Quality Characteristics and Nutritional Value of Improved Cassava (*Manihot Esculenta*) Varieties in Marigat, Baringo County, Kenya

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Abstract- Culinary characteristics and nutritional values of newly bred cassava root varieties in Baringo County, Kenya were evaluated. 51 varieties were grown and harvested at 16 months at KALRO in Marigat. Sensory evaluation was done by trained panelists for appearance, taste and texture using hedonic scale 1-5 (1 = worst, 5 = very good). Ten (n=10) highly accepted cassava varieties were further processed for nutritional quality using HPLC and compared with U.S.D.A-21 standards. Surface appearance scored highest mean (3.16 ± 0.72) followed by taste (2.64 ± 0.71) and texture (2.41 ± 0.29). ANOVA test showed significant mean differences between sensory characteristics. Protein levels of R252m were highest (2.05% per 100g), lower than the 3% USDA-21 standards. Fats ranged from 0.17% to 1.24 % with P12m value above the standards. CHO values were high with POROs recording highest (93.51% per 100gm), higher than the U.S.D.A-21 standards. Mineral elements were below the USDA-21 standards. Ca ranged from 3% to 6.92 % per 100g for P15m while P117o had the highest Fe content (1.5 % per 100g). P was found in large amounts with P15m leading with 96% per 100gm. CHO, Fe and P. Fat, K, Protein and Fe had significant positive correlations with sensory qualities (p = 0.634, 0.513, 0.487, 0.846 respectively). The paper recommends greater efforts to promote cassava breeding for higher quality attributes for better culinary characteristics and nutritional values. This may enable communities in the ASAL to benefit from improved cassava varieties towards attaining better health and nutrition.

Index Terms- ASAL, cassava roots, culinary characteristics, nutritional qualities

I. Introduction

The global rising food security needs in society has become a debatable topic with researchers seeking solutions to effective and efficient ways of coping with the situation. This paper focuses on cassava production as a source of vital nutrients and a food security crop for poor rural communities. The crop has particularly been significant in arid and semi-arid regions of developing countries. In the central Rift Valley of Kenya, new varieties of the crop have been introduced. However, little is known about variability of critical root nutritional and quality traits necessitating the need for a study that is a result of this article. Cassava roots when left attached to the main stem can remain in the ground for several months without becoming inedible and farmers often leave cassava plants in the field as a security against drought, famine or other unforeseen food shortages (Bokanga, 2001). However, incipient quality deterioration starts after the roots have reached maturity, e.g. starch content decreases while fibre increases. The roots after harvesting start actively deteriorating within 2-3 days and rapidly become of little value for consumption or industrial application (Hahn, 2007). This initial physiological deterioration is followed by microbial deterioration 3–5 days after (Rickard & Coursey, 1981). Due to the large amounts of material required for industrial processing, two to three days of pre-process storage of cassava root is inevitable, during which time physiological changes that reduce starch yield and the quality of processed cassava products occur in the raw material (Akingbala *et al*., 1989; Ihedioha *et al*., 1996).

Cassava is drought resistant and can tolerate poor soils and require less farm inputs to survive. Since cassava is mostly vegetative propagated through stem cutting, it is able to withstand dry periods up to 5 months (Dele *et al*., 2001) and has no fixed planting dates or time of harvest thus rarely fails as a crop. Cassava is a multi-purpose crop whose economic value is derived from the roots as a source of starch both for human consumption and industrial purposes. The leaves are used as vegetables which are rich in vitamins and the stem used as wood fuel. The crop has several attributes that have made it attractive for small scale farmers with limited resources in marginal agricultural areas. However it also has some negative attributes such as bulkiness, high perishable and toxicity in some varieties which do not out way the benefits. The bitter cassava varieties are mainly for industrial uses.

Cassava is an excellent source of digestible carbohydrates and therefore high in energy, but a poor source of protein. Other vegetables must be supplemented to make a nutritionally balanced diet. Table 1 shows the raw material content of cassava compared to other roots and tuber crops.

Table 1: Nutritional Content of Some Selected Roots and Tubers per 100gm

% FW	Cassava	Potato	Sweet Potato	Yam
Dry Matter	30-40	20	19-35	21-24
Starch	27-36	13-16	18-28	18-25
Sugar	0.5-2.5	0-0.2	1.5-5.0	0.5-1.0
Protein	0.5-2.0	2.0	1.0-2.5	2.5
Fibre	1.0	0.5	1.0	0.6
Lipids	0.5	1.0	0.5-6.5	0.2
Vitamin A (mg/100g)	17	Trace	900	117
Vitamin C (mg/100g)	50	31	35	24
Ash	0.5-1.5)	1.0-1.5	1.0	0.5-1.0
Energy (KJ/100g)	607	318	490	439
Starch Extraction Rate	22-25	8-12	10-15	N/A

Source: Scott Gregory *et al*, 2000, International Potato Centre, Lima, Peru, FW-fresh weight

The objectives of this study were to determine the cooking qualities of the newly bred cassava root varieties sampled from KALRO Marigat, Kenya, to identify the overall acceptability of sampled boiled cassava roots and to establish the nutritional characteristics of sampled cassava roots with acceptable culinary qualities.

1.1 *Area of Study*

The study was undertaken in Marigat Division which is located in the arid and semi-arid lowlands of Baringo County situated 100km North of Nakuru, Kenya. The rainfall in Marigat is 337 inches annually. Marigat Division has 743.2sq km with climate temperatures of mainly 32.3*F. The land is mainly inhabited by Agro-Pastoralists (IFRC, 2008). Twenty Percent (20%) of the area has tillable soils and other parts are rocky with alluvial deposits of rock boulders (Agriculture Annual Report Marigat District Office, 2009).

Cassava production is increasing through the promotion of extension services from Ministry of Agriculture and KALRO Marigat Station, Kenya which has developed a research station in Marigat area for plant breeding purposes. Their major project is to breed cassava that is low in cyanide, early maturing, and of pest and disease resistance. This study adopted an experimental research design to determine the quality characteristics of the cassava roots.

II. Materials and Methods

2.1 *Sampling of Cassava Roots:*

Fifty (N=50) cassava varieties were harvested at KALRO-Marigat after 16 months of maturity. One cassava root was picked from Eldoret municipal market and coded P0R0s in order to be used for comparison with those from KALRO. The total sample was therefore N= 51 cassava roots which were all evaluated for culinary characteristics. Cooking was done and evaluated at University of Eldoret Food Laboratory to determine the culinary characteristics. Eight (8) sensory evaluation panelists semi-trained and familiar with cassava brainstormed on important qualities to use in sorting and eliminating the overtly unacceptable varieties of cassava roots. It was agreed that roots that were rotten, woody, with dark brown streaks after peeling, fibrous and with roots that had off-white standard color were considered unsuitable for processing.

Figure 1 is a summary of the steps followed in the evaluation of the sampled out 51 cassava root varieties. Elimination was done at stage I where the panelists observed for appearance and eliminated n=25 varieties. At stage II ease of cooking was done whereby n=16 varieties were eliminated. In the final stage, sensory evaluations was used to test the mealiness of the cassava roots and nutritional analysis for the most acceptable varieties which were n=10.

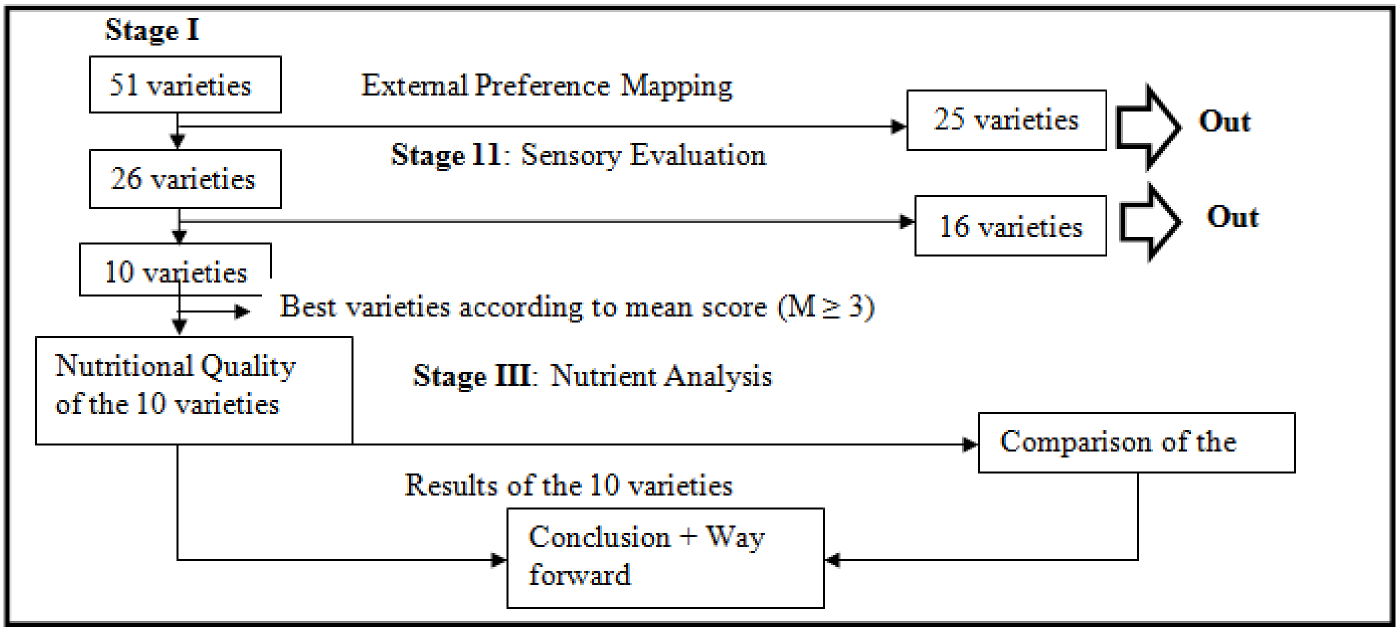

Figure 1: Sampling of cassava roots

2.2. *Ease of Cooking*

To test the ease of cooking of cassava roots, an experiment was conducted using Uzoma *et al* (2000) protocol. The roots of the n-26 were prepared according to the methods described by Oyewole *et al (*1996). They were peeled and the tail and head regions were removed and discarded. They were further washed, peeled and cut into cubes weighing 100 g each. The samples were labeled and placed in clear plastic bags to prepare for cooking. A five-litre aluminum pan of 2.5 lbs was used to boil water and five coded varieties were randomly picked and immersed in boiling water at once. Checking was done at five minutes interval for ease of cooking using a folk. The cooking time for all samples was controlled to a maximum of 20 minutes. Samples were removed when cooked, or when maximum time was attained and placed on labeled plates for sensory evaluation. The panelists were provided with clean distilled drinking water for rinsing their mouths after tasting every sample. Trained panelists comprising male and female adults rated the cooked cassava samples for ease of cooking. Roots that were glassy, fibrous and hard to chew were further rejected. The roots (n=10) were retained for sensory evaluation and nutritional qualities.

2.4 Mealiness of the Roots.

This is an attribute used in describing cassava roots which when boiled become soft and chewable (Ngeve, 1998). Non-cookable roots of some cassava varieties (the bitter varieties) would never boil soft no matter how long they are heated and are used for factory products. Glassy roots are difficult to chew even after several hours of boiling while mealy roots cook or boil easily and are floury in texture and can easily be eaten like a boiled potato. Thus, all cassava was categorized to reflect the degrees of mealiness. The cooked samples were divided into small pieces and placed randomly on labeled plates. Each panelist was given a glass of water to rinse his or her mouths before the next sample. Each of the samples was rated for surface appearance (surface color); mealy (floury); taste (mouth feel and after taste); texture (feel of the tongue before chewing). Sensory evaluation was carried out using a method by Iwe (2002) using a five point hedonic scale (5 = very good, 4 = good, 3 = fair, 2 = poor, 1 = worst). A product with a mean score of M=≥3 for a given attribute was considered acceptable and each accepted variety was further sampled for its culinary aspects by six trained panelists.

2.5 *Nutrient Analysis*

Cassava root products with a mean score ≥3 for the attributes given for mealiness (surface color, mealiness, taste and texture) were considered for nutritional analysis. The accepted roots were washed, peeled and sliced thinly with manual chipper as recommended by Igbeka (1987) then packed 500gm in labeled brown paper sachets. The samples were then placed in an electric drier to reduce the moisture content to 12.7% safe for storage then milled using a maize miller as recommended by (CTA, 2007). The ground samples were weighed to 200gms each and packed for nutrients analysis which was done using HPLC (High Performance Liquid Chromatography) to determine the proximate and mineral compositions. Inferential statistics were used in the experimental results which were subjected to Analysis of Variance (ANOVA) and Independent Sample T-tests.

III. Results

3.1 Culinary Aspects of Cassava Roots

A five point hedonic scale (5-very good; 4-good; 3-fair; 2-poor; 1-worst) was used carried out sensory evaluation. The characteristics considered during the sensory characterization were surface appearance, mealiness, taste and texture of the cooked cassava roots. The overall acceptability was given by the average of the four characteristics tested. A cassava variety with an overall mean score of of ≥ 3 and above was retained.

Accordingly, 9 out of the 25 cassava varieties from KARI were retained, which translated to a percentage retention of 36%. In addition, the control variety (POROs) was also retained as its overall mean was 3. Varieties that were ranked highest on sensory characteristics were P12m, P117o and RIP44o (M = 4.25, SD = 0.50, and M=4.75-0.50) respectively, whereas three varieties R365m, R271m and the control (POROs) scored lowest equal values of (M = 3.25, SD= 0.50) (see Table 2).

Table 2: Mean Sensory Evaluation Scores of the 26 Cassava Roots

Variety	Surface appearance	Mealiness	Taste	Texture	Mean (M)	SD	Remark
P12m	5	4	4	4	4.25	0.50	Retained
P12s	4	2	3	2	2.75	0.96	Rejected
P15m	4	3	4	3	3.50	0.58	Retained
P15s	1	1	1	1	1.00	0.00	Rejected
P15o	2	1	2	3	2.00	0.82	Rejected
P117o	4	5	4	4	4.25	0.50	Retained
P117m	2	2	3	2	2.25	0.50	Rejected
R252m	4	3	3	3	3.25	0.50	Retained
R252o	2	2	2	1	1.75	0.50	Rejected
R252s	3	3	3	2	2.75	0.50	Rejected
R365m	3	3	3	4	3.25	0.50	Retained
R365o	3	1	1	1	1.50	1.00	Rejected
R365s	3	3	3	3	3.00	0.00	Rejected
R271m	3	3	3	4	3.25	0.50	Retained
R271o	2	1	1	1	1.25	0.50	Rejected
R271s	3	2	1	2	2.00	0.50	Rejected
POROs	3	3	4	3	3.25	0.50	Retained
P114m	2	1	1	1	1.25	0.50	Rejected
P114o	3	3	3	2	2.75	0.50	Rejected
R1P44s	2	3	2	2	2.25	0.25	Rejected
R1P44o	5	5	4	5	4.75	0.50	Retained
R1P42m	4	4	5	5	4.50	0.58	Retained
R1P42s	5	4	4	4	4.25	0.50	Retained
R3P51m	2	1	1	1	1.25	0.50	Rejected
R1P81m	2	1	1	1	1.25	0.50	Rejected
R182m	1	1	1	1	1.00	0.00	Rejected

n=26

The mean scores obtained from the cassava varieties that were accepted were also determined. The overall mean values for sensory characteristics ranged from M = 3.00 - M = 4.75 which indicated an acceptable mean threshold. Comparing the means of the sensory characteristics, surface appearance 3.16 ± 0.72 scored the highest mean score whereas texture 2.41 ± 0.29 was the least scored (see Table 3). Generally, R1P44o had the best overall sensory characteristics (4.75 ± 0.5).

Table 3: Results Showing the Mean Scores of the 10 acceptable cassava roots

Variety	Surface appearance	Mealiness	Taste	Texture	Mean
P117o	4	5	4	4	4.25 ± 0.50
P12m	5	4	4	4	4.25 ± 0.50
P15m	4	3	4	3	3.50 ± 0.58
POROs	3	3	3	3	3.00 ± 0.00
R1P42m	4	4	5	5	4.50 ± 0.58

R1P44o	5	5	4	5	4.75 ± 0.50
R1P42s	5	4	4	4	4.25 ± 0.50
R252m	4	3	3	3	3.25 ± 0.50
R365m	3	3	3	4	3.25 ± 0.50
R271m	3	5	3	4	3.75 ± 0.82
Mean ± SEM	3.16 ± 0.72	2.60 ± 0.26	2.64 ± 0.71	2.41 ± 0.29	

3.2 Differences in Sensory Qualities

The data was then subjected to ANOVA test to determine if there were significant differences in the sensory qualities of the ten acceptable cassava varieties. The results are shown in Table 4. There were significant mean differences between the sensory characteristics and the cassava varieties at 5% level of significance in the values of surface appearance, mealiness and taste (F=3.895, F=2.538P and 0.0383) all at P<0.05 respectively. However, there was no significant difference noted in the cassava varieties in their texture. Generally the overall mean values of the scores were also found to be significantly different among the ten cassava varieties (F=2.672, P<0.05).

Table 4: ANOVA Results of Relationship between Sensory Characteristics of 10 Highly acceptable Cassava Varieties

		Sum of Squares	Df	Mean Square	F	P-value
Surface appear	Between Groups	35.741	9	3.971	3.895	0.037*
	Within Groups	17.333	17	1.020		
	Total	28.074	26			
Mealiness	Between Groups	17.241	9	1.916	2.538	0.0433*
	Within Groups	12.833	17	0.755		
	Total	20.074	26			
Taste	Between Groups	18.583	9	2.065	2.492	0.0383*
	Within Groups	14.083	17	0.828		
	Total	22.667	26			
Texture	Between Groups	7.833	9	0.870	1.153	0.682
	Within Groups	12.833	17	0.755		
	Total	20.667	26			
Mean	Between Groups	17.453	9	1.939	2.672	0.039*
	Within Groups	12.339	17	0.726		
	Total	19.792	26			

*Significant at p<0.05

3.3 *Nutritional Characteristics*

3.3.1 *Proximate Analysis*

The proximate composition considered during the study was varied with respect to USDA-21 standards as summarized in Table 5. CHO values for the cassava were high and ranged from 84.00 units to 93.51 % per 100g, which were all higher than the recommended USDA-21 levels for all varieties with the control (POROs) leading in CHO and could have been due to difference in harvesting period. This therefore indicates that in terms of provision of energy, the bred varieties of cassava were good despite the fact that they had stayed underground for sixteen months. The protein levels ranged from 1.25% to 2.05% per 100g, which was lower than the USDA-21standard requirement of 3% per serving, with POROS (1.25%) having the least amount. The low and sometimes large variation in protein content of cassava could be contributed to genetic makeup, growing environment or length of stay in the soil and the bred varieties seem to have been an improvement of the norm. Fats ranged from 0.17% to 1.24% with only one cassava sample having values above the USDA-21 standards (P12m-1.24%; USDA-21-1%). Dietary fibre and ash contents values were in traces reflecting that the varieties of cassava in the study area are low in fiber and ash contents. Proximate composition of the variety picked from local market (POROs) had minor differences noted compared to the KALRO varieties except for CHO values, despite the length of time and the differences in the growing environment (see Table 5).

Table 5: Proximate Composition of the Acceptable Cassava Root Varieties (%/100g)

Nutrients	P12m	P15m	P117o	R252m	R365m	R271m	POROs	R1P44o	R1P42m	R1P42s	SPs
Protein	1.85	1.75	1.95	2.05	1.85	1.65	1.25	1.45	1.45	1.55	3
Fat	1.24	0.21	0.22	0.17	0.18	0.15	0.18	0.17	0.18	0.34	1
CHO	84.00	87.34	88.72	88.98	90.67	88.81	93.51	90.88	87.78	89.01	78
D/Fibre	0.048	0.078	0.0515	0.047	0.055	0.082	0.027	0.04	0.088	0.068	3.7
Ash	0.094	0.135	0.093	0.109	0.089	0.122	0.045	0.078	0.093	0.094	1.3

Sps= Standard per servings (USDA-21) for adults; D/fibre= Dietary fibre

3.3.2 Mineral element composition

The mineral element composition of the cassava varieties are shown in Table 6. Ca in the KALRO varieties ranged from a low of 3.00% to a high value of 6.92 % per 100g with variety P15m recording the highest value of 6.92%. The control (POROs) had 3.25% which was generally lower than most of the KALRO varieties. Fe ranged from 0.53% to 1.56 % per100g with P117o recording highest value. It was noted that all varieties except R271m (0.53%) had higher Fe values than the USDA-21 standards (0.6%). These positive findings show that researchers bred improved varieties. Traces of Mn were noted with values ranging from 0.33% to a high of 2.36% per 100g whereby P117o (2.36%) recorded highest. Values of P ranged from 0.014% to 0.0774% whereas the content of K was found in large amounts and ranged from 56% to 96%. The control (POROs, 56%) recorded lowest in K whereas (P15m, 96%) had the highest value. All the mineral elements in the cassava were found to be below the USDA-21 standards except Fe. The observed values for proteins and other minerals contents suggest that KALRO has bred and released varieties with improved mineral values in Kenya.

Table 6: Mineral Element Composition of the ten Cassava Root Varieties

Nutrient (%/100g)	P12m	P15m	P117o	R252m	R365m	R271m	POROs	R1P44o	R1P42m	R1P42s	SPs
Ca	5.04	6.92	4.67	5.04	5.07	6.61	3.25	3.00	5.47	4.63	33.0mg
Fe	1.04	1.14	1.56	1.23	1.42	0.53	0.61	1.1	0.72	1.08	0.6gm
Mn	1.50	0.33	2.36	0.45	1.77	1.50	0.80	0.14	2.10	0.65	43.3mg
P	0.068	0.030	0.059	0.038	0.041	0.774	0.014	0.034	0.021	0.04	558mg
K	83	96	93	60	80	84	56	66	72	85	3.9mcg

Sps= Standard per servings (USDA-21) for adults

3.4 Correlation Analysis

Correlation between sensory quality and proximate composition of the cassava varieties are shown in Table 7. Protein and fat had significant positive correlation with sensory qualities (p values 0.487, 0.634 respectively) whereas CHO were highly negatively correlated with sensory qualities (p value = 0.691, $p < 0.05$). This indicates that as values of protein and fats increase, the sensory quality of the cassava improves while an increase in the content of carbohydrates reduces the overall sensory quality of the cassava. Dietary fibre and ash did not affect the sensory quality of the cassava indicating that cassava quality may be less determined by these variables.

Table 7 also depicts the correlation between sensory quality and mineral element composition of the cassava varieties. Only Fe (P=0.486) and K (0.513) had significant positive correlation with sensory qualities at $p<0.05$.. This indicates that as content of Fe and K increase, the sensory quality of the cassava improved. As shown in the results below the cassavas were deficient in Fe and K than the recommended levels and therefore any increase in these two mineral elements will probably improve the overall quality of the cassava.

Table 7: Spearman Rank Correlation between Sensory Evaluations and Nutrient

Nutrient	Pearson Correlation	Sig. (2-tailed)
Protein	0.487	0.048*
Fat	0.634	0.049*
CHO	-0.691	0.027*
Dietary Fibre	-0.079	0.827
Ash	0.179	0.621
Ca	0.074	0.839
Fe	0.486	0.045*
Mn	0.301	0.398
P	-0.274	0.444
K	0.513	0.020*

Values N = 10

*Correlation is significant at the 0.05 level (2-tailed)

IV. DISCUSSION AND CONCLUSION

Cassava varieties harvested at the same time and under the same conditions may differ substantially in quality due to a number of factors including genetic conditions, resistance to environmental condition and other intrinsic factors resulting in differences in nutritional and sensory qualities.

The cassava roots with acceptable cooking qualities were only 18% out of the N=51. This suggests that researchers should do more work in developing cassava varieties that satisfy the gastronomical tastes of people especially with respect to their texture, taste and mealiness. These differences are reflected in the rejection and acceptance of some cassava varieties.

Nutritional tests on the retained n = 10 cassava roots generally revealed low levels of protein, fat, dietary fibre, and ash compared to the recommended USDA-21standards per serving. However, CHO values were higher in all the retained varieties relative to the recommended USDA-21 levels. The cassava roots had higher levels of iron than the recommended standards whereas calcium, manganese phosphorus and potassium were found to be lower than the USDA-21 recommended standards. A study by Chavez, Sanchenz, and Ceballos (2005) reported large differences in protein content of roots ranging from 0.95%-6.42% per 100g an indication of possibility to improve protein through breeding. The varieties developed by researchers will be useful in supplying energy requirements to farmers and domestic animals because of high CHO content. A person requires enough energy for daily activities. In addition to fuelling activities, the research suggests that CHO can also promote recovery when consumed after exercise and is known to keep ones central nervous system functioning at optimal levels. However, cassava is poor in supplying protein and fats. Given the high protein deficiency in developing countries, it will be germane for researchers to develop varieties that are more fortified in proteins and all the micronutrients so as to curb malnutrition and hidden hunger.

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