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Elevated Iron Levels in Machine-Grinded Cassava (*Manihot esculenta*, *Euphorbiaceae*) in Iwo, Southwest Nigeria as Determined by Atomic Absorption Spectrometry

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Abstract

The potential of trace amounts of elements to contaminate food during processing in some local communities of Nigeria has since been a subject of concern. In Iwo, South West Nigeria, the processing method of converting the highly perishable cassava tubers to more stable products such as the roasted granular product, *Gari* involves grating/grinding of peeled cassava tubers and this process is suspected to introduce trace elements into the final product. This study determined and compared the levels of trace elements in peeled and machine-grinded cassava tuber samples. Peeled cassava tuber samples and machine-grinded cassava tuber samples were collected, prepared by acid digestion and filtration. Elemental analysis was carried out using PG-990 Atomic Absorption Spectrophotometer in the flame configuration mode. Iron (9.500 ± 0.025 mg/kg), Copper (11.200 ± 0.025 mg/kg) and Magnesium (251.317 ± 0.038 mg/kg) were present in the peeled cassava tubers; while for the machine-grinded cassava tubers, Iron (63.075 ± 0.025 mg/kg), Copper (11.650 ± 0.025 mg/kg), Magnesium (250.500 ± 0.250 mg/kg) and Manganese (0.650 ± 0.025 mg/kg) in addition were present. Comparison of these results revealed that Iron concentrations for machine-grinded cassava tubers were significantly higher than peeled cassava tubers ($p < 0.05$). This result suggests that the grinding process during cassava preparation might have introduced Iron, a trace element contaminant to the product (*Gari).* This report reveal that the appropriate health authorities and regulatory agencies need to set limits with a view of safeguarding consumers' health.

Keywords: Atomic Absorption Spectrometry, Cassava, Contaminants, Elemental analysis, Public health

1. Introduction

Manihot esculenta, (Euphorbiaceae) originating from Brazil and Paraguay (Stephen, 1995) and commonly referred to as cassava, is considered to be the third most important source of food in the tropical and sub-tropical regions of the world, coming behind rice and maize (Cock, 1985). Cassava is a major source of carbohydrate for the tropical population (Onwueme, 1978; Wheatley et al., 1995). It is also the staple food of at least 500 million people (Cock, 1985). The Food and Agriculture Organisation, (FAO) of the United Nations (UN), viewed Nigeria as the largest producer of cassava in the world, ahead of Thailand, Brazil and others. (FAO, 2006). The FAO also views cassava production in other African countries, the Democratic Republic of the Congo, Ghana, Madagascar, Mozambique, Tanzania and Uganda as appearing small in comparison to Nigeria's substantial output. Fresh cassava tubers are highly perishable, hence cannot be kept in fresh conditions for more than a few days after harvest without serious deterioration in quality (Leaky and Wills, 1977). Consequently, to extend its shelf life, some processing methods have been devised locally to convert the highly perishable tubers to more stable products and at the same time reduce its toxicity. One such form is a roasted granular product prepared from peeled, fermented, grated/grinded cassava tubers known as Gari (Asiedu, 1989). The process of grating/grinding of peeled cassava tubers locally is suspected to introduce trace element contaminants to the product at admissible or toxic doses which need to be evaluated, hence this study. These metals, when taken into the body through food contamination cause damage to human health (Obanijesu & Olajide, 2009). It is well established that high exposure to trace metals in cassava could result in an array of diseases to both human and animals (Idakwoji, 2016). Food safety therefore is an important aspect of a nation's economic stability (Onianwa et al., 1999; Adekunle & Akinyemi, 2004). Although these elements rarely reach a level of toxic concentration after ingestion, there is still need to control their presence and set limits consequent of the very small difference that exists between their permissible and toxic doses. Atomic absorption spectroscopy (AAS) was employed to determine selected chemical elements present and their concentrations in peeled cassava tubers and in machine-grinded cassava tubers respectively. Previous studies by AAS have confirmed the presence of high levels of metal contaminants in food crops like cassava and plantain particularly in oil-exploration communities while lower levels were reported in non-oil impacted soils (Ndiokwere & Ezihe, 1990; Hart et al., 2005; Idodo–Umeh & Ogbeibu, 2010; Echem, 2010; Kalagbor et al., 2015). Metals are substances possessing high electrical conductivity, malleability, and lustre, which can lose their electrons to form cations. These metals are abundant in the earth's crust and are variously distributed in the atmosphere. They are monitored by the properties of the given metal and various environmental factors (Khlifi & Hamza-Chaffai, 2010). Iwo, South-west Nigeria where our study was carried out is a non-oil impacted community. Results of studies like this, and its practical relevance for human nutrition and public health need to be carefully evaluated in the attempt to interpret dietary analyses in a diagnostic context. Heavy metals are known to bio-accumulate in the system and portend a serious health risk. Ingestion of heavy metals is known to disrupt important physiological processes in living cells and is reportedly associated with serious systemic pathological conditions including cancer (Jaishankar et al., 2014; Adejumo et al., 2016). Additionally, standards need to be set and enforced in the cassava processing centres. Hence, this study determined and compared the levels of selected trace elements in peeled and machine-grinded cassava tuber samples from Iwo, south-west, Nigeria.

2. Materials and Methods

2.1 Sample Preparation

Peeled cassava tuber samples and machine-grinded cassava tuber samples were collected from some cassava processing centres in Iwo, south-West Nigeria. Collected samples were prepared by air-drying and acid digestion at the Chemistry Laboratory of the Bowen University, Iwo. One gram (1g) each of the samples was measured analytically and concentrated HNO_3 (5 ml) was added in a Teflon beaker and heated on a hot plate for about 10 min after which perchloric acid (1 ml) was added and then heated for about 30 - 45 min. The digested sample was cooled to room temperature and filtered. The filtrate was then transferred into a volumetric flask (25 ml) and made up with distilled water. Two other replicate samples were prepared to achieve triplicate measurements in both cases. The digested samples were analysed with the line source PG 990 Atomic Absorption Spectrophotometer, LS AAS, used in the flame configuration mode. It is a fully automated instrument for flame and/or graphite furnace analysis, incorporating two background correction systems, the deuterium lamp method and the self-reversal method.

2.1.1 Atomic Absorption Spectrometric Analysis

Air was allowed to mix with acetylene gas from the gas cylinder in good proportion to ignite the burner of the Spectrophotometer. Immediately after ignition, the spectrophotometer was calibrated using the blank (distilled water) and standard solution (as supplied with the spectrophotometer). The aerosol of the sample was then aspirated through the nebulizer into the flame for analysis. Analysis was done for each element of interest at their specific wavelength using the hollow cathode lamp of the element under investigation and the result was displayed on the computer read-out.

3. Results

We measured mean concentrations of selected elements for peeled and machine-grinded cassava tuber samples respectively. The mean concentrations of the elements, Mn, Zn, Pb, Fe, Cu and Mg analysed for both groups is presented in Table 1. Mean concentrations for manganese, zinc and lead for peeled cassava tubers were not detectable while it was quantifiable for manganese in machine-grinded tubers. Zinc and lead could also not be detected in machine-grinded tubers. The method detected iron, copper and magnesium for both categories of samples. There were no significant differences in both groups of samples for copper and magnesium; although a significantly greater mean concentration of iron was observed for the machine-grinded tubers. Data has been presented at 95% (± 2S) confidence level for triplicate measurements in each of the cases. Table 2 shows the daily dietary allowance for the elements analysed as recommended by National Research Council, USA, (Recommended Dietary Allowances, 2011).

Table 1. Mean values for determined elements in cassava samples

Elements	Concentrations (mg/kg)	
	Peeled Cassava Tubers	Machine-Grinded Tubers
Manganese	Nd	0.650 ± 0.025
Zinc	Nd	Nd
Lead	Nd	Nd
Iron	9.500 ± 0.025	63.075 ± 0.025
Copper	11.200 ± 0.025	11.650 ± 0.025
Magnesium	251.317 ± 0.038	250.500 ± 0.250

Nd=Not detected.

Table 2. Recommended dietary allowances per day of elements for humans

		Recommended Dietary Allowances per day, (Elements) in mg/d				
	Age Group	Mn	Zn	Fe	Ca	Mg
Children	4 – 8 years	1.5	5	10	1000	130
Males	14 – 18 years	2.2	11	11	1300	410
	31 – 50 years	2.3	11	8	1000	420
	51 – 70 years	2.3	11	8	1000	420
	> 70 years	2.3	11	8	1200	420
Females	14 – 18 years	1.6	9	15	1300	360
	31 – 50 years	1.8	8	18	1000	320
	51 – 70 years	1.8	8	8	1200	320

	> 70 years	1.8	8	8	1200	320
Pregnancy	14 – 18 years	2.0	12	27	1300	400
	19 – 30 years	2.0	11	27	1000	350
	31 – 50 years	2.0	11	27	1000	360
Lactation	14 – 18 years	2.6	13	10	1300	360
	19 – 30 years	2.6	12	9	1000	310
	31 – 50 years	2.6	12	9	1000	320

(Source: Recommended Dietary Allowances, National Academies Press (US); 2011.

4. Discussion

Comparison of the results in Table 1, revealed that iron concentrations for the peeled cassava tubers (9.500 ± 0.025 mg/kg) and the machine-grinded cassava tubers (63.075 ± 0.025 mg/kg) showed a marked significant difference ($p < 0.05$) while the other elements displayed no significant differences. This result suggested that the process of grinding cassava might have introduced trace element contaminants, in this case; iron to the product (Gari). Also, comparing the iron content of 63.075 ± 0.025 mg/kg obtained for the machine-grinded cassava tubers (Table 1) with the Recommended Dietary Allowance, (RDA) for varying age and gender groups as shown in table 2, we observe that for children, the RDA is 10 mg per day, for males in the age group 14 – 18 years, the RDA is 10 mg/d and for other age groups it is 8 mg/d. For females, the RDA is 15 mg/d in the age group 14 – 18 years, 18 mg/d in the 31 – 50 years age group and 8 mg/d for the other age groups. For all age groups for pregnant women, the RDA is 27 mg/d. For lactating women in the 14 – 18 years age group, the RDA is 10 mg/d and it is 9 mg/d for other age groups. Heavy consumption of the product (Gari) by consumers may not conform to these tolerable limits of the RDA values for varying age/gender groups. Previous studies in the riverine area of Nigeria also reported elevated levels of iron (92.40 mg/kg) in cassava and other crops (Hart et al., 2005; Kalagbor et al., 2015) consequent of heavy metal pollution of an oil-exploration area.

The current study has nutritional implications and appreciation of the modifying action of factors likely to influence iron trace-element intake in Gari is a promoter of studies like this. Solomons and Jacob, in 1981, stated that iron and zinc are the two most abundant trace minerals in the human body and these elements play a significant role in health and disease. Zinc is an important nutritive factor as well as a co-factor for many metalloenzymes. Zinc is also required for growth and cell-division and its deficiency is associated with syndromes that cause short stature and dwarfism (Wells et al., 1987); aside leading to a decrease in blood urea nitrogen (BUN) and increase in blood ammonia (Smith et al., 1973). Iron is contained in haemoglobin and important for maintaining a healthy immune system; it also aids the digestion of certain foods. The bioavailability of iron which is defined as the extent to which iron is absorbed from the diet and used for normal body functions (Hurrell and Egli, 2010) is approximately 14% to 18% from mixed diets that include substantial amounts of meat, seafood and vitamin C. Heme iron found in animal foods that contain hemoglobin, such as meat, fish and poultry is the best form of iron for us, because our bodies readily absorb up to 40% of it. On the other hand, the non-heme iron from plant-based protein is less readily absorbed by our bodies. Therefore the heme iron is a large source of dietary iron for humans ("Iron-Fact Sheet for Health Professionals," 2019). We believe that dietary iron, usually in form of iron compounds containing iron in the oxidized form may be part of a healthy diet, but metal is not (Ries, 2014). Food safety is a serious concern for every food manufacturer and one contaminant that can cause some consumer pain and grief is a piece of metal. Metal is not a trace mineral we expect to find in our food. The food production industry is run on machinery, and consequently, contaminants may sometimes enter the production line, which need to be checked. Though iron is used in the body to make tendons and ligaments, and certain chemicals in the brain are controlled by the presence or absence of iron; excess iron levels can enlarge the liver, may provoke diabetes and cardiac failure. Haemochromatosis, a genetic disease is equally a condition resulting from excessive iron absorption. Therefore, the effect of increased Fe level in the machine-grinded cassava tubers and hence the final product (Gari) on the uptake and transport of these two most abundant dietary trace minerals in the human body cannot be overemphasized and may need further investigation. Results of this and similar studies, and its practical relevance for human nutrition especially with respect to the magnitude of the "iron effect" need to be carefully balanced when striving to interpret dietary analyses in a diagnostic context. Iron accumulation is reportedly related to certain neurological disorders such as Alzheimer disease, Parkinson disease, type 1 neurodegeneration with brain iron accumulation, and other disorders (Sadrzadeh and Saffari, 2004) which are undesirable.

5. Conclusion

We conclude therefore, that machine-grinded cassava tubers in Iwo, south-west Nigeria are contaminated with iron. Suspected introduction of trace element contaminants such as iron to the product (Gari) as a consequence of the cassava grinding process require that the rusty conditions of the grinders be addressed by appropriate health authorities and regulatory agencies. Since metal toxicity depends upon the absorbed dose, the route and duration of exposure whether acute or chronic that can cause various disorders (Jaishankar et al., 2014); it is necessary to set standards for these elements and enforce compliance particularly in a country like Nigeria where the product is heavily consumed with a view to safeguarding public health.

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