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Agronomicand Nutritional Evaluation of Sweet potato (*Ipomoea batatas*(L.) Lam) Accessionsfor Genetic Variability

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Abstract :*Ipomoea batatas* (L.) Lam, the sweet potato, has enormous potential for ensuring food and nutrition security. Nevertheless, local cuisines hardly ever employ it because sweet potatoes lack qualities that lend themselves to being prepared as a local dish, breeders have clarified this poor utilization. Sweet potato is widely considered to beone of the world's most important staples that have been earmarked by the global initiatives to fight micronutrient deficiency, particularly vitamin A deficiency.Sweetpotatoseedswere sourced from International Potato Center, Kumasi, Ghana, Mozambique, localgermplasm of the National Root Crops Research Institute (NRCRI), Umudike, in Nigeria as well as vines from farmers' fields at different locations in Jos, Plateau State and Bauchi State, Nigeria. The beta-carotene, dry matter, and sugar contents of the germplasm, together with other agronomic and qualitative features, were assessed during the cropping seasons in two different locations. The present study sought to contribute to the pre-breeding knowledge base required for the improvement of sweetpotato nutritional quality targeting β-carotene, dry matter, starch, sucrose and minerals such as iron, zinc, calcium and magnesium as a sustainable strategy to reduce the problems associated with the micronutrient deficiencies and malnutrition among people in developing countries.The range of values observed for the dry matter, total sugar content, and beta-carotene were 26–40%, 15.35–42.29 (mg/100g) DW, and 20.00–34.40%, respectively. JAB BAWO and FARAA PC yielded the lowest and highest values for

beta-carotene content, respectively. MUSG 0621 x 07 x 105141-8 recorded the highest dry matter content, while the lowest was obtained by FARAA PC.

Keywords: Beta-carotene, Micronutrients, Vitamin A deficiency,Genetic Variability, Sweetpotato

Introduction

Sweetpotato (*Ipomoea batatas* [L.] Lam) is an important crop that is cultivated in 119 countries on an area of 8.3 million hectares for food, feed and industrial raw material (FAOSTAT, 2013).It is a tropical American crop belonging to the family *Convolvulaceae* and a hexaploid, with chromosome number (2n=6x=90).The crop is the third most significant root crop in sub-Saharan Africa, following yam and cassava, with 13.37 million hectares under cultivation (FAOSTAT, 2012). Sweetpotato has recently received greater research-related attention due to its adaptability to different environmental conditions and nutritional value, especially the orange-fleshed varieties making it a major crop to solve vitamin A deficiency in pregnant mothers and children (Julianti, *et al.*, 2017). FAOSTAT (2015) reported that popular sweetpotato cultivars in many African societies including Nigeria are the hard, non-sweet types with high dry matter which agrees with Jogo *et al*., (2021) who reported that low-yielding varieties of poor nutritional quality have been the major challenge in its production in Nigeria.

Its high protein, mineral, and dietary fiber content sets it apart from most staples in terms of nutrition (Jaarsveld*et al.,* 2005). Sweetpotato is an inexpensive source of β-carotene, anthocyanin, carbohydrate, vitamins and minerals. The orange-fleshed sweetpotato varieties are important sources of β-carotene which is the major precursor of vitamin A (Chassy*et al.,* 2008), while the purple fleshed sweetpotato varieties contains a high content of anthocyanins and other polyphenolic components (Steed and Truong, 2008).

Sweet potato is widely considered to be one of the world's most important staples that have been earmarked by the global initiatives to fight micronutrient deficiency, particularly vitamin A deficiency (FAOSTAT, 2015). Sweetpotato has a great potential to alleviate food insecurity, malnutrition, and poverty though its level of utilization has remained low over the years despite the release of many improved varieties and the various incentives by the government to boost massive production (Adu-Kwarteng*et al*., 2017).

The nutritional composition of sweetpotato which is important in meeting human nutritional needs include: carbohydrates, carotenes, thiamine, riboflavin, niacin, potassium, zinc, sodium, manganese, magnesium, calcium, iron, vitamins A and C

and high-quality protein. Sweetpotato particularly provides energy in the human diet in the form of carbohydrates (Antia *et al.,* 2006). Because of the various roles that sweetpotato play around the world, the concept of nutritional quality and its contribution must transform to meet specific roles in the human diet.

The objective of the study therefore was to contribute to the pre-breeding knowledge base required for the improvement of sweetpotato nutritional qualities targeting β-carotene, dry matter, starch, vitamins and minerals such as iron, zinc, calcium, magnesium and protein as a sustainable strategy to reduce the problems associated with vitamin A and micronutrient deficiencies and malnutrition among people in developing countries thereby leading to an increased food security and thus enhance skills and knowledge base of sweetpotato breeders, research scientists and extension workers towards improved sustainable agricultural productivity in Nigeria.

Materials and methods

Germplasm Collection and Agronomic Practices

Sweet potato accessions sourced from different areas of collection were evaluated under rain fed conditions in two locations (Jos, plateau state and Owerri, Imo state) to determine the agronomic and nutritional quality traits. Three- months old sweetpotato vine cuttings of between 25 – 30cm long, with 3 to 4 nodes were obtained from the nursery and planted in the field on ridges of 3m long at an inter and intra row spacing of 1.0m and 0.3m respectively. Two border rows were planted to envelope the experimental area in order to avoid border effects. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications.The fields were weeded regularly before the ground was covered by vines development in all the locations. Insecticides were used to prevent the plants against insect pests as well. Harvesting was done at 120 days after planting.

Sample Preparation and Laboratory Determination of Agronomic and Nutritional Traits

Harvested roots were put together into a composite pile, packed into labeled plastic polythene bags and samples of five roots were taken to the laboratory for analysis. Samples were sorted based on the size of roots. The roots were washed with running tap water to remove soil particles and debris. They were allowed to dry and packed into brown paper bags which were labeled with respect to plot numbers and names of the accessions. The roots arranged in the brown paper bags were lined up according to accession. Samples were prepared by cutting each root lengthwise into four sections with kitchen knives. Two opposite sections of each of the sectioned

roots were taken to prepare samples of approximately 50 g by slicing them using a kitchen knife and were placed in transparent polythene bags. The samples were then crushed to break into small particles and dried in an oven at 100^0 C for 12 hours. Dried samples were weighed, milled into flour in a stainless steel mill (3383-L70, Thomas Scientific, Dayton Electric Manufacturing Company Limited, Niles, IL 60714, USA). The milled samples were stored in sealed transparent bags which were duly sealed.

Data Analysis

The data collected were subjected to Analysis of Variance (ANOVA) using Genstat statistical package, the GenStat Discovery Edition (Version 4, VSN International Limited, United Kingdom, 2007). Mean separation was carried out using the Least Significant Difference (LSD) test at 5% level of significance. In terms of agronomic qualities, marketable and unmarketable roots were determined, while beta carotene, dry matter, total sugars, and starch content as well as minerals like protein, iron, and zinc content were determined for nutritional traits.The Quality and Nutrition Laboratory of the International Potato Centre (CIP), Lima, Peru, created the Workflow for Sample Preparation and employed near-infrared reflectance spectroscopy (NIRS) study of sweet potatoes to assess the attributes.Dry matter content was calculated as the ratio of the dry sample expressed as a percentage of the weight of the wet sample.

Estimation of Genetic Variability

Genetic analysis was also carried out to determine the genotypic and phenotypic contributions to observed variations and obtain the estimates of genotypic and phenotypic coefficients of variability, broad sense heritability and expected genetic advance under selection for all attributes studied. Genotypic variance was obtained as the mean difference between the accessions and error mean squares $\left(\delta_g^2 = MS\left(\delta_p^2\right) - EMS\left(\delta_e^2\right)\right)$, and the phenotypic variance as the sum of genotypic and environmental variance $\left(\delta_p^2 h = \delta_g^2 + \delta_e^2\right)$.

The genotypic and phenotypic coefficients of variability were obtained using the formula of Burton (1952);

$$\text{GCV (\%)} = \frac{\sqrt{\delta_g^2}}{\bar{x}} X \frac{100}{1}$$

$$\text{PCV (\%)} = \frac{\sqrt{\delta_p^2 h}}{\bar{x}} X \frac{100}{1}$$

Where; $ĥ^2_b = \frac{\delta_g^2}{\delta_p^2} X \frac{100}{1}$

δ_g^2 = genotypic variance

$\delta_p^2 h$ = phenotypic variance

$\overline{X}$ = sample mean

h_{bs}^2 = heritability

Heritability was obtained by the variance component analyses (Hanson *et al.*, 1956) and the expected genetic advance (%) was calculated from the formula by Allard *et al.,*(1964) as;

GA = K x $ĥ^2$ x Vp

Where; GA = Genetic Advance

K or i = estimated 2.06 (for 5% selection intensity in large samples from a normally distributed population) is the selection differential measured in terms of phenotypic standard deviations.

h^2 = Heritability

V_p= phenotypic variance = phenotypic standard deviation $\left(\sqrt{\delta_p^2 h}\right)$

Results and Discussion

The performance of the selected best performing accessions from Jos and Owerri for beta-carotene, dry matter and sugar contents presented in Table 1 revealed that significant differences were recorded among the accessions for all the characters. The ranges of values found for the total sugar content, dry matter, and beta-carotene were 20.00-34.40%, 26-40%, and 15.35–42.29 (mg/100g) DW, respectively.. The lowest and the highest values for beta-carotene content were obtained by JAB BAWO and FARAA PC, respectively. FARAA PC recorded the lowest dry matter content whilst MUSG 0621 x 07 x 105141-8 recorded the highest dry matter content. Similarly, DANKALI and FARAA PC were the accessions that gave the lowest and highest total sugar content, respectively.

Table 1: Performance of the selected accessions for beta-carotene, dry matter and sugar content from Jos and Owerri

S/No.	Accessions	Total sugar (%)	Beta-Carotene (mg/100g)DW	Dry matter (%)
1	FARAA PC	34.40	42.29	26
2	44216 PC	23.40	32.10	35
3	SANTOMPONA	25.70	18.20	30
4	LOCAL x 105193-4	25.80	16.75	32
5	LOCAL x 105141-8	23.45	20.24	25
6	MUSG 0621 x 07 x 105097-12	23.80	43.32	37
7	MUSG 0621 x 07 x 105193-4	22.84	32.10	36
8	MUSG 0621 x 07 x 105199-29	24.90	34.41	38
9	MUSG 0621 x 07 x 105141-8	26.80	27.43	40
10	MUSG 0621 x 07 x 105053-3	32.20	24.88	36
11	CENTEMMAL OP	28.40	17.28	37
12	JAB BAWO	21.73	15.35	35
13	KANKULE	21.25	17.14	37
14	ZAKI	20.88	16.70	39
15	ZAUNA INUWA	23.10	16.15	36
16	YAR TARO	25.57	15.65	38
17	DANKALI	20.00	16.56	37
	SED (P<0.05)	**2.32**	**1.45**	**3.30**

The ANOVA result indicated significant differences among the sweetpotato accessions studied. Significant genetic variation was shown by the results, which suggests that meaningful selection and the advancement of these qualities are feasible (Mohammed *et al*., 2012; Nwangburuka and Denton, 2012). Moreover, these illustrated the presence of genotype-level variability that can be utilized to produce desired trait combinations in certain varieties. Additionally, the divergences suggest that differentiating parents from these groups can be chosen in order to increase the amounts of sugar, dry matter, and beta-carotene in sweet potatoes.

Tables 2 and 3 indicate the range of values observed for the individual attributes together with their grand mean, coefficient of variation (CV), and standard error of mean (SE) for the Jos and Owerri locations, respectively. The iron grand mean was 1.63, while the starch grand mean was 89.77%. The ranges for the Coefficient of variability (CV) and the standard error (SE) were 5.68 for starch to 46.83% for marketable root weight for accessions from Owerri location (Table 3), and 0.14 for zinc to 7.05 for beta-carotene respectively, for the accessions at Jos location (Table 2). The grand mean ranged from 0.85 for zinc and 27.49 for total sugar and the ranges for the Coefficient of variability (CV) and standard error were 3.79 for total sugar to 42.72% for protein and 0.14 for zinc to 6.59 for beta-carotene respectively at Owerri location (Table 3).According to Zhang *et al*. (2001) and Tumwegamire*et al.* (2011), the findings of their investigations correspond with this discovery.

Table 2: Descriptive statistics for the agronomic and nutritional traits of the thirty sweetpotato accessions from Jos

Traits	Range	Grand Mean	CV (%)	SE
Dry matter	35.00 – 47.33	39.96	12.10	5.55
Beta-carotene	18.27 – 26.27	23.09	35.70	7.05
Total sugars	39.00 – 52.67	46.98	38.40	4.62
Starch	11.90 –135.00	89.77	5.68	3.26
Protein	6.03 -13.67	8.08	22.20	0.87
Iron	1.30-1.99	1.63	11.56	0.27
Zinc	1.38 -2.88	2.27	11.65	0.14
Unmarketable root weight	6.00 – 7.67	6.87	41.60	1.08
Marketable root weight	3.67 – 15.00	7.26	46.83	0.88

Table 3: Descriptive statistics for the agronomic and nutritional traits of the thirty sweetpotato accessions in Owerri

Traits	Range	Grand Mean	CV (%)	SE
Dry matter	25.00 – 45.00	27.00	6.40	5.45
Beta-carotene	4186 – 61.75	23.50	5.30	6.59
Total sugars	19.00 – 42.40	27.49	3.79	0.19
Starch	18.14 –40.12	23.79	5.68	1.17
Protein	2.17 -6.27	3.59	42.72	0.28
Iron	5.18-6.96	6.96	20..46	0.26
Zinc	0.43 -1.83	0.85	11.65	0.14
Unmarketable root weight	0.34 – 6.53	2.58	9.55	0.45
Marketable root weight	0.15 – 4.54	2.06	30.84	1.16

Tables 4 and 5, respectively, display the components of variation for the agronomic and nutritional characteristics of the sweetpotato accessions in the Jos and Owerri sites. Table 4 shows that the error variance for the Jos location ranged from 0.009 to 374.50, whereas the genotype x environment interaction variance ranged from 0.000 to 3.250. The dry matter had the lowest values while the highest values were recorded for beta-carotene and starch. Generally, the values for the genotype x environment interactions were lower than those of the genotypic variance and the error variance. However, the values for the genotypic variance were lower than those for the error variance for all the traits except dry matter and starch.

According to Table 5, the error variance for the Owerri location ranged from 0.004 to 20.48, while the genotype x environment interaction variance ranged from 0.001 to 3.40. The highest values were found for beta-carotene and starch, while the lowest values were found for dry matter. The genotype x environment interactions generally had values that were lower than the genotypic variation and the error variance. All of the traits' genotypic variance values, however, were smaller than their error variance values.

Table 4: Agronomic and nutritional trait variance components for the sweet potato accessions in Jos

Traits	σ^2g	σ^2p	σ^2e	σ^2gxe
Dry matter	12.812	25.37	12.560	0.000
Beta carotene	1.320	12.69	11.370	3.250
Total sugar	6.134	41.39	35.260	0.610
Starch	1481.7	1856.20	374.500	1.600
Protein	2.115	4.94	2.828	0.110
Iron	0.004	0.09	0.009	0.011
Zinc	0.157	0.46	0.300	0.010
Unmarketable root weight	0.008	0.66	0.669	0.560
Marketable root weight	4.680	35.21	39.890	0.350

Table 5: Agronomic and nutritional trait variance components for the sweet potato accessions in Owerri.

Traits	σ^2g	σ^2p	σ^2e	σ^2gxe
Dry matter	0.002	0.006	0.004	0.001
Beta carotene	21.250	28.470	7.220	3.400
Total sugar	8.680	29.160	20.480	0.750
Starch	7.800	22.680	14.580	1.570
Protein	0.320	1.190	0.870	0.150
Iron	1.248	1.320	0.072	0.030
Zinc	0.005	0.035	0.030	0.020
Unmarketable root weight	1.660	2.800	1.140	0.300
Marketable root weight	1.350	2.250	0.900	0.400

σ^2g= Genotypic variance; σ^2p= Phenotypic variance; σ^2e= Environmental variance;
σ^2gxe= Genotype x Environmental variance.

When assessing genotype adaptability, choosing parents, and developing genotypes with higher end-product quality, the G x E interaction is crucial. Selection for such traits may be made more difficult by the notable G x E interaction that was found. The presence of G x E suggests that a variety of settings should be used for

selection. This is due to the fact that selection only advances when it becomes possible to distinguish between the effects of genotype and environment. Because of its orange-flesh color, beta-carotene may be an exception, and it may be regulated by a small number of genes (Miller et al., 1958).

The genotypic coefficient of variation (GCV), the phenotypic coefficient of variation (PCV), the heritability and genetic advance for the traits of the sweetpotato accessions are represented in table 6 and 7 for Jos andOwerri locations respectively. In both locations, the phenotypic coefficient of variation (PCV) values were generally larger than the genotypic coefficient of variation (GCV) values. In Jos, the PCV values varied from 12.60% for dry matter content to 48.37% for starch content, while in Owerri, they were 0.29% for dry matter to 72.82% for marketable root weight. A similar trend was observed for the GCV which ranged from 1.29% for root weight to 43.22% for starch in Jos, and 0.16% for dry matter to 56.40% for marketable root weight in Owerri. The broad sense heritability ranged from 1.19 for unmarketable root weight to 79.80 for starch in Jos, and 14.29 for zinc to 60.00 for marketable root weight in Owerri. For the genetic advance, the highest value obtained was 7082.43 for starch content while the lowest value obtained was 1.99 for unmarketable root weight in Jos, and in Owerri, the highest value obtained was in beta-carotene, 820.41, while the lowest value was recorded in dry matter 5.32, Table 6 and 7 respectively.

Table 6: Genotypic and phenotypic coefficient of variation, heritability and genetic advance for the traits of sweetpotato accessions from Jos

Traits	**Genotypic Coefficient of variation**	**Phenotypic Coefficient of variation**	**Heritability (H^2b)**	**Genetic Advance (GA)**
Dry matter	8.96	12.60	50.49	523.88
Beta-carotene	4.97	15.43	10.40	76.32
Total sugars	5.27	13.69	14.82	196.41
Starch	43.22	48.37	79.80	7082.43
Protein	18.00	27.50	42.79	195.92
Iron	4.03	18.53	4.72	2.92
Zinc	17.62	29.88	34.78	48.59
Unmarketable root	1.29	11.84	1.19	1.99

weight				
Marketable root weight	29.77	81.64	13.29	162.45

Table 7: Genotypic and phenotypic coefficient of variation, heritability and genetic advance for the traits of sweetpotato accessions from Owerri

Characters	**Genotypic Coefficient of variation**	**Phenotypic Coefficient of variation**	**Heritability (H^2b)**	**Genetic Advance (GA)**
Dry matter	0.16	0.29	33.33	5.32
Beta-carotene	19.61	22.70	74.64	820.41
Total sugars	10.72	19.64	29.77	331.13
Starch	11.74	20.02	34.39	337.23
Protein	15.76	30.39	26.89	60.43
Iron	16.05	16.51	94.55	223.99
Zinc	8.32	22.01	14.29	5.59
Unmarketable root weight	49.94	64.86	59.29	203.95
Marketable root weight	56.40	72.82	60.00	185.40

Environmental factors could explain the variations in the variance of genotype and phenotype. It is essential, therefore, that germplasm testing procedures are designed to maximize the genetic effects relative to the environmental and interaction effects. The error variances were larger than the G x E interaction variances in magnitude. This indicates that testing of the accessions took place in suitable sampling settings. To maximize the genetic impact of variables with smaller genetic variation than the error variance, however, a high number of repetitions might be needed. Environmental influences may be the cause of the observed trend between PVC and GVC, which is in accordance with the findings of the report by Denton and Nwangburuka (2011).

High PCV and GCV values which were detected for marketable root weight, starch content, beta-carotene, total sugars, zinc and protein suggest that these traits accounted for the highest variation observed in the sweetpotato accessions. This means that there may be useful genetic variation in the gene pool to provide for

substantial amount of improvement through breeding for these traits. GCV provides a measure to compare the genetic variability present in various quantitative traits. However, it is not possible to estimate heritable variation with the help of the GCV alone, (Prasad *et al.*, 1981). The GCV together with heritability estimates would give the best picture of the amount of advance to be expected from selection.

Heritability demonstrates the extent to which genotype selection based on phenotypic performance can work. With the exception of iron and unmarketable root weight, which exhibited low heredity for the accessions from the Jos location, broad-sense heritability estimates in this study ranged from medium to high. Additive gene effects affect traits with medium to high heritability (Denton and Nwangburuka, 2011). This implies that phenotypic selection will be successful. Since genetic advance is commonly predicted as the product of the heritability and the selection differential, the usefulness of heritability estimates is enhanced when they are used in conjunction with the selection differential (the degree to which the mean of the selected lines exceeds the mean of the entire population).

Combining genetic progress, broad-sense heritability, and GCV increases the accuracy of predictions about an individual's response to selection. Therefore, substantial genetic gain is not always associated with high GCV and high heritability. Genetic gain will be minimal if GCV is high and non-additive gene effects—such as dominance and epistasis—are the primary cause of heritability. However, if GCV is high and additive gene effects are the major cause of heritability, a substantial genetic advance might be anticipated.

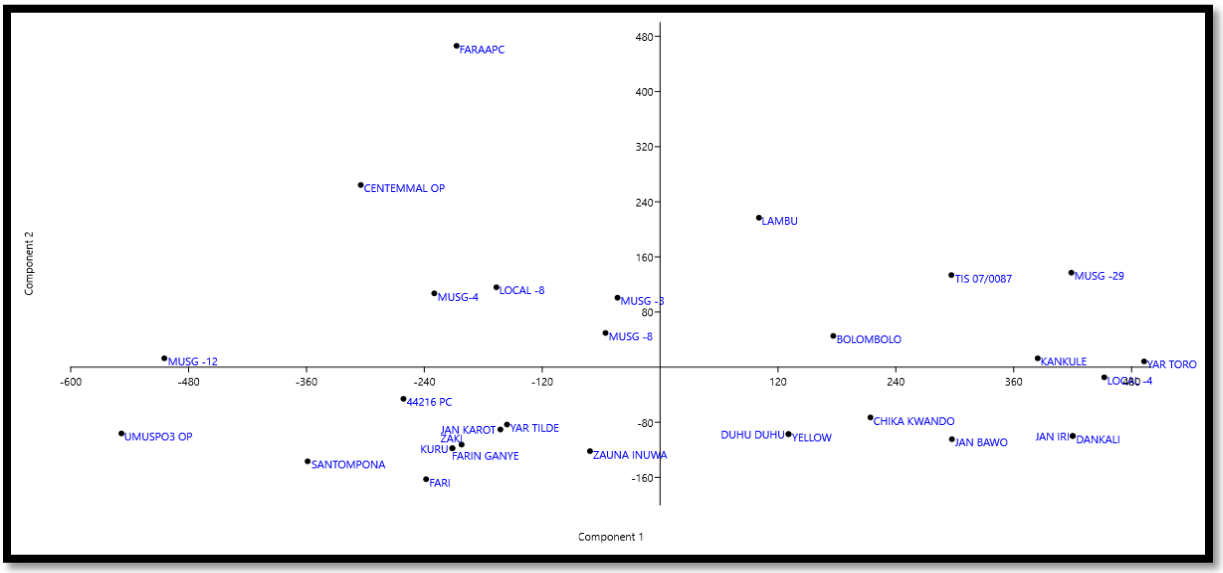

Figure 1: Principal Coordinate analysis of the thirty sweetpotato accessions from Jos and Owerri

The distribution of Principal component (PC) 1 andPrincipal component (PC) 2 among the selected accessions shown in figure revealed that four groups were detected for the accessions. Beta-carotene content and total sugars were bunched together in quadrant 1, only dry matter content and beta-carotene content were found in quadrant 2 and 4 respectively, while, no character was found in the third quadrant. The accessions were distributed in the four quadrants. Most of the accessions that were found in the different quadrants are related to one another, for example, FARAAPC and CENTEMAAL OP that were found in quadrant 1 are from CIP, Ghana and CIP, Mozambique. JANKAROT, FARIN GANYE and ZAUNA INUWA that were found in quadrant 2 are from Jos, DANKALI, CHIKA KWANDO and YELLOW that was found in quadrant 3 are from Bauchi state, while in the fourth quadrant , KANKULE and LAMBU are from Jos, BOLOMBOLO and YAR TORO are from Bauchi state, Nigeria.

Sweet potatoes with a high dry matter content can become non-sweet due to the significant negative correlation between sugars and starch and the substantial positive association between total sugar and beta-carotene content. A similar observation was made by Grunebergetal., (2009), who also reported that development of non-sweet sweetpotato should not be toodifficult. However, developing non-sweet high dry matter and high beta-carotene sweetpotatocould be challenging due to the strong negative association between dry matter and beta-carotene and the positive association existing between beta-carotene and the sugars. Breeding for such cultivars may require many cycles of selection and hybridization to break genetic linkages associated with the traits. However, beta-carotene seems to be controlled by a limited number of genes and should be easy to manipulate. The results also showed that dry matter, sugar content and most of the physicochemical traits (except protein) may indirectly be selected using beta-carotene content (the orange-fleshed colour).

Conclusion

This study investigated the mineral content of various sweet potato varieties in Nigeria. Mineral content varies among the sweet potato accessions examined. In order to improve nutritional and health status and combat malnutrition, these orange-coloured flesh accessions are therefore promising cultivars that might be promoted through food intended for a particular target group, such as children and pregnant women.Certain genotypes of sweet potatoes exhibit either complete absence or minimal presence of α-amylase and β-amylase in their storage roots. When cooking, frying, or processing, these genotypes do not become particularly sweet. Normal starch-to-maltose hydrolysis cannot occur in the absence of an

adequate quantity of the enzymes.A considerable amount of improvement in beta-carotene, dry matter, and sugar contents could be achieved by selecting superior genotypes for the management of sweetpotatogermplasm and for crop improvement initiatives in Nigeria. This is attainable because the accessions under study contain sufficient useful genetic variation.

Declaration of competing interest : The authors declare they have no conflicts of interest associated with this work.

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