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Research Application Summary

Influence of crop age on nutritional quality of fresh roots from popular coastal Kenyan cassava varieties

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Abstract

Cassava is an important crop in coastal Kenya commonly harvested at 12 months after planting but earlier during food shortages. Effect of early harvesting on root quality has not been well established. Varieties Tajirika, Karembo and Kibanda Meno (roots) were harvested at different ages from Agricultural Research Centres, and studied for pysico-chemical characterstics. Results showed significant ($P < 0.05$) interaction effect of varieties and crop age on dry matter, starch, carbohydrate, energy, fiber, ash and hydrogen cyanide contents. Karembo and Tajirika had peak dry matter (43.42% and 41.42%, respectively) at 12 months while the peak for Kibanda Meno was 44.99% at 9 months. Mean starch content varied with variety; Karembo (27.3 %), Kibanda Meno (27.4 %), and Tajirika (28.5%). Karembo and Tajirika had peak carbohydrates at 12 months while the peak for Kibandameno was at 9 months. Vitamin C was highest at 6 months for Karembo (6.4 mg/100g). Kibanda Meno and Tajirika had highest vitamin C (6.1 and 7.0 mg/100g, respectively) at 9 months. Iron was highest at 3 months for Karembo (3.63 mg/100g) and Tajirika (5.33 mg/100g) but at 9 months for Kibandameno - 7.12 mg/100g. Peak Zinc was for Karembo (2.1 mg/100g) at 6 months Kibandameno (1.94 mg/ 100g) and Tajirika (1.75mg /100g) at 12 months. While hydrogen cyanide increased from 8.6 to 9.3% in Karembo between 9 and 12 months, it decreased from 7.8 to 5.2% and from 5.1 to 4.5% on Tajirika and Kibandameno, respectively. The results indicate that Kibandameno and Tajirika can be harvested as from nine months after planting.

Key words: Cassava varieties, Coastal Kenya, hydrogen cyanide, months after planting, physico-chemical

Résumé

Le manioc est une culture importante dans les régions côtières du Kenya, généralement récoltée 12 mois après la plantation mais plus tôt pendant les pénuries alimentaires. L'effet d'une récolte précoce sur la qualité des racines n'est pas bien établi. Les variétés Tajirika, Karembo et Kibanda Meno (racines) ont été récoltées à différents âges dans les centres de recherche agricole et étudiées pour les caractéristiques physico-chimiques. Les résultats ont montré un effet d'interaction significatif (P <0,05) des variétés et de l'âge des cultures sur la matière sèche, l'amidon, les glucides, l'énergie, les fibres, les cendres et les contenus en cyanure d'hydrogène. Karembo et Tajirika avaient un pic de matière sèche (43,42% et 41,42%, respectivement) à 12 mois tandis que le pic pour Kibanda Meno était de 44,99% à 9 mois. La teneur moyenne en amidon variait selon la variété; Karembo (27,3%), Kibanda Meno (27,4%) et Tajirika (28,5%). Karembo et Tajirika avaient un pic de glucides à 12 mois tandis que le pic pour Kibandameno était à 9 mois. La vitamine C était la plus élevée à 6 mois pour Karembo (6,4 mg / 100 g). Kibanda Meno et Tajirika avaient la vitamine C la plus élevée (6,1 et 7,0 mg / 100 g, respectivement) à 9 mois. Le fer était le plus élevé à 3 mois pour Karembo (3,63 mg / 100g) et Tajirika (5,33 mg / 100g) mais à 9 mois pour Kibandameno - 7,12 mg / 100g. Le pic du zinc était de (2,1 mg / 100 g) pour Karembo à 6 mois ; (1,94 mg / 100 g) pour Kibandameno et (1,75 mg / 100 g) pour Tajirika à 12 mois. Alors que le cyanure d'hydrogène etait passé de 8,6 à 9,3% pour Karembo entre 9 et 12 mois, il a diminué de 7,8 à 5,2% et de 5,1 à 4,5% pour Tajirika et Kibandameno, respectivement. Les résultats indiquent que Kibandameno et Tajirika peuvent être récoltés à partir de neuf mois après la plantation.

Mots clés: Variétés de manioc, côte Kenyane, cyanure d'hydrogène

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Introduction

Cassava remains an important food crop in the coastal region of Kenya, ranking second after maize. The crop has successfully been incorporated into many farming systems (FAO, 2005) making it very popular among smallholder farmers. It is one of the traditional crops, and it is significant in coastal dishes and menus (Githunguri, 1995). The Coast region of Kenya experiences unfavorable temperatures and rainfall but cassava thrives under these sub optimal conditions, thus making it the only food crop of hope to farmers. It therefore has the potential to provide food to rural households during harsh weather conditions when other food crops fail (Imungi *et al.,* 1989).

In 2008, the Kenya Agricultural Research Institute (KARI) released eight improved cassava varieties for production and consequent utilization by farmers in coastal Kenya (KARI, 2009). These varieties were bred for high yield, pest and disease resistance, leaving out post-harvest issues. This created information gaps that need to be addressed. For example, the new varieties still needed to be studied to determine their nutrient build up trends.

Cassava roots are recommended to be harvested at 12 months after planting (Muli *et al.,* 2008; Geth *et al.,* 2009) but this only applies under ideal food security situations. Under food shortage, farmers start harvesting cassava as early as three or six months after planting when they notice cracks on the ground (FAO, 2005).

Limited research has been conducted to evaluate the quality of cassava roots harvested earlier than recommended. The parameter that has been studied most in research on cassava root quality is dry matter content, but not its components that include carbohydrates, fiber, and ash. Cassava roots also contain micronutrients that can be exploited to improve nutrient security for the cassava growing and/or consuming communities. In recent years, consumers and food processors have shown considerable interest in foods' nutritional quality (Shobha *et al.,* 2012). Exploitation of micronutrients especially in cassava roots can only be fully achieved if studies are carried out to determine their levels.

It is important to note that cassava is also known to contain hydrogen cyanide that is poisonous to both humans and livestock (Wobeto *et al.,* 2007). This compound has hardly been studied to determine its concentration in cassava roots at various stages of growth to ascertain consumers' safety especially for the cassava varieties grown in coastal Kenya. Consumption of unsafe levels of hydrogen cyanide for prolonged periods has been associated with the Konzo disease which mainly affects children, (Nhassico *et al.,* 2008). This study sought to evaluate cassava root dry matter, carbohydrate, energy, starch, fiber, ash, protein, fat, hydrogen cyanide and selected micronutrients contents in relation to crop age.

Materials and methods

Acquisition of raw materials. Cassava roots from three popular varieties: Tajirika, Kibanda Meno and Karembo used in this study were obtained from mother blocks at three Kenya Agricultural and Livestock Research Organization (KALRO) Centres; Masabaha, Matuga and Mtwapa. Roots were harvested according to months; 3, 6, 9 and 12 after planting. Pysico -chemical analysis was done at University of Nairobi food laboratories. Methods of analysis for analyzing nutrients were obtained from AOAC (2012) guided by different protocols according to the parameter studied.

Carbohydrates were determined by difference. The total of moisture content, fat, ash, protein and fibre contents were subtracted from 100 as guided in AOAC. (2012) protocol (31). The energy content was obtained by multiplying the value of crude protein, fat and carbohydrate by factors of 4, 9 and 4 respectively as in indicated by Omosuli (2014). Protein content in cassava roots was determined as per AOAC (2012) protocol (05). Hydrogen cyanide determination was carried out using distillation method. Cassava roots were macerated using a laboratory blender and samples of 10 g root mash was placed into distillation flask and allowed to stand for three hours before distillation. Distillation and consequent determination of hydrogen cyanide was carried out as described by Omonsoli (2014). For Vitamin C, approximately 15 ml (10%) TCA was added into flat bottomed flask containing cassava roots mash and filtered. A total of 15 ml filtrate sample was collected. The filtrate sample was then mixed with 5 ml of 4% potassium iodide solution then titrated with N- bromisumccinimide solution. The rest of the procedure was as described in AOAC. (2012) protocol (21).

Determination of Iron and Zinc Content. Cassava root mash sample (4g) for determining mineral Iron was ashed in a muffle furnace at 500^{o}C for 4 hours. It was then digested by adding 10 mls of 20% HCL to boiling, then filtered into 100 ml volumetric flask and topped to mark using distilled water. Using atomic absorption spectrophotometer (A.A.S) mineral iron and zinc level were determined according to AOAC (2012) protocol (8).

Experimental design and data analysis. The statistical design used in the study was a Complete Randomized Design, where varieties and crop growth stage were independent variables. Data were collected on the following parameters: Hydrogen cyanide levels, Carbohydrates, Starch, Fiber and Dry matter, protein, fat and selected micronutrients contents. Results from laboratory analyses were subjected to the analysis of variance (ANOVA), using the General Linear Model (GLM) of the Statistical Analysis System (SAS version 9.1). Means were separated using Least Significant Difference (LSD) test, the differences being significant when $p \leq 0.05$.

Results and Discussion

There was significant ($p < 0.05$) interaction between variety and crop age on all the studied parameters (Table 1). There was significant ($p < 0.05$) difference in carbohydrate content accumulation for the improved varieties and Kibanda Meno – the local variety. The improved varieties had peak accumulation of carbohydrates at 12 months while Kibanda Meno had its peak at 9 months after planting. Crop age (6 to 9 months) had significant ($p < 0.05$) effect on carbohydrate content in Kibanda Meno and Tajirika, where Tajirika had the highest increase at 9 months age at 31.8 %. The carbohydrate content of Karembo was 37.6 % at 9 and 40.5 % at 12 months after planting. These results are within the range of carbohydrates contents that was reported by (Richardson, 2013) who tested six mature improved varieties harvested at between 12 and 13 months after planting. The six varieties evaluated by (Richardson, 2013) had carbohydrates content of between 26.3 % and 39.6 %. However, the nutritional content of cassava depends on geographic location, variety, age of the plant and the specific plant part (root or leaves) and environmental conditions (Salvador *et al.,* 2014).

Crop age had significant ($p < 0.05$) effect on energy content of cassava roots between 3 and 12 months after planting. There was 17.9 %, 41.3% and 40.1 % change in energy (kcal) accumulation for Karembo, Kibanda Meno and Tajirika, respectively. Variety Karembo had accumulated 11 % energy content from 3 to 6 months after planting while Kibanda Meno and Tajirika had 38 % and 17.1 %, respectively, at the same period. Energy content in Kibanda Meno increased by 3 % while energy content in Tajirika roots increased by 7%, when left in the field further up to 9 and 12 months after planting, while variety Karembo added 9.4% energy content over the same period of time. These results show that energy content of coastal varieties is averagely higher compared to those varieties reported by Montagnac (2009). At 12 months after planting energy content of the coastal varieties was as follows; Karembo had 169.8 kcal, Kibanda Meno had 155.7 kcal and Tajirika had 161.2 kcal. The varieties tested by Montagnac (2009) had energy content of between 110 and 149 kcal per 100 g. This is a positive indicator that popularizing cassava varieties in the coast region can help households acquire a bigger percentage of the daily required calories. This makes them more suitable for processing whole root product.

Change in protein content for variety Karembo, from 3 to 6 months after planting was 74.7% decrease, 4.5% decrease from 6 to 9, however protein content increased from 0.21 % to 0.50% from 9 to 12 months after planting (Table 1), this culminates to 138% increase.

Variety Kibandameno showed a decrease of 37.8% from 3 to 6 months after planting, 7.14% increase from 6 to 9 months after planting and a decrease of protein content of 3.33% from 9 to 12 months after planting. Variety Tajirika showed a decrease of 42% from 3 to 6 months after planting, then an increase of 117.24% from 6 to 9 months after planting. Another increase of 22.2% protein content was shown from 9 to 12 months after planting. These results indicate a significant ($p < 0.05$) interaction effect of crop age and variety on protein content. Karembo had the highest protein content at 3 months after planting followed by Tajirika whose highest protein content was at 12 months after planting (Table 1). Variety Kibanda Meno had its peak protein at month 6 while Karembo's peak was at month 3. This is similar to the results of the study carried out by Benesi *et al.* (2004) and Richardson (2013) where six varieties evaluated for quality showed a range of 1.20 to 2.10% protein at 12 and 13 months after planting; these authors also observed that protein content is quite low in cassava roots, with Salcedo *et al.* (2010) showing that protein content in cassava roots ranged between 1and 3%. This shows that the popular varieties grown in coastal Kenya have lower protein content than other varieties elsewhere. It is advisable therefore that consumers supplement cassava roots dishes with protein source. Also in order to maximize on the little protein contained in cassava roots Tajirika is best harvested at 12 months, Kibanda Meno at 6 months and Karembo at three months after planting.

The change in root hydrogen cyanide content between 3 and 12 months after planting was 0.12% to 9.34%, 0.12% to 5.24% and 0.13% to 4.47% for Karembo, Kibanda Meno and Tajirika, respectively (Table 1). While longer period in the field from 3 to 6 months after planting had no effect on root hydrogen cyanide content in Karembo, Kibanda Meno and Tajirika accumulated 22 and 37 times more cyanide over the same period of time. Longer period in the field from 9 to 12 months showed increase in accumulation of hydrogen cyanide content in the roots of Karembo by 8%, while the same period caused reduction of hydrogen cyanide content in the roots of Kibanda Meno and Tajirika by 33% and 12%, respectively. These results are higher compared to results reported by Onwuka *et al.* (2007) whose two varieties (one improved and a local) had hydrogen cyanide levels of 3.1mg and 3.6 mg, respectively in roots harvested at full maturity, i.e., over 12 months after planting. The results however compared well with those reported by Ubwa *et al.* (2015). The accepted hydrogen cyanide levels is up to 10mg/kg that is equivalent to 10ppm (Codex, 1989). On the other hand hydrogen cyanide levels that were reported to be endemic with reference to Konzo disease were between 47 and 614mg/kg. The coastal varieties have hydrogen cyanide range of between 12 mg/kg and 93m/kg- conversion done using Endmemo convertor table (Endmemo, 2017). Variety Karembo however had dangerously high cyanide content across the studied crop ages.

The change in vitamin C content in variety Karembo was 585.89% accumulation from 3 to 6 months after planting, after which there was 31% reduction from 6 to 9 month after planting and then a further 26.79% reduction from 9 to 12 months after planting. Variety Kibanda Meno had persistent decline in vitamin C content from 3 to 6 months (796.21 %), 6 to 9 months (7.97 %) and from 9 to 12 months after planting (22.94%). Variety Tajirika had a vitamin C content increase of 445.38% from 3 to 6 months after planting, then an increase of 23% from 6 to 9 months after planting and a decrease of 13.76% from 9 to 12 months after planting. Therefore, varieties Karembo and Kibanda Meno showed a decreasing trend in vitamin C content when left in the field for a period beyond 6 months after planting, while Tajirika's vitamin C content started decreasing when left in the field beyond 9 months after planting. There was therefore significant (p< 0.05) interaction effect between vitamin C content (mg/100g) and crop age. The results showed substantial high content of vitamin C in all the three varieties, Karembo 64.2 mg/100g, Kibanda, Meno 66 and mg and Tajirika 69.6 mg/100g. These results are higher than those reported by Montagnac (2009) whose results were 14.9 to 50 mg/100g. They however compare well with those reported by Davidson (2017). Salvador *et al.* (2014) postulates that chemical content of cassava varies depending on the plant part, climatic and environmental condition and agro – ecological location of production. Peak vitamin C content also significantly varied especially for Tajirika. Karembo and Kibanda Meno attained their highest vitamin C content at six months after planting. Tajirika had its highest level of vitamin C at 9 months after planting. The results indicate that cassava roots for Karembo and Kibanda Meno lose vitamin C when left in the field longer than six months after planting. The percent drop in vitamin C content was as follows; Karembo 30.9mg and Kibanda Meno 7.9 mg when harvested at 9 months after planting instead of at 6 months after planting. Tajirika's vitamin C content however dropped when the variety was left in the field beyond 9 months after planting.

Variation in mineral contents. The change in variety Karembo for mineral iron content was a persistent accumulation from 3 to 6 months after planting (41.05%) and 25.23% from 6 to 9 months after planting. At 9 to 12 months after planting the results showed 12.62 % decline in mineral iron content. Variety Kibanda Meno had 28.9 % decline in mineral iron content from 3 to 6 months, an increase of 134.98 % from 6 to 9 months after planting, then a decrease of 26.97 % from 9 to 12 months. Variety Tajirika showed a decrease of 46.15 % from 3 to 6 months after planting, then another decrease of 17.42 % from 6 to 9 months after planting. There was further decrease of 5.48% mineral iron content from 9 to 12 months after planting. The results therefore showed significant (p< 0.05) interaction effect on cassava roots in relation to iron content. Kibanda Meno had higher iron content in all the crop ages compared to the improved varieties (p≤0.05). At 3 months after planting, Kibanda Meno had 4.3 mg/100g iron content whih was higher (14.7 %) than Karembo's iron content that stood at 3.6mg/100g. Peak iron content was found to be at the tender crop age of 3 months after planting for the improved varieties, Karembo having 3.6 mg/100 and Tajirika 5.3mg/100, while variety Kibanda Meno had its peak iron content (7.12 mg/100) at 9 months after planting. These results are within the range reported by Ifeabunike *et al.* (2017) iron content of 2.25 mg/100g for bitter varieties and 4.0mg for the sweet varieties. Studies carried out by Chavez *et al.* (2000) showed a mean iron content of 9.6 mg in cassava roots, while Montagnac's results were at 0.3 mg/100 to 14.0 mg/100 (Montagnac, 2009). This is however expected since cassava nutrients and/or physical characteristics are influenced by several factors as stated by Salvador *et al.* (2014) and Montagnac (2009) found a mean Iron content of 0.27 mg/100g in cassava roots.

Change in mineral zinc content showed 176.32% accumulation in variety Karembo when left in the field from 3 to 6 months after planting, then there was a 60% reduction when the crop was left in the field from 6 to 9 months after planting, but there was 73. 81% accumulation of mineral zinc from 9 to 12 months after planting. Variety Kibanda Meno showed 54.72 % increase in mineral zinc content from 3 to 6 month after planting, but with

18.28% reduction of mineral zinc from 6 to 9 months after planting, and then 190% accumulation of mineral zinc content from 9 to 12 months after planting. Variety Tajirika showed 96.83% change from 3 to 6 months after planting, then the period of 6 to 9 months after planting recorded 20.97% decline in mineral zinc content but there was 16.67% accumulation at 9 to 12 months after planting. These results showed significant ($p< 0.05$) interaction effect on cassava roots in relation to zinc content. Variety Karembo had the highest Zinc (2.1 mg/100g) content at 6 months after planting; Tajirika and Kibanda Meno had their peak zinc content at 12 months at 1.75mg/100g and 1.94 mg/100, respectively. Tajirika's Zinc content was 1.75 while Kibanda Meno was 1.46 mg/100g. These results are within the peak that was reported by Charles *et al.* (2005), where their five cassava varieties had zinc content range of between 1.4 and 4.25 mg/100g.

Conclusion and Recommendation

From the results of this study, it was concluded that maturity stages have influence on cassava roots' quality but leaving the crop in the field for longer period after planting does not warrant maximum root quality in terms of nutrient levels. However at 9 months after planting, most nutrients evaluated in this study recorded higher percentages compared to the other crop stages. Further three varieties popularly grown in coastal Kenya had considerably high cyanide content and as such it is recommended that processing be done before utilization.

Table 1. Means of Proximate nutrients content (%) of three coastal cassava varieties as affected by crop age

Cassava root nutrients	Cassava varieties	3 months after planting	6 months after planting	9 months after planting	12 month after planting
Carbohydrates	Karembo	39.00 ± 0.01 ^{c}	37.28 ± 0.28 ^{de}	37.58 ± 0.37 ^{d}	40.48 ± 0.26 ^{ab}
	Kib-meno	30.01 ± 0.01 ^{h}	39.86 ± 0. 2 ^{b}	40.81 ± 0.24 ^{a}	37.12 ± 0.16 ^{de}
	Tajirika	35.84 ± 0.17 ^{f}	26.65 ± 0.06 i	35.15 ± 0.14 ^{g}	36.86 ± 0.69 ^{e}
Energy (kcal)	Karembo	139.49± 0.63 ^{f}	155.0 ± 0.15 ^{d}	155.15± 1.40 ^{d}	169.81± 0.74 ^{ab}
	Kib-meno	122.81 ± 4.04 ^{h}	169.04 ± 1.77 ^{b}	173.52 ± 0.10 ^{a}	155.65 ± 0.68 ^{d}
	Tajirika	134.79 ± 0.63 ^{g}	115.12 ± 0.77 ^{i}	150.69± 1.08 ^{e}	161.23± 3.72 ^{c}
Vit- C	Karembo	9.36 ± 0.721 ^{g}	64.2 ± .35 ^{abc}	44.3 ± 0.06 ^{e}	32.43 ± 0.78 ^{f}
	Kib-meno	7.39 ± 0.61 ^{g}	66.23 ± 3.7 ^{a}	60.95 ± 0.96 ^{bcd}	46.97 ± 7.75 ^{e}
	Tajirika	10.38 ± 0.08 ^{g}	56.61 ± 0.78 ^{d}	69.63± 0.74^{a}	60.05 ± 1.0 ^{cd}
Iron	Karembo	3.63 ± 0.03 ^{bed}	2.14 ±1.6^{d}	2.68 ± 0.12^{c}	2.41 ± 0.18 ^{d}
	Kib-meno	4.26 ± 0.03 ^{bc}	3.03 ± 1.31 ^{c}	7.12 ± 2.2 3^{a}	5.20 ± 0.08 ^{b}
	Tajirika	5.33 ± 0.00 ^{b}	2.87 ±1.72 ^{c}	2.37 ± 0.24 ^{d}	2.24 ± 0.18 ^{d}
Zinc	Karembo	0.76 ± 0.01^{e}	2.10 ± 0.28 ^{a}	0.84 ± 0.21 ^{de}	1.46 ± 0.29^{bc}
	Kib-meno	0.53 ± 0.03^{e}	0.82 ± 0.05 ^{d}	0.67 ± 0.5 ^{e}	1.94 ± 0.25 ^{a}
	Tajirika	0.63 ± 0.05^{e}	1.24 ± 0.00 ^{cd}	1.50 ± 0.07 ^{bc}	1.75±0.14 ^{ab}
Protein	Karembo	1.13 ± 0.03 ^{d}	0.77 ± 0.01 ^{fg}	0.74 ± 0.06 ^{h}	0.88 ± 0.05 ^{ef}
	Kib-meno	0. 41 ± 0.01 ^{h}	1.54± 0.11 ^{ab}	0.94 ± 0.00 ^{e}	1.15 ± 0.00 ^{d}
	Tajirika	1.33 ± 0.08 ^{c}	1.49 ± 0.04 ^{b}	1.12 ± 0.05 ^{d}	1.63 ± 0.06 ^{a}
Hydro- Cyanide	Karembo	0.12 ± 0.00 ^{c}	85.0 ± 0.01 ^{c}	8.62 ± 0.76 ^{b}	9.34 ± 0.45 ^{a}
	Kib-meno	0.12 ± 0.01 ^{f}	2.62 ± 0.12 ^{e}	5.10 ± 0.01 ^{d}	4.47 ± 0.54 ^{d}
	Tajirika	13.00 ± 0.01^{f}	4.80 ± 0.30 ^{d}	7.80 ± 0.38 ^{c}	5.24 ± 0.03^{d}

Means followed with the same superscript in the same row are not significantly different at 5% level of significance

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