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RESEARCH ARTICLE

Assessment of levels of selected macro and microelements present in biofortified provitamin-A cassava varieties

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ABSTRACT

Biofortification of cassava varieties has become a common means of improving essential elements to boost food quality. This study investigated the amount of macro and microelements present in some vitamin A-fortified cassava varieties developed by cassava breeders at the International Institute of Tropical Agriculture (IITA) Ibadan. The roots of three pro-vitamin fortified cassava varieties IBA154800, IBA164785 and IBA164791 growing at the field of the IITA cassava breeding unit were harvested and were profiled for the macro and microelement using a Tecator digester and AAS. The Mg, Zn, Cu, K, Fe and Na contents were read in triplicates. Data collected were analysed using ANOVA and correlation (SAS 9.4 version) and the differences in the varietal means were separated using the least significant differences at a 5% level of significance. The macro elements Mg, K, and Na differed significantly across the varieties and ranged from 0.114 (IBA164791) to 0.143 (IBA164785), 1.463 (IBA164791) to 2.147 (IBA164785), and 29.138 (IBA164785) to 37.433 (IBA154800), respectively. The microelements Fe, Cu and Zn also differed significantly amongst the varieties and ranged from 19.021 (IBA164791) to 29.874 (IBA164785), 1.463 (IBA164791) to 2.147 (IBA164785), and 29.138 (IBA164791) to 37.433 (IBA154800), respectively. The relationship between Zn and Fe (-0.88), and between Na and Cu (-0.85) were significantly strong and negative. The relationship between Fe and Mg (0.89), Mg and Cu (0.85), and Mg and K (0.71) were significantly strong and positive. The biofortified variety IBA164785 had a higher improvement rate in the macro and microelements investigated.

Keywords: *Manihot spp.,* biofortification, micronutrients and provitamin-A.

INTRODUCTION

Plants consist of a variety of compounds, which are substances combining two or more elements. Carbohydrates serve as the primary energy source absorbed by the human body, particularly in regions like Africa where diets are rich in starch (Ikeh et al., 2023). Carbohydrates, characterized by polyhydroxyl alcohol with potentially active carbonyl groups, can exist as aldehydes or ketones. They encompass different classes, including monosaccharides, disaccharides, and polysaccharides. Polysaccharides like cellulose and starch consist of chains of glucose molecules (Anoma & Thamilini, 2016).

Cassava (*Manihot esculenta*), originating from Latin America, is a tropical perennial crop pivotal to tropical African agriculture. Its significance as a carbohydrate source is expected to grow, especially in regions where economic constraints hinder dietary changes (Akparobi et al., 2006). Cassava production holds considerable social and economic value (Madubuike et al., 2014). Despite its high carbohydrate content and low protein levels, cassava serves as a vital energy source for human consumption. Fresh cassava roots contain approximately 75-80% moisture, 0.70-2.50% ash, 32-35% carbohydrates, 2-3% protein, and 0.1% fibre, (Oluwole et al., 2004). However, due to its high moisture content, cassava rapidly deteriorates within 48-72 hours if not properly processed (Saravanan et al., 2016). This necessitates rapid processing of various products with extended shelf life, reducing transportation costs to urban markets (Taiwo, 2006). Traditional cassava processing involves several steps, including peeling, fermenting, drying, milling, roasting/toasting, sieving, steaming, pounding, and mixing in cold or hot water. These processes yield products such as fufu, garri, starch, high-quality cassava flour, and tapioca (Udoro et al., 2008).

Cassava is chemically composed of two elemental categories: macro and microelements. Microelements, also known as trace elements, constitute substances comprising less than 0.01% of the body mass in physiological terms. This category encompasses all elements except those comprising the organic matrix (carbon, hydrogen, nitrogen, oxygen, and sulphur) and the major minerals (calcium, potassium, and phosphorus). Trace elements play a vital role in human nutrition due to their essential or toxic nature. Essential trace elements such as copper (Cu), iron (Fe), and zinc (Zn) are crucial and are found in various food materials depending on factors like crop varieties, maturity, genetics, and soil conditions, among others (Petry et al., 2016). These elements are essential for biological systems. Excessive dietary intake of zinc can result in adverse effects like vomiting, headache, nausea, fever, tiredness, anaemia, and abdominal pain (Ahmadi et al., 2020).

Additionally, exceeding safe threshold values of copper and zinc can lead to neurological impairment, headache, and liver disease. The presence of high levels of trace metals in food products is concerning due to pollution levels and their toxic effects on animals and humans. Given that cassava comprises compounds composed of elements, it is crucial to conduct qualitative and quantitative analyses on cultivated samples to determine the quality and quantity of elements present. The study aims to assess trace elements in three cultivars of bitter cassava plants, which are typically composed of diverse compounds.

MATERIALS AND METHODS

Experimental location and source of experimental materials

The experiment took place at the International Institute of Tropical Agriculture (IITA) in Ibadan, Nigeria. The bitter cassava genotypes utilized in the study were obtained from the cassava breeding unit located at IITA, Ibadan, Nigeria.

Cassava Genotypes

The cassava genotypes utilized in the experiment are IBA154800, IBA164785, and IBA164791.

Apparatus and Reagents

The apparatus used included the Tecator Model 40 Digester (TECATOR Fack S – 26301, Hoganas, Sweden), Pyrex digestion tubes, and Tecator, 70 ml with a special mask. The reagents employed were concentrated Nitric acid, concentrated Perchloric acid, and concentrated Hydrochloric acid.

Procedure

We measured out 100 mg of plant tissue samples that had been ground and dried in an oven at 65°C, placing them into a 70 ml Pyrex digestion tube. To each tube, we added 5 ml of the HNO3-HCLO4 agent (at a 2:1 ratio by volume) under a fume hood and allowed them to stand overnight at room temperature. Subsequently, we positioned the tubes in the aluminium digestion block situated inside the fume hood, setting the temperature control of the digester installed outside the fume hood to 150°C for a digestion period of 1.5 hours. The temperature was then raised to 230°C, and the samples were left to digest for an additional 30 minutes, reaching the white fuming stage. Afterwards, the digester temperature was reverted to 150°C. We introduced 1 ml of the HCL reagent (consisting of 1 part concentrated HCL and 1 part water) into each tube, heating the content at 150°C for approximately 30 minutes. Upon switching off the digester, we removed the tubes from the digestion block and swiftly added 30 ml of distilled water to each tube. The tubes were then topped up with water to reach a total volume of 50 ml before thoroughly mixing the contents. Subsequently, the solution was transferred for the determination of essential elements using Atomic Absorption Spectrophotometry (AAS).

Determination of Mg, Zn, Cu, K, Fe and Na using AAS

Standard solutions of the essential elements were prepared in an aqueous solution for AAS reading in triplicates. The AAS was set up according to the manufacturer's instructions. Standardized concentrations of the elements were read and recorded. The concentrations of the elements in the sample were read and recorded in triplicates.

Statistical analysis

Analyze the amount of elements identified using ANOVA (SAS 9.0). Separate differences in the genotypic mean using Least Significant Differences at a 5% level of probability. Additionally, determine the relationship between the different elements using linear correlation.

Figure 1. Three yellow cassava varieties were used for the identification of micro and macro elements

RESULTS

Table 1 displays significant variations in the levels of Magnesium, Potassium, and Sodium across the three evaluated cultivars of bitter cassava. The highest percentage of Magnesium was observed in IBA164785 (0.143±0.001), which significantly exceeded the Magnesium content in IBA164791, recording the lowest percentage (0.114±0.001). Regarding Potassium percentage, IBA164785 (2.147±0.01) exhibited a notably higher value compared to both IBA15400 (1.821±0.031) and IBA164791 (1.463±0.025), which demonstrated the lowest content. The Sodium content (in parts per million) among the three bitter cassava cultivars indicated that IBA154800 (37.433±0.505) had a significantly higher level than both IBA164791 (30.613±0.811) and IBA164785 (29.138±0.747), which recorded the lowest values.

The levels of Iron, Copper, and Zinc detected in the three cultivars of bitter cassava, showcasing significant differences among the genotypes were presented in Table 2. In terms of Iron content, no significant difference was observed between IBA154800 (25.766±2.399) and IBA164785 (29.874±2.366), both of which were notably higher than IBA164791 (19.021±2.366), which exhibited the lowest Iron content. IBA164785 recorded the highest Copper content (1.064±0.157), significantly surpassing both IBA154800 (0.522±0.157) and IBA164791 (0.701±0.002), which demonstrated similar levels. Lastly, IBA164791 (18.579±0.168) displayed the highest Zinc quantity among the three bitter cassava cultivars, significantly exceeding IBA164785 (15.339±0.114) and IBA154800 (14.882±0.080), which exhibited the lowest Zinc levels.

The relationship between and within the micro and macro elements extracted from yellow cassava varieties is shown in Figure 2. The relationship between Zn and Fe (-0.88), and between Na and Cu (-0.85) were significantly strong and negative. The relationship between Fe and Mg (0.89), Mg and Cu (0.85), and Mg and K (0.71) were significantly strong and positive. The relationship between Cu and Zn, Cu and Fe, Cu and K, K and Zn, K and Na, K and Mg, Mg and Zn, Mg and Na, Fe and Na, and between Na and Zn were not significant.

Table 1. Amount of Magnesium, Potassium and Sodium detected in 3 cultivars of bitter cassava

Varieties	Mg (%)	K (%)	Na (PPM)
IBA154800	0.117±0.001^{b}	1.821±0.031^{b}	37.433±0.505^{a}
IBA164785	0.143±0.001^{a}	2.147±0.010^{a}	29.138±0.747^{c}
IBA164791	0.114±0.001^{c}	1.463±0.025^{c}	30.613±0.811^{b}
LSD (0.05)	0.001	0.047	1.399

Note: Means labelled with the same alphabet letter within the group are not significantly different from each other. LSD (Least Significant Differences) at a significance level of $P \leq 0.05$.

Table 2. Amount of Iron, Copper and Zinc detected in 3 cultivars of bitter cassava

Varieties	Fe (PPM)	Cu (PPM)	Zn (PPM)
IBA154800	25.766±2.399^{a}	0.522±0.157^{b}	14.882±0.080^{c}
IBA164785	29.874±2.366^{a}	1.064±0.157^{a}	15.339±0.114^{b}
IBA164791	19.021±2.366^{b}	0.701±0.002^{b}	18.579±0.168^{a}
LSD (0.05)	4.749	0.257	0.252

Note: Means labelled with the same alphabet letter within the group are not significantly different from each other. LSD (Least Significant Differences) at a significance level of $P \leq 0.05$.

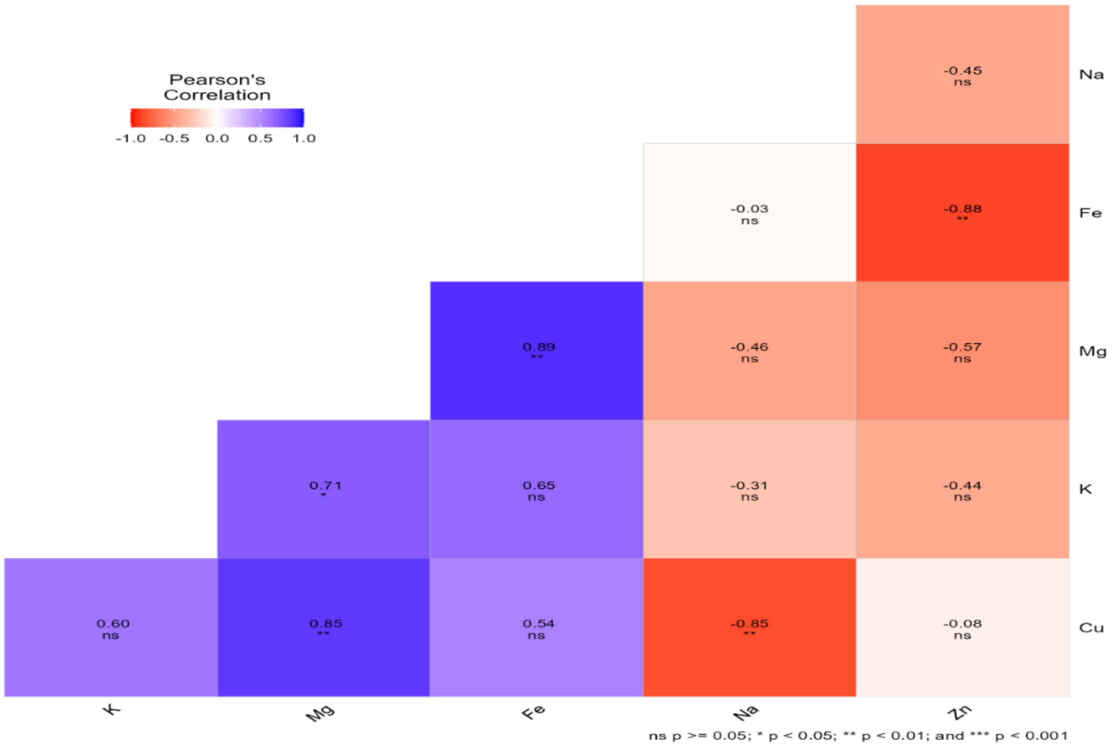

Figure 2. Correlation between the micro/macro elements extracted from yellow cassava varieties

DISCUSSION

Approximately 500 million people worldwide rely on cassava as a primary source of carbohydrates, with small-scale farmers, often working in marginally productive soils, being the predominant cultivators (Montagnac et al., 2009). Cassava exhibits a remarkable ability to thrive in adverse environmental conditions, including regions plagued by mineral and vitamin deficiencies, such as African soils (Zekarias et al., 2019). However, the cultivation of cassava under these challenging conditions can directly or indirectly contribute to increased morbidity and mortality in the region due to the consumption of less nutritious cassava products, upon which many depend. Consequently, breeders have undertaken the biofortification of cassava varieties to enhance their nutritional value.

The most common micronutrient deficiencies in cassava include vitamin A, iron (Fe), and zinc (Zn) (Inacio et al., 2024). In this study, variations were observed in the elemental composition of different pro-vitamin A cassava varieties, reflecting slight differences in their genetic makeup. Specifically, IBA164785 exhibited high levels of Mg and K, along with the lowest Na content, whereas IBA154800 had the highest Na content. Gil and Buitrago (2009) previously reported high K content in biofortified cassava varieties. Fe and Zn contents were notably high across all three biofortified cassava varieties in this study. However, IBA164785 displayed the highest levels of Fe and Cu, while Zn was highest in IBA164791. These findings regarding the essential elements surpassed the quantities. (Inacio et al., 2024) despite the different biofortified cassava varieties used in their study compared to ours.

Maintaining adequate levels of essential micronutrients in the human body is vital for normal growth and development, as excessive amounts can lead to various health challenges. Moreover, the presence of one micronutrient can impact the availability of others. For instance, a negative relationship was observed between Zn and Fe in this study, supporting Godswillet al., (2020) assertion that excess Zn can lead to deficiencies in Fe and Cu. This inverse relationship extends beyond micronutrients, as evidenced by the strong negative correlation between Na and Cu. Liu et al. (2019) also noted that elevated Na levels in the body can reduce elements such as Cu, Mg, and K, as observed in our study.

CONCLUSION

Cassava stands out as a valuable source of carbohydrates, proteins, vitamins, and minerals, constituting a staple food for millions of people worldwide. However, the distribution of these essential micro and macro elements is often inadequate across many cassava varieties. Given the significant cyanide content present in cassava varieties, processing becomes essential to mitigate cyanide levels, albeit resulting in the loss of vital micro and macro elements. Therefore, the development of a group of vitamin A biofortified cassava varieties hold importance, as they can help offset the loss of vitamins and ensure the provision of adequate minerals to humans. This significance is underscored by the findings of this study, which highlight the potential of three biofortified cassava varieties in addressing these nutritional concerns.

CONFLICT OF INTERESTS

The authors declare no conflict of interest.

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