IMPACT OF PROCESSING METHODS ON THE LEVELS OF IRON, ZINC AND MAGNESIUM IN YAM (*Dioscorea species*)

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Abstract: Different methods of processing yams have the potential of affecting their retention of micronutrients such as iron, zinc and magnesium. The present study investigated the effects of frying, roasting and sun-drying of yams on the concentrations of Fe, Zn and Mg. The concentrations of Fe in the three controlled (raw and unprocessed) yam varieties ranged between 71-82 mg/kg; Zn between 45-46 mg/kg and Mg between 322-371 mg/kg. Across the three treatments, statistically significant ($P < 0.05$) reductions were observed in the concentrations of Fe, Zn and Mg when the samples were roasted, sun-dried or fried. The only exception was in the fried white yam (FW) where the reduction in the concentration of Fe was statistically not significant ($P > 0.05$). In real terms, the percent reduction of Fe in the roasted samples was approximately 40% in all the yam varieties. In the same vein, Zn reduction was between 53-73% (white and yellow yams respectively). Mg loss was greater (61.4%) in the roasted yellow yam variety. Statistically significant ($P < 0.05$) inter-varietal variations were observed when the roasted, fried and sun-dried samples were compared in relation to the levels of Fe, Zn and Mg in the three yam varieties.

Keywords: Yam, iron, zinc, magnesium, roasting, frying

Introduction

Yam, *Dioscorea species* is an important staple in much of West Africa (Omonigho and Ikenebomeh, 2000). It is generally cultivated all over the world for its rich and edible tubers. Yams are annual or perennial tuber-bearing and climbing plants belonging to the family Dioscoreaceae. Some species of yam originated from Africa before spreading to other parts of the world while others originated from Asia and have spread to Africa (Hahn *et al.*, 1987). Today, yams are grown widely throughout the tropics and they have a large biological diversity including more than 600 species worldwide (Burkill, 1960; Coursey, 1967) but only six are widely cultivated in West and Central Africa. These cultivated species are *D. alata*, *D. bulbifera*, *D. dumetorum* (Pax), *D. esculenta* (Lour), *D. cayenensis* and *D. rotundata.* Wild types of yam also exist and may be used as food after undergoing processing during the hunger seasons (Tetteh and Saakwa, 1994). A few yam species are also grown and used as health food and for medicinal purposes (Farombi *et al*., 1997; Albrecht and McCarthy, 2006). In the West African yam zone, which is the principal producer on a global basis, *D. alata*, *D. rotundata*, and *D. cayenensis* are commonly grown.

Water yam (*Dioscorea alata* L.), also referred to as greater yam, Asian greater yam and ten-month yam (Martin, 1976) is more important as food in West Africa and the Caribbean than in Asia and the Americas where it originated, and has been competing with the most important native species, *D. rotundata* Poir. *D. alata* species is the highest yielding among the yam species and can store relatively longer than other species (5-6 months) after harvest. It is also known for its high nutritional content, with crude protein content of 7.4%, starch content of 75-84%, and vitamin C content ranging from 13.0 to 24.7 mg/100 g (Osagie, 1992). The texture of its flesh is usually not as firm as that of white yam and is less suitable than other species for the preparation of the most popular food products from yam (fufu and pounded yam especially) in the West Africa region. However, it is reported that *D. alata* is a major staple food in Côte d'Ivoire, where it constitutes about 65% of the yam grown in the country (Orkwor, 1998). In the West Indies, Papua New Guinea and New Caledonia, *D. alata* is the major food yam grown and consumed by the people (Orkwor, 1998).

White yam (*Dioscorea rotundata* Poir) remains the principal yam cultivated in West Africa. Its cultivation has also spread to other parts of the world. It is grown extensively in the West Indies, and to some extent in East Africa. There are very large numbers of cultivars of *D. rotundata* that are grown, especially in West Africa. Unfortunately, the taxonomic position of most of these cultivars, and of cultivars of yam generally, is somewhat confused, partly because there are no universally accepted names for the cultivars, and partly because detailed descriptions of the distinguishing features of each cultivars are lacking, making referencing to cultivars ambiguous and unreliable (Onwueme, 1978; Otoo*et al.*, 2009). The situation, therefore, is one in which each locality has its own unique series of names for the different cultivars (Onwueme, 1978). The various cultivars can be identified by their tubers during storage or by their shoot characteristics while they are growing on the field. Identification may be based on tuber shape, tuber-skin colour and structure, tuber flesh colour and tuber-flesh texture; or on the colour of sprout and shoot tips, quantity (Otoo *et al.*, 2009) and distribution of spines and bloom on the stem, and leaf shape, size, and colour (Onwueme, 1978).

Yellow yam (*Dioscorea cayenensis*) is native to Africa. It is one of the most cultivated yam species. Yellow yam has yellow flesh, caused by the presence of carotenoids. It looks similar to the white yam in outer appearance; its skin is usually a bit firmer and less extensively grooved. The yellow yam has a longer period of vegetation and a shorter dormancy period than white yam (Otoo *et al.*, 2009).

Generally, annual world production of yam is about 40 million tones and per capita consumption is estimated to be 256.4 g per day in the major production zones (FAOSTAT, 2005). The nutritional value of yam is higher than some other root and tuber crops such as cassava (Latham, 1969). Its protein content is about 3 - 6% as compared to 1 - 2% in cassava (Charles *et al*., 2004). Yams are reported to contain relatively high levels of minerals (Fe, Zn, Ca, K, Mg, P, Na, Cu, Mn, etc.) (Afoakwa and Sefa-Dedeh, 2001). Iron (Fe) is an important trace element found in yam and is essential in the human body. It plays crucial roles in haemopoiesis, control of infection and cell- mediated immunity (Beard, 2001). Iron deficiency anaemia is the most prevalent micro-nutritional deficiency and is estimated to affect more than one billion people worldwide (Trowbridge and Martonell, 2002). The Nigeria food consumption and nutrition survey 2001 - 2003, showed that 27.45% of children less than five years, 24.3% of mothers and 35.3% of pregnant women suffered from iron deficiency (Maziya-Dixon *et al*., 2004). Zinc (Zn) is an essential micronutrient found in yam that is essential for human growth and immune functions (Black, 2003). An estimated 20% of the world population is reported to be at risk of inadequate zinc intake (Hotz and Brown, 2004). The Nigeria food survey showed that zinc deficiency affects 20% of children less than five years, 28.1% of mothers and 43.9% of pregnant women (Maziya-Dixon *et al*., 2004). Magnesium is also another important element found in yam and essential for humans. It plays crucial roles in hundreds of enzyme reactions involved in the synthesis of DNA and proteins (Sojka and Weaver, 1995), forms structural components of bones and is required for proper nerve conduction and muscle contraction. Deficiencies in magnesium could lead to muscle cramping, abnormal heart contractions, depression, etc. (WHO, 2004).

Three principal traditional methods used for preparing yams for consumption in coastal West Africa, especially Nigeria, are frying, boiling and roasting the tuber (Omonigho and Ikenebomeh, 2000). Several traditional household food-processing methods can affect the bioavailability of micro-nutrients in plant-based diets. These include thermal processing, mechanical processing, soaking, fermentation and germination, (Hotz and Gibson, 2007). The aim of this study was to investigate the effect of various preparation and pretreatment methods on the mineral retention of yams. The specific objectives of the study included;

i) To investigate the Fe, Zn and Mg contents of untreated yam species
ii) To investigate the effect of various pre-treatments and preparation methods of yam species on their micronutrient (Fe, Zn and Mg) levels.

Materials and Methods

Sample collections

Three varieties of yam tuber samples (*Dioscorea alata* L, *Dioscorea rotundata* Poir and *Dioscorea cayenensis*) mostly consumed in Wukari LGA of Taraba state were used in this research. The samples were procured from "Wukari Yam Market" Taraba state. The different varieties of yam were peeled and then rinsed in clean water before been subjected to different treatments (roasting, frying and sun drying). The control group was left raw and unprocessed. The samples were afterwards sliced into chips and allowed to dry under mild sunlight and then ground into flour using mortar and pestle.

All glasswares were washed with detergent and rinsed with deionized water. They were then soaked for 24 h in 10% nitric acid solution and dried in an oven before use. Analytical grade reagents were used and standard solutions of trace elements were freshly prepared on the days of analyses.

Sample digestion

Samples were digested according to the method described by the Association of Official Analytical Chemists (AOAC, 2006). Briefly, 5 g of each sample was weigh into 250 ml conical flask, 10 ml *aqua regia* (nitric acid and HCl in a ratio of 1:3) was added and then evaporated on a hot plate in a fume cupboard until the black fumes disappeared leaving the white fumes. The resulting sample was then made up to 50 ml using deionized water and then filtered into clean universal bottle for atomic absorption spectrometric (AAS) analysis.

Heavy metal analysis

The digested samples were subjected to heavy metal analysis and it was done using a Thermo Scientific iCE 3000 Atomic Absorption Spectrometer to aspirate for the presence of heavy metals (Zn, Mg, and Fe). Standard addition technique (SAT) was used to calibrate the instrument in order to check and correct matrix. Standards were prepared by serial dilution techniques within the range of each metal determined. The standards used were Analar grade. The instrument was first calibrated with solutions of metal standards before the analysis. The same process was carried out to determine each of the element concerned using different lamps. The elements measured were Zn, Mg and Fe.

Statistical analyses

The data obtained from the various metal determination experiments (AAS) were subjected to statistical analyses using one-way Analysis of Variance (ANOVA) at 95% confidence level (SPSS version 21.0).

Results and Discussion

The AAS results are presented in Tables 1. The concentration values presented are the mean ± Standard Error (SE) and were calculated from the equation 1.

$$Conc.(mg/kg) = \frac{[Conc.of\ sample\ (ppm) - Conc.of\ blank\ (ppm)] \times Vol.(50\ ml) \times 1000}{Weight\ of\ Sample\ (g) \times 1000} \quad \text{(Eqn. 1)}$$

The Table shows the effects of different processing methods on the levels of iron, zinc and magnesium in the three (3) yam samples. Table 2 shows the percentage reduction of the mean concentrations of Fe, Zn and Mg values in the three (3) yam varieties. The true mineral retention (TMR) of Fe, Zinc and Mg are presented in Table 3 and were calculated as in equation 2 (Murphy *et al*., 1975; Maziya-Dixon *et al*., 2017):

$$TMR\ (\%) = \frac{Mineral\ per\ g\ of\ cooked\ food \times g\ of\ food\ after\ cooking}{Mineral\ per\ g\ of\ raw\ food \times g\ of\ food\ before\ cooking} \times 100 \quad \text{(Eqn. 2)}$$

Table 1: Effects of different processing methods on the levels of iron, zinc and magnesium in white, yellow and water yams (mg/kg)*

Yam	Sample	Fe	Zn	Mg
White yam	CW	75.23 ± 0.01	45.93 ± 0.01	341.29 ± 0.01
	RW	45.63 ± 0.01	18.94 ± 0.01	204.07 ± 0.01
	SW	31.76 ± 0.01	28.12 ± 0.01	211.64 ± 0.01
	FW	69.25 ± 0.01	35.93 ± 0.01	271.43 ± 0.01
Yellow yam	CY	71.46 ± 0.01	45.85 ± 0.01	322.54 ± 0.00
	RY	42.43 ± 0.01	12.35 ± 0.01	124.53 ± 0.01
	SY	33.87 ± 0.01	25.13 ± 0.01	179.86 ± 0.01
	FY	66.03 ± 0.01	34.54 ± 0.01	261.04 ± 0.01
Water yam	CWY	82.35 ± 0.01	44.96 ± 0.01	371.05 ± 0.01
	RWY	51.64 ± 0.00	21.42 ± 0.00	251.35 ± 0.01
	SWY	35.63 ± 0.01	25.76 ± 0.01	184.63 ± 0.00
	FWY	65.72 ± 0.01	36.24 ± 0.01	271.04 ± 0.00

*values represent mean of three readings ± SEM; CW - Control white yam, RW - Roasted white yam, SW - Sun-dried white yam, FW – Fried white yam, CY – Control yellow yam, RY – Roasted yellow yam, SY – Sun-dried yellow yam, FY – Fried yellow yam, CWY – Control water yam, RWY – Roasted water yam, SWY – Sun-dried water yam and FWY – Fried water yam

Table 2: Percentage reduction of the concentrations of Fe, Zn and Mg values in white yam (%) compared to control*

Sample	Fe	Zn	Mg
RW	37.7[a]	58.8[a]	41.1[a]
SW	56.6[a]	38.8[a]	38.0[a]
FW	5.4[b]	21.8[a]	20.5[a]
RY	40.6[a]	73.1[a]	61.4[a]
SY	52.6[a]	45.2[a]	44.2[a]
FY	7.6[a]	24.7[a]	19.1[a]
RWY	37.3[a]	52.4[a]	32.3[a]
SWY	56.7[a]	42.7[a]	50.2[a]
FWY	20.2[a]	19.4[a]	27.0[a]

*Values with superscript[a] are statistically significant ($P < 0.05$) when compared to control; those with superscript[b] are statistically not significant ($P > 0.05$) when compared to control and those with superscript[c] represent control

Table 3 True mineral retention (%) of the three processed yam samples compared to control*

Sample	Fe	Zn	Mg
RW	61[a]	41[a]	60[a]
SW	42[a]	61[a]	62[a]
FW	94[b]	78[a]	80[a]
RY	59[a]	30[a]	39[a]
SY	47[a]	55[a]	56[a]
FY	92[b]	75[a]	81[a]
RWY	63[a]	48[a]	68[a]
SWY	43[a]	57[a]	50[a]
FWY	80[a]	81[a]	73[a]

*Values with superscript**a**are statistically significant ($P < 0.05$) when compared to control; those with superscript**b** are statistically not significant ($P > 0.05$) when compared to control and those with superscript[c] represent control

Yams are better known for their starchy tubers and nutritional calories than their mineral content. However, they are also a rich source of minerals and vitamins. Yams are boiled, roasted, baked, fried or in parts of Africa, also mashed into a sticky paste or dough called fufu or pounded yam after boiling. These processing methods have the potential of affecting their retention of micronutrients such as iron, zinc and magnesium. The present study investigated the effects of frying, roasting and sun-drying of yams on the concentrations of Fe, Zn and Mg. The concentrations of Fe in the three controlled (raw and unprocessed) yam varieties ranged between 71-82 mg/kg; Zn between 45-46 mg/kg and Mg between 322-371 mg/kg (Table 1).Across the three treatments, statistically significant ($P < 0.05$) reductions were observed in the concentrations of Fe, Zn and Mg when the samples were roasted, sun-dried or fried. The only exception was in the fried white yam (FW) where the reduction in the concentration of Fe was statistically not significant ($P > 0.05$). In real terms, the percent reduction of Fe in the roasted samples was approximately 40% in all the yam varieties. In the same vein, Zn reduction was between 53-73% (white and yellow yams, respectively). Mg loss was greater (61.4%) in the roasted yellow yam variety (Table 2). Adepoju *et al*. (2017) had earlier studied the effects of roasting and frying on the concentrations of Fe, Zn and Mg in yellow yam. Their findings agree with the observations in the current study in terms of the general percent reduction in the minerals. However, there were wide variations with regards to the specific values compared with this work. However, the observed remarkable reductions in the concentrations of the minerals was irrespective of the yam variety and was in consonance with the observations of Adepoju *et al*. (2012) that processing yams into various products resulted into a significant ($P < 0.05$) loss in all mineral contents. Statistically significant ($P < 0.05$) inter-varietal variations were observed when the roasted, fried and sun-dried samples were compared in relation to the levels of Fe, Zn and Mg in the three yam varieties. For example, roasting significantly ($P < 0.05$) affected Zn levels in *Dioscorea cayenensis* more than in *rotundata* and *alata* species. Sun-drying affected Fe levels more than other processing methods and was better retained when the yams were roasted. Frying was observed to be the best processing method in terms of mineral retention (Table 3). Between 73-94% of the minerals were retained when the yams were fried. Mg was better retained in *Dioscorea cayenensis* and *alata* than in *Dioscorea rotundata* when the yams were sun-dried. Although, fairly recently, Maziya-Dixon *et al*. (2017) observed a nearly 100% retention of Zn when *Dioscorea rotundata* was boiled, the highest Zn retention in the present study was 80% when *Dioscorea rotundata* was fried. On the whole however, this signifies that the various processing methods affected the three yam varieties differently in terms of the micronutrients of interest.

Conclusion

Considering the results obtained from these analyses, it can be concluded that the three processing methods have negative impact on the micronutrients measured. Frying yam however, may have the greatest benefits in terms of mineral retention. Also, the findings from this research work would help consumers ascertain a suitable pretreatment method to use while cooking yam. The findings can be used by consumers, food scientists and nutritionists in choosing the best processing method to increase the retention of much-needed micronutrient in yams.

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Conflict of Interest

Authors declare that there is no conflict of interest reported in this work.

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