pruned and unpruned root storage resulted in significant reduction in cyanogenic potential of cassava after 7 days of storage but lower level of cyanogenic compounds were found in pruned roots. In some varieties, pruning increased the acceptability level of stored roots by up to 3 points and in none of the varieties it led to reduced acceptability.

Therefore, pruning is a potential technology for extending cassava roots shelf-life. It improves the acceptability of the fresh roots which can be marketed for longer periods hence benefiting both the farmers and traders. However, inconsistent varietal responses to pruning were observed. These call for proper assessment of each variety to be pruned. Therefore varieties such as Nyaraboke, Njule, TME14 and Hoima are recommended for the pruning technology. Since all of them, apart from TME14, are local varieties that are susceptible to viral diseases such as cassava mosaic disease and cassava brown streak disease, the development of a seed system to deliver clean planting materials of these varieties to farmers to ensure consistent supply of the roots to the market is recommended.

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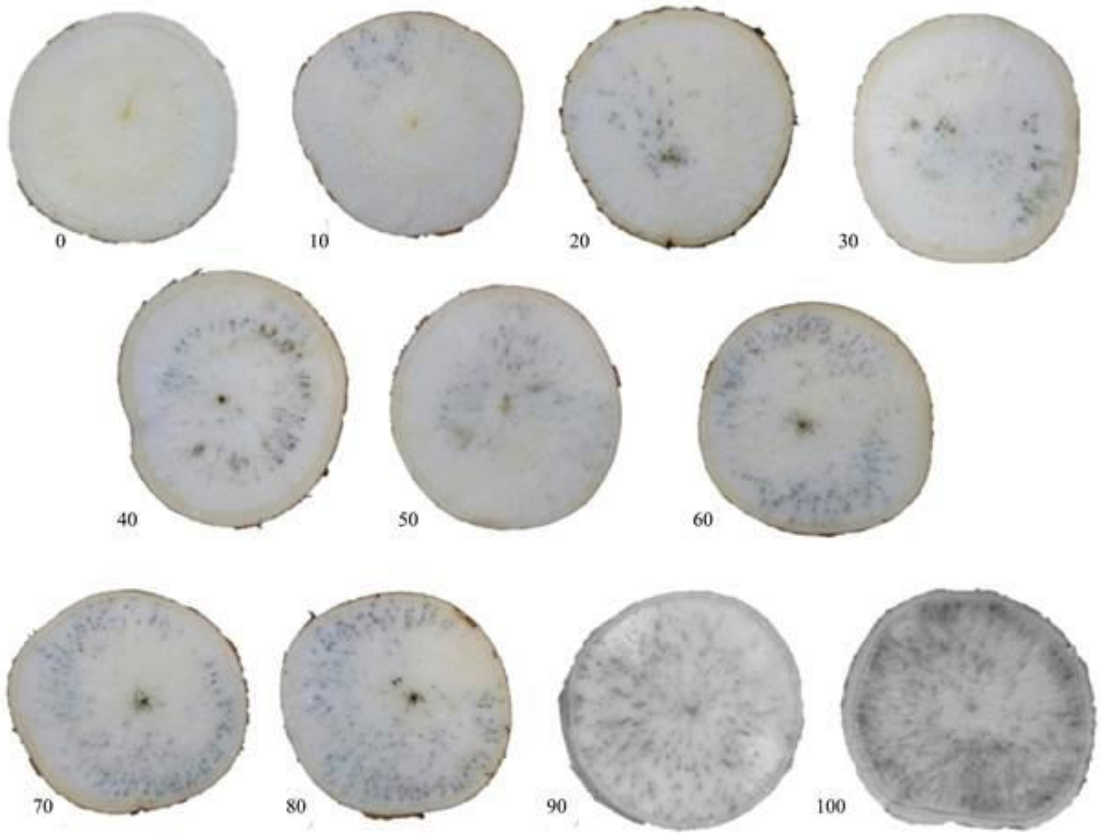
Appendix 1: Reference chart for scoring level of PPD



Adapted from Venturini et al. (2015)

Appendix 2: Sensory evaluation score sheet

Panelist: ……

Date: Time: ……
……...

Instructions
You are provided with cooked cassava samples before you. Each sample is identified by a coder. Please taste the samples before you and mark in the corresponding box a number that corresponds to your preference on the scale of 1 to 9 as indicated in the Key below. Rinse your mouth with the water provided before and after tasting each of the samples

Key:

Dislike extremely	1
Dislike very much	2
Dislike moderately	3
Dislike slightly	4
Neither like nor dislike	5
Like slightly	6
Like moderately	7
Like moderately	8
Like extremely	9

Sample codes
Appearance
Taste
Aroma
Texture
Mouth feel
Overall acceptability

Other comments: ……..

……..