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Evaluation of Micronutrients, Bioavailability Micronutrients and Antinutrients in African Yam Bean (*Sphenostylis stenocarpa*) Seeds

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Abstract

This study investigated the micronutrients, bioavailability of micronutrients, correlations among micronutrients and antinutrients in the seeds of African yam bean (AYB), accessions. The biochemical analysis of the seeds of Tropical *Sphenostylis stenocarpa* (TSs) AYB accessions; TSs 9, TSs 60, TSs 93, TSs 111, and TSs 116 were carried out. The results revealed significant ($p<0.05$) variations in the micronutrient contents of the AYB seeds. Potassium (K) was in the range of 241.0-271.0 mg/100 g, Manganese (Mn) 2.83-6.11, Phosphorus (P) 323.65-385.20 mg/100 g, Magnesium (Mg) 72.20-101.36 mg/100 g, Iron (Fe) 9.22-21.35 mg/100 g, Calcium (Ca) 286.50-414.0 mg/100 g, Zinc (Zn) 12.70-23.61 mg/100 g, Copper (Cu) 6.34-8.64 mg/100 g, Chromium (Cr) 0.041-0.081 and Sodium (Na) 35.85-51.95 mg/100 g. The molar ratio of phytate: Zinc was from 1.24-2.09, Ca/P 0.84-1.21 and Na/K ranged from 0.15-0.19. Potassium was positively and significantly ($p<0.001$) correlated with Cr (r = 0.91***), Mg (r = 0.94***) and Mn (0.81***). Manganese was positively and significantly associated with Fe (r = 0.90***) and Ca (r = 0.94***), Magnesium showed positively significant relationship with Cr (r = 0.75*), Fe showed significantly positive relationship with Cr (r = 0.80**). Calcium was positively and significantly associated with Cr (r = 0.92***). The TSs 111 had the highest concentrations of Mn, P and Cu. TSs 9 ranked the highest for Mg, K, Mg, Zn, and Na. TSs 93 was the most prominent accession for Fe and Ca concentrations. AYB seeds are micronutrient-dense and excellent sources of bioavailable minerals. The consumption of diets made from AYB seeds is recommended for enhanced nutrition and health of households.

Keywords: African Yam Bean, Micronutrients, Bioavailability, Minerals, Antinutrients, Seeds.

Introduction

One of the major challenges that is currently facing the agriculturists and food experts is how to ensure that a population of about 10 billion people by 2050 are food and nutrition secured, considering the problems encountered in producing crops under changing climates coupled with a number of biotic and abiotic stresses (Food and Agricultural Organization, (FAO) 2019). This FAO report further indicated that approximately 690 million were undernourished in 2019 and the number rose sharply to 720-811 million in 2020 during the COVID-19 pandemic. Approximately two billion people are deficient in the essential micronutrients needed to develop both mentally and physically (Hunter et al., 2022). This implies that if nothing significant is done and these challenges remain the same, attaining zero hunger will be almost unachievable by 2030 (Singh et al., 2022). There is also the concern about the increasing cost of healthcare as unhealthy diets and lifestyles are causing a rise in the number of people suffering from diabetes, obesity and cardiovascular diseases. Of all the dietary recommendations made since the past few decades to cause a significant reduction in these chronic diseases, the most effective but most uncommon are those that are plant-based (Tuso, et al. 2013).

Plant-based foods have received more research attention and are advocated to be more consumed in recent times due to better understanding and awareness of their nutrient quality, nutrient density, and nutraceutical advantages especially when they are well produced and well processed. Edible legumes are regarded as "super-food" crops because of their huge potentials for human health, human and livestock nutrition and income generation. Some among the numerous health benefits of consuming legumes as outlined by Ndidi et al. (2014a) include: hypoglycemic, hypocholesterolemic, anticarcinogenic, and antiatherogenic effects. Their nutraceutical advantages are the reasons why they are consumed in the prevention or management of chronic diseases that include cardiovascular diseases and type-2-diabetes. Legumes also play invaluable roles in sustainable and eco-friendly agriculture. They are being exploited for their potentials in soil fertility enhancement and management through the decomposition of their huge biomass (of shoots and roots) and the biologically fixed nitrogen through their root nodules.

Several thousands of the varieties of major legumes such as cowpea, soybean, common bean, etc. have been exploited for decades for food and nutrition. Decades ago, some indigenous grain legumes were major parts of agri-food and farming systems but due to negligence and the fact that many of these indigenous grain legumes have some constraints to their production and or processing, they have become scarce in traditional cropping systems and cuisines. They are now referred to as neglected, minor, under-utilized, lost, forgotten and under-exploited grain legumes. Bioversity International/IFAD (2021) noted that neglected and underutilized crop species, have been relegated to the margins of scientific research. Enhancing their yields and overcoming challenges in their cultivation, processing, and marketing have received less attention. This trend needs to be reversed because investing in these crops offers a strategic opportunity to unlock several livelihood benefits, especially for disadvantaged people in both rural and urban environments. (Bioversity International/International Fund for Agricultural Development, 2021).

African yam bean (AYB) is one of these multipurpose but neglected and lesser-known grain legumes of tropical origin. It produces appreciable yields of edible tubers and edible seeds. The seeds of AYB are rich in protein, carbohydrates, minerals, and have appreciable levels of fibre but low in fat (Baiyeri et al., 2018a&b; Shitta et al., 2022). African yam bean tubers are rich in protein, minerals while the levels of the antinutrients in the tubers are within the range reported for most tropical root and tuber crops (Baiyeri and Samuel-Baiyeri 2023). African yam bean seeds are used in the preparation of delicious cuisines in African communities, where the crop is consumed. It could be roasted, boiled, steamed, fried alone or in combination with other ingredients. The seeds of AYB are also used in seasoning of soups (Ngwu et al., 2014; Sam, 2019). Its seeds have been reported to be excellent for the fortification of food products like cereal flour and breakfast meals (Idowu, 2014; Okoye and Obi, 2017). AYB seeds are recently being discovered as promising ingredients in enriching animal feeds (Ojuederie and Balogun 2017).

In spite of the huge opportunities in this legume for food, nutrition and income generation for the farmers that grow them, the production and utilization of AYB have been reported to be constrained by a number of factors (Baiyeri et al., 2016). These include long cooking time, long gestation period, high staking costs, lack of improved varieties, poor conservation of AYB genetic resources, inadequate funding for AYB research and the poor awareness of its nutraceutical and nutritional potentials (Baiyeri et al., 2016). Some of these challenges have resulted in low yields and reduced farmers' and consumers' interests in including it in their cropping systems and every day meal plans. African yam bean that was once considered an important food crop for households in southern Nigeria is no more widely consumed as it used to be and the crop is gradually going into extinction (Baiyeri et al., 2018; Baiyeri and Samuel-Baiyeri, 2023).

The earlier nutritional studies looked at proximate, minerals and or anti-nutrients in AYB seeds (Amen 2007; Ndidi et al., 2014; Ajibola and Olapade 2016; Ojuederie and Balogun, 2017 Baiyeri et al., 2018a, Adegboyega et al., 2020). Results of these studies revealed how nutrient-dense the AYB seeds were and the levels of antinutrients in them. The information is not sufficient in understanding levels of micronutrients that could be absorbed by humans that consume AYB seeds. Documented information on the bioavailability of minerals in AYB seeds is scarce in literature. Understanding the biological activity of individual nutrients and how they interact with other nutrients and food components from whole foods is crucial for fully maximizing nutrient-density in food crops (Melse-Bonstra, 2019). Investigating micronutrients and their bioavailability in African yam bean seeds could provide useful information that could further create awareness of its potentials for food and nutrition and promote its utilization.

Objectives of the study

The general objective of the study was to investigate micronutrient concentrations in seed of the African yam bean accessions (cultivars) and their bioavailability. Specifically, the study determined:

1. variations in the micronutrient composition of the AYB seeds.
2. bioavailability of some of the micronutrients in seeds.
3. strength of relationships that exist among the micronutrients in the AYB seed.

4. prominent AYB accessions for micronutrients in the seeds.

Materials and methods

***Materials*:** The agronomic evaluation of the accessions was conducted at the Research Farm in the Faculty of Agriculture, Ikole Campus of the Federal University, Oye-Ekiti, Nigeria in 2021. The seeds of AYB analysed in this study were collected from the agronomic evaluation of AYB accessions. The seeds of the Tropical *Sphenostylis stenocarpa* (TSs) AYB accessions; TSs 9, TSs 60 and TSs 93, TSs 111, and TSs 116 used for this research were harvested from the AYB agronomic evaluation field. The initial seeds of the AYB accessions used for the agronomic study were sourced from the Genetic Resources Centre of the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria.

***Preparation of materials*:** Extraneous components and bad seeds in the seeds of the African yam bean accessions were manually removed. An electric mill was used to grind the clean seeds into fine flour. The ground samples of the AYB seeds were used for the various biochemical analyses using standard laboratory procedures.

Determination of the micronutrient composition of the AYB seeds: Micronutrients in the AYB seeds were analysed using AOAC (2005) method 968.08. Utilising the Buck Scientific Atomic Absorption Spectrophotometer (Model: 210VGP) and particular cathode lamps for each of the minerals: potassium (K), manganese (Mn), phosphorus (P), magnesium (Mg), iron (Fe), calcium (Ca), zinc (Zn), copper (Cu), chromium (Cr), and sodium, the mineral concentrations in samples of digested AYB seeds were determined. Using of a flame photometer, sodium and potassium were measured (Model: FP10). Based on calibration curves of mineral standard solutions, the metals were quantified. Each batch of analysis contained blanks, and verified reference standards were utilized to evaluate the analytical method's precision.

Anti-nutrient determination in the seeds of African yam bean accessions: The Amorim (2008) method was used to determine tannin in the AYB seeds. Phytate content of the AYB seeds were determined according to the method of Latta and Eskin (1980).

Calculation of molar ratios: The phytate: Zn, phytate: Fe, Ca: phytate, Ca x phytate: Zn molar ratios were calculated as previously described by Norhaizan and Faizadatul (2009). Molar ratios between the minerals and antinutrients (bioavailability indices) were obtained by dividing the mole of the phytate with the moles of the minerals.

Statistical analysis: Data collected were subjected to analysis of variance (ANOVA) using the *R* statistical analysis software. The ANOVA was done using the library *Agricolae*. The Pearson's correlation was done to understand the strength of relationships that existed among the micronutrients and the antinutrients studied in the AYB seeds analysis using the library *Hmisc*. The standard deviation from the mean was analysed using the library: *Psych*.

Results

Micronutrients composition of the AYB seeds

Table 1: Micronutrient Composition (mg/100 g) of the Seeds of African Yam Bean Accessions

Accession	K	Mn	P	Mg	Fe	Ca	Zn	Cu	Cr	Na
TSs 9	271.0	5.11	377.85	101.35	15.00	386.9	23.61	6.34	0.081	51.95
TSs 60	256.0	4.44	323.65	86.11	13.47	336.0	19.31	7.82	0.063	40.25
TSs 93	256.0	5.61	341.55	78.63	21.35	414.0	21.09	8.17	0.076	38.55
TSs 111	267.0	6.11	385.20	92.35	18.32	391.0	15.64	8.64	0.084	45.39
TSs 116	241.0	2.83	341.70	72.20	9.22	286.5	12.70	6.55	0.041	35.85
F-LSD$_{(0.05)}$	5.39	0.49	3.82	1.78	0.77	4.84	0.37	0.21	0.009	0.91
Mean	258.2	4.82	353.99	86.13	15.47	362.88	18.47	7.50	0.069	42.40
CV	0.81	3.95	0.42	0.80	1.94	0.52	0.79	1.07	4.88	0.83

K=Potassium; Mn=Manganese; P=Phosphorus; Mg=Magnesium; Fe=Iron; Ca=Calcium; Zn=Zinc; Cu=Copper; Cr=Chromium; Na=Sodium; TSs=Tropical Sphenostylis stenocarpa; F-LSD=Fisher's least significant difference; CV=Coefficient of variation.

Table 1 shows the results of the micronutrient composition of the AYB seeds. All the minerals analysed in the seeds of the AYB accessions were significantly ($p<0.05$) influenced by accession. TSs 9 (271.0 mg/100 g) had the highest potassium concentration, followed closely by TSs 111 (267.0 mg/100 g) while TSs 116 (241.0 mg/100 g) had the least K concentration. The manganese contents of the AYB seeds ranged from TSs 116 (2.83 mg/100 g) to TSs 111 (6.11 mg/100 g). TSs 111 (385.20 mg/100 g) also recorded the highest phosphorus content while TSs 60 (323.65 mg/100 g) had the least phosphorous content. Magnesium ranged from TSs 9 (101.35 mg/100 g) to TSs 116 (72.20 mg/100 g). TSs 93 (21.35 mg/100 g) had the highest concentration of iron followed by TSs 111 (18.32 mg/100 g) while TSs 116 (9.22 mg/100 g) had the least iron concentration ratio. Calcium ranged from TSs 93 (414.0 mg/100 g) to TSs 116 (286.5 mg/100 g). TSs 9 (23.61 mg/100 g) was the most prominent accession for zinc concentration and followed closely by TSs 93 (21.09 mg/100 g). TSs 116 (12.70 mg/100 g) had the least zinc content. TSs 111 (8.64 mg/100 g) had the highest copper concentration while TSs 9 (6.34 mg/100 g) had the least content. TSs 111 (0.084 mg/100 g) was the most prominent accession for chromium content, next to it was TSs 9 (0.081 mg/100 g) while TSs 116 (0.041 mg/100 g) had the least chromium contents. Sodium ranged from TSs 9 (51.95 mg/100 g) to TSs 116 (35.85 mg/100 g).

Antinutrient composition of the AYB seeds

Table 2: The Anti-nutrient Composition (mg/100 g) of the Seeds of African Yam Bean Accessions

Accession	Tannin	Phytate
TSs 9	87.15	294.45
TSs 60	68.55	256.45
TSs 93	77.71	267.55
TSs 111	76.15	308.25
TSs 116	56.25	264.45
F-LSD$_{(0.05)}$	2.16	9.41
Mean	73.16	287.23
CV	1.15	1.32

TSs=Tropical *Sphenostylis stenocarpa*; F-LSD=Fisher's least significant difference; CV=Coefficient of variation

Table 2 shows the results of the antinutrients of the seeds of the AYB accessions. The antinutrients were significantly ($p<0.05$) affected by accession. Seeds of TSs 9 (87.15 mg/100

g) had the highest concentration of tannin and were statistical higher than the rest of the seeds of the AYB accessions in their tannin concentrations. Next to it were TSs 93 (77.71 mg/100 g) and TSs 111 (76.15 mg/100 g). TSs 116 (56.25 mg/100 g) had the least tannin content. TSs 111 (302.25 mg/100 g) had the highest concentration of phytate followed closely by TSs 9 (294.45 mg/100 g) while TSs 60 (256.45 mg/100 g) had the least phytate content.

Bioavailability of micronutrients in the AYB seeds

Table 3: Bioavailability of the Micronutrients in the Seeds of African Yam Bean Accessions

Accession	Phytate:Zinc (±SD)	Ca:Phy:Zn (±SD)	Phy:Fe (±SD)	Ca/P (±SD)	Na/K (±SD)
TSs 9	1.24±0.02	11.92±0.30	1.66±0.03	1.02±0.01	0.19±0.00
TSs 60	1.32±0.00	11.03±0.08	1.61±0.07	1.04±0.01	0.16±0.00
TSs 93	1.26±0.02	12.98±0.27	1.06±0.03	1.21±0.01	0.15±0.00
TSs 111	1.95±0.00	19.05±0.07	1.42±0.03	1.02±0.01	0.17±0.00
TSs 116	2.09±0.07	14.75±0.37	2.43±0.06	0.84±0.01	0.15±0.00
F-LSD$_{(0.05)}$	0.086	0.643	0.126	0.025	0.004
Mean	1.56	13.95	1.64	1.03	0.16
CV	2.14	1.79	3.00	1.00	1.00

Phy=phytate; Ca=calcium; Zn=zinc; Fe=iron; Na=sodium; K=potassium; F-LSD=Fisher's least significant difference; CV=Coefficient of variation; F-LSD=Fisher's least significant difference; CV=Coefficient of variation; Tropical Sphenostylis Stenocarpa

The results of the bioavailability of micronutrients are shown in Table 3. The phytate: Zn molar ratio was from TSs 9 (1.24) to TSs 116 (2.09). TSs 60 (11.03) had the least Ca × phy:Zn ratio in the seeds of the AYB accessions while TSs 111(19.05) has the highest content. TSs 116 (2.43) also recorded the highest value for phy: Fe while TSs 93 (1.06) had the least phytate: Fe content. Ca/P ratio ranged from TSs 116 (0.84) to TSs 93 (1.21). TSs 9 (0.19) was the highest for Na/K ratio in the AYB seeds, while TSs 116 and TSs 93 both recorded the least value for Na/K ratio (0.15).

Pearson's correlation coefficients among the micronutrients and the antinutrients in the AYB seeds

Table 4: Pearson's Correlation Coefficients among the Micronutrients and Antinutrients in the Seeds of the African Yam Bean Accessions

	K	Mn	Mg	P	Fe	Ca	Zn	Cu	Cr	Na	Tan	Phyt
K	1.00											
Mn	0.81**	1.00										
Mg	0.94***	0.59	1.00									
P	0.71	0.54	0.68*	1.00								
Fe	0.54	0.90***	0.25	0.29	1.00							
Ca	0.75*	0.94***	0.52	0.47	0.94***	1.00						
Zn	0.65*	0.50	0.61	0.10	0.49	0.67*	1.00					
Cu	0.20	0.66*	-0.05	0.02	0.69*	0.49	-0.10	1.00				

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Cr	0.91***	0.96***	0.75*	0.64*	0.80**	0.92***	0.63	0.45	1.00			
Na	0.91***	0.53	0.98***	0.77**	0.23	0.51	0.60	0.18	0.72*	1.00		
Tan	0.91***	0.80**	0.82**	0.59	0.67*	0.87**	0.84**	0.10	0.91***	0.83**	1.00	
Phyt	0.73*	0.62	0.69*	0.97***	0.35	0.51	0.08	0.16	0.70*	0.74*	0.58	1.00

**** Correlation is significant at the 0.001 level; ** Correlation is significant at the 0.01 level; * Correlation is significant at the 0.05 level Na = sodium K = potassium Fe = iron Ca = calcium Zn = zinc Cu = copper Mg = magnesium Mn = manganese P = phosphorus Tan= Tannin Phyt=phytate*

The result of the Pearson's correlation among the micronutrients is shown in Table 4. Potassium was positively and significantly ($p<0.001$) correlated with chromium (r = 0.91***), sodium (0.91***), and tannin (0.91***) and was significantly ($p<0.05$) and positively linked with phytate (0.73*). Manganese was also positively and significantly ($p<0.01$) linked with iron (r = 0.90***), calcium (r = 0.94***) and chromium (r = 0.96***). Manganese had a significantly positive relationship with copper (r = 0.66*) and tannin (0.80**). Magnesium also showed a positively significant relationship with chromium (r = 0.75*), sodium (r = 0.98***), tannin (r = 0.82**) and phytate (r = 0.69*). Phosphorous was positively and significantly linked with chromium (r = 0.64*), sodium (r = 0.77**) and phytate (r = 0.97***). Iron had a significantly positive relationship with copper (r = 0.69*), chromium (r = 0.80**) and tannin (r = 0.67*). Calcium was positively associated with chromium (r = 0.92***), zinc (r = 0.67*) and tannin (r = 0.87**). Zinc was positively and significantly related with tannin (r = 0.84**). Chromium was positively and significantly associated with sodium (r = 0.72*) and tannin (r = 0.91***). Sodium was positively and significantly linked with tannin (r = 0.83**) and phytate (r = 0.74*).

Discussion

The micronutrients in the AYB accessions studied have shown that AYB seeds are micronutrient-dense and are especially rich in potassium, iron, zinc, magnesium, calcium, manganese, and phosphorous. The levels of these micronutrients in the AYB seeds were higher than what has been reported for these micronutrients in twenty-five improved cowpea varieties (Boukar et al., 2010). The levels of these micronutrients in the seeds of the AYB in this study exceeded what had been reported for them in AYB seeds in earlier studies (Ndidi et al, 2014b; Ojuederie and Balogun, 2017, Baiyeri et al; 2018a). The observed higher micronutrient contents in AYB seeds in the present study could have been due to genotypic differences, crop management and also the influence of the environment on the concentration of these minerals in the AYB seeds. These micronutrient results have demonstrated that AYB seeds could enhance food and nutrition security and obviate the need for food supplements among both the elites and resource-limited people that consume dietary preparations made from AYB seeds. Factors like climatic and edaphic conditions, genotypic characteristics, and crop management practices have been reported to influence the nutritional composition of crops (Odhav et al., 2017).

It is worth nothing that TSs 111 had the highest concentrations of manganese, phosphorous and copper and ranked second highest in potassium, magnesium, calcium, and iron. TSs 111 has been early reported for nutrient-density in AYB seeds (Baiyeri et al., 2018). TSs 9 ranked the highest for potassium, magnesium, zinc, sodium and ranked second highest for chromium. TSs 93 was the most prominent accession for iron and calcium concentration. These excellent accessions (TSs 111, TSs 93 and TSs 9) with respect to micronutrients are especially recommended for human dietary preparations and consumption. The potentials of these nutrient-dense AYB accessions for being parents could be exploited in developing nutritional improved AYB varieties by AYB breeding programmes for enhanced micronutrient contents.

The antinutrients in the AYB seeds were lower in concentration than what has been reported for tannin and phytate in AYB seeds by Ndidi et al. (2014b). It is worth noting that the levels of tannin and phytate in the AYB seeds in this study were lower than the (110-820 mg/100 g) tannins and 360-510 mg/100 g) phytate reported in cowpea (Kalpanadevi and Mohan, 2013;), and the tannins (170-1770 mg/100 g) and phytate (310-2080 mg/100 g) concentrations reported in common beans (Shang et al., 2016; Shi et al., 2018). This suggests that with good processing, levels of antinutrients in AYB seeds should not be a major challenge to its consumption for humans and its inclusion in livestock feeds production. Sprouting, roasting, sun drying, soaking, boiling, dehulling, steaming and fermentation in legumes activate the enzymes phytase that enhances the breakdown of phytate (Lee et al., 2016).

The phytate/zinc molar ratios of the AYB seeds were much lower than the 15.0 critical value. Indicating that zinc bioavailability in AYB seeds should therefore be optimum. Ca x phy/Zn was reported as a better indicator of Zn bioavailability (Ola and Oboh 2001). They opined that Ca x phy/Zn molar above 0.5 mol/kg would negatively affect the bioavailability of zinc. The Ca x phy/Zn ratios obtained in the present study were higher than 0.5 which suggests bioavailability of Zn may be affected in the raw AYB seeds. Since processing reduces the phytate concentration and enhances nutrient bioavailability, there is need for further studies that will investigate bioavailability of zinc in processed AYB seeds. The molar ratio for phytate:Fe was slightly higher than 1:00; which is the critical value for iron bioavailability. This suggests iron absorption may be affected in the unprocessed AYB seeds. Processed AYB seeds and other dietary preparations from it may most likely have enhanced iron bioavailability.

The Na/K ratio is very important because of its role in high blood pressure control Yusuf et al. (2007). They opined that Na/K ratio that is less than 1 is excellent for high blood pressure control (Yusuf et al., 2007). The Na/K ratios in the present study were all below 0.2 indicating that the seeds of AYB will be excellent food for people with high blood pressure and hypertension. Foods that were rich in phosphorus promoted the excretion of calcium in urine and therefore led to reduction in bone calcium levels. Foods were considered excellent if their Ca/P were above one, that is (>1) (Akinyeye et al., 2010). All the AYB accessions evaluated in the present study had Ca/P ratios that were above one (>1); indicating they are excellent sources of bone calcium.

The results of the correlation analysis showed some interesting association among the minerals. Most of the micronutrients; Mn, Fe, Ca, Mg, Cr, Cu, P, Zn had strong and positive correlations among themselves. Highly significant and positive correlations among some of these minerals have been reported by Boukar et al. (2010). The high positive relationships between any pair of these micronutrients suggest the possibility to simultaneously increase them through crop management and plant breeding. The positive correlation among some of the micronutrients phytate and tannin implies research efforts are needed by AYB breeding programmes to select and breed for improved AYB varieties that combine high micronutrient contents with low antinutrient concentration. Genetic engineering, marker-assisted selections and other novel breeding approaches may be useful in improving nutritional traits in AYB. These nutritional traits can be combined with high-yield and other farmer-preferred traits in AYB. Although a lot has been said about the negative roles of antinutrients, recently, research has shown that a number of bioactive non-nutrients compounds such as phytate have huge health benefits that include anticarcinogenic effects, antioxidant properties and anti-neoplastic effects. Phytate offers protection against diabetes mellitus, renal stones and coronary heart disease (Geraldo et al., 2022). The complete removal of antinutrients such as phytates from AYB seeds may therefore not be the best since they have potentials for enhancing human health at low concentrations, especially after food processing. Multi-disciplinary interventions that involve the nutritionists, food scientists, plant breeders, agronomists, public health experts, medical doctors, and other relevant professionals are required in order to determine the levels of bioactive compounds or antinutrients that should remain or be in edible portions of crops before and after breeding and processing for optimal nutritional and health benefits in the edible portions of AYB.

Conclusion

The study has revealed significant ($p<0.05$) variation in the micronutrient and antinutrient compositions of the AYB seeds. The seeds were micronutrient-dense and have the potentials for enhancing health, food and nutrition security among those that consume the processed seeds. The bioavailability ratios revealed the potentials in AYB seeds in enhancing blood glucose regulation and enhanced bone health. The Pearson's correlation results have shown interestingly strong, significant and positive relationships among the micronutrients which suggest the possibility of developing micronutrient-dense improved African yam bean varieties through breeding and selection.

Recommendations

1. Healthy and quality food products and dietary preparations should be developed from AYB by nutritionists and food experts in order to promote the utilization of AYB.
2. Consumption of AYB dietary preparations should be encouraged for the prevention chronic diseases and calcium deficiency-related problems by dieticians, nutritionists and medical professionals and extension agents through, sensitization, television and extension programmes.
3. Variation, strong and positive relationships among micronutrients should be maximized and exploited by the agronomists and plant breeders in developing

micronutrient-dense improved AYB varieties.

4. Levels of antinutrients that should be bred for or that should remain in prepared foods from AYB seed require the coming together of experts from various fields related to nutrition, medical sciences, crop breeding and crop production.

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