Global Journal of Science Frontier Research: D
Agriculture and Veterinary
Volume 16 Issue 4 Version 1.0 Year 2016
Type : Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4626 & Print ISSN: 0975-5896

Comparison of Three Sweet Potato (*Ipomoea Batatas* (L.) Lam) Varieties on Nutritional and Anti-Nutritional Factors

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Keywords: *sweet potato, variety, proximate, mineral, anti-nutritional factors.*

GJSFR-D Classification : FOR Code: 300202

COMPARISONOFTHREESWEETPOTATOIPOMOEABATATASLLAMVARIETIESONNUTRITIONALANDANTINUTRITIONALFACTORS

Strictly as per the compliance and regulations of :

Comparison of Three Sweet Potato (*Ipomoea Batatas* (L.) Lam) Varieties on Nutritional and Anti-Nutritional Factors

Endrias Dako [α], Negussie Retta [σ] & Gulelat Desse [ρ]

Abstract- In this study the nutritional and anti-nutritional status of yellow, white and orange fleshed sweet potato varieties (Ipomoea batatas L. Lam) in their raw roots unpeeled and peeled were determined. The nutritional and anti-nutritional values of three sweet potato varieties were significantly ($p<0.05$) varied due to cultivar variation, processing conditions and their interaction. Orange sweet potato variety contains the highest level of moisture, fat, ash, carbohydrate, energy, calcium and iron in unpeeled condition and fiber, moisture, fat, ash, calcium, iron and zinc in peeled condition. On the other hand, yellow sweet potato variety contains the highest level of protein, phytate, phytate: calcium, phytate: iron and phytate: zinc molar ratios in both unpeeled and peeled conditions while the highest value of fiber, oxalate and tannin in unpeeled condition. White sweet potato variety contains the highest and lowest values of phosphorus and phytate in both unpeeled and peeled conditions and it was found in intermediate position for other nutrients compared to other two cultivars. Due to peeling, the fat, carbohydrate and energy values were significantly increased but all other parameters were significantly decreased.

Keywords: sweet potato, variety, proximate, mineral, anti-nutritional factors.

I. Introduction

Root and tuber crops refer to any growing plant that stores edible material in underground root, corm or tuber (Ugwu, 2009). Many of the developing world‘s poorest farmers and food insecure people are highly dependent on root and tuber crops as a source of food, nutrition, and cash income (Scott *et al*., 2000). The nutritional value of root and tuber crops lies in their potential ability to provide one of the cheapest sources of dietary energy in the form of carbohydrates. The amount of energy supplied by these crops is about one third of that of an equivalent weight of grains such as rice or wheat because these crops have high water content than cereals. However, the high yields of these root and tuber crops ensure an energy output per hectare per day which is considerably higher than that of grains (Woolfe, 1987).

In Ethiopia, sweet potato (*Ipomoea batatas L.* Lam) production ranks third after Enset (*Enset ventricosum* (W.) Cheesman) and potato (*Solanum tuberosum L.*) compared to other root and tuber crops. It is one of the major traditional food crops in the country. The crop cultivation is common in densely populated areas of the South, South-West and Eastern parts of the country and Southern Nation and Nationalities People Regions (SNNPR) is the highest producing area. It is an important food crop during hunger periods in areas such as Wolaita, Sidama, Kanbata Tanbaro, Gamo Gofa and Hadiya zones in SNNPR from February to May (Endale *et al.,* 1994).

When compared to other crops sweet potato is an attractive crop among farmers due to its high productivity, universal uses, high caloric content and good taste. Other important characteristics of sweet potato are; it tolerant adverse environmental conditions such as drought, it requires low soil fertility, high rainfall and very little labor and care (CIP, 1995). In addition to these attributes, it has also short production cycle, high nutritional value and sensory attributes in terms of flesh colors, taste and texture (Woolfe, 1992; Bovell-Benjamin, 2007; ILSI, 2008). Moreover, it contributes to food security and farmers' income in countries like Ethiopia (Terefe and Geleta, 1994).

Currently different varieties of sweet potato cultivars are cultivated and consumed in Ethiopia. These cultivars contain different skin colors (e.g. pink, cream, orange and white) and flesh colors (e.g. white, cream, orange and yellow). As with all crops the nutritional status of sweet potato cultivars vary from place to place depending on the climate, soil type, the crop variety and other factors (Ingabire and Hilda, 2011). Depending on the variety, sweet potatoes are rich in carbohydrates, dietary fiber, ash, ß-carotene, minerals and other nutrients (Woolfe, 1992; Bovell-Benjamin, 2007; ILSI, 2008). However, with all its desirable traits, sweet potatoes also contain potential plant toxins and anti-nutritional factors such as phytate, oxalate and tannin (Olayiwola *et al.,* 2009; Eluagu and Onimawo, 2010) that affect the nutrient utilization in the body. Thus, this study was conducted with the aim of selecting sweet potato variety with high nutritive value and low anti-nutritive factors among three sweet potato varieties (yellow-fleshed, white-fleshed and orange-fleshed) currently cultivated and consumed in Ethiopia.

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II. Materials and Methods

a) Description of the sampling area and sampling methods

The plant stems and leaves, storage root skin and flesh color of three sweet potato cultivars collected from Areka Agricultural Research Center which are used for current study were shown in Figure 2.1a, b and c.

Koka-6 variety Falaha variety Kulfo variety

Figure 2.1a : Three sweet potato varieties stems and leaves

Koka-6 variety Falaha variety Kulfo variety

Figure 2.1b : Sweet potato varieties storage root skin colors

Koka-6 variety Falaha variety Kulfo variety

Figure 2.1c : Sweet potato varieties storage root flesh colors

(Photographs by author)

b) Experimental study setting

A laboratory experiment was conducted at the laboratories of Addis Ababa University of Food Science and nutrition program and Ethiopian Health and Nutrition Research Institute.

c) Preparation of sweet potato flour

Flour from sweet potato was prepared based on the method described by Adeleke and Odedeji (2010) and shown in figure 2.2. In the laboratory, within 24 hours of harvesting for all varieties root samples with all root sizes were carefully selected and mixed separately for purpose of including all size in the study. The selected samples were manually cleaned by hand followed with clean water to remove adhering materials and soils. Then the cleaned samples were divided in to two parts for further operation. One portion was hand peeled and submerged in water to avoid enzymatic browning and then sliced to uniform thickness using a stainless steel knife. The slices were blanched in hot water ($80^0{}_C$) for 5 minutes in order to inactivate enzymes that may cause browning reaction and followed by immediate cooling in cold water to avoid further cooking (Eluagu and Onimawo, 2010). The cooled slices were then drained on perforated plastic tray. The slices were dried in a hot air oven (drying oven model, DHG-9055A) at 60^0c until the chips were brittle and easy to be milled (overnight). The dried samples were milled into fine powder using electric grinder (High-Speed sampling machine model- FW100) until to pass through 0.425mm sieve. Sample preparation for second portion was the same as above except that the cleaned samples were unpeeled.

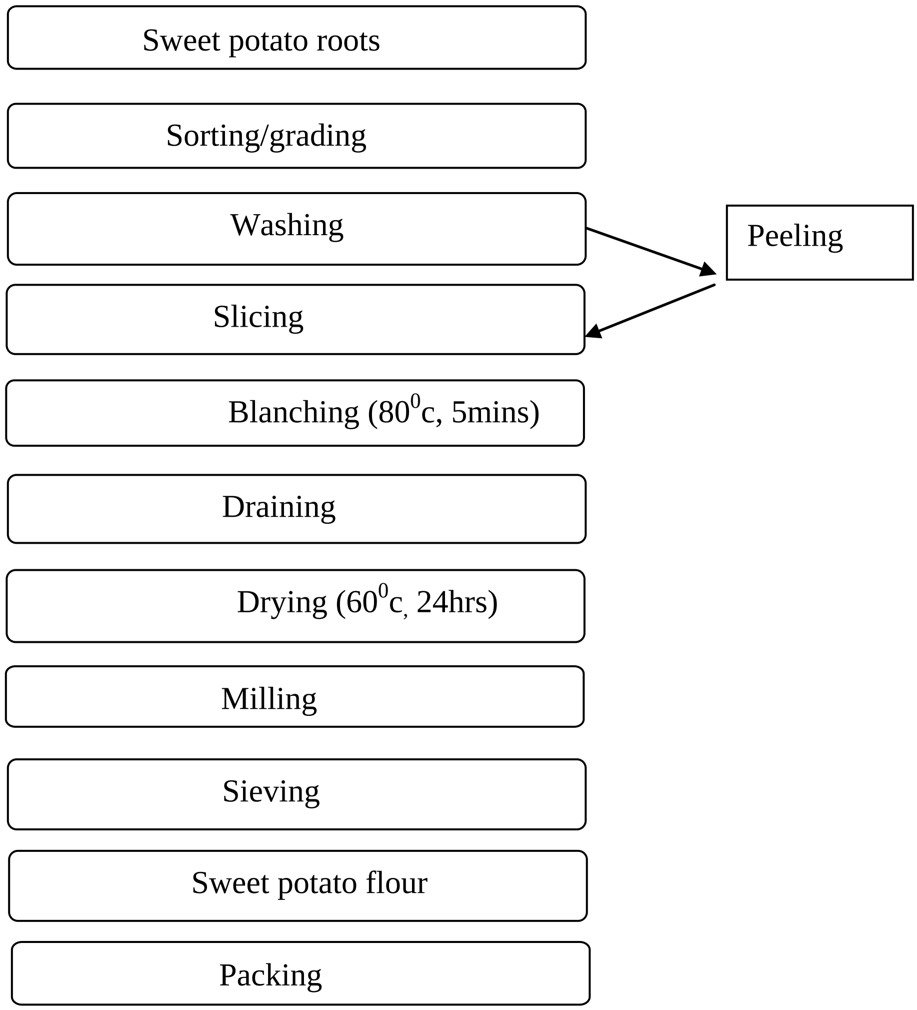

Figure 2.2 : Flow chart for the preparation of sweet potato flour

d) *Methods of Analysis*

i. *Proximate analysis*

The moisture content was determined according to AOAC (2000) using the official method 925.09 by oven drying. Crude fiber content was determined according to AOAC (2000) using official method 962.09. Protein content was determined according to AOAC (2000) using the official method 979.09. Total ash content was determined according to AOAC (2000) using the official method 923.03.The crude fat content was determined according to AOAC (2000) using official method 4.5.01. Total carbohydrate content was calculated by difference using the formula as follows: Carbohydrate (%) = 100 – (% crude protein + % crude fiber + % total ash + % crude fat)

Total energy content was obtained using Atwater conversion factors 4, 9 and 4 for each gram of crude protein, crude fat and carbohydrate and expressed in calories, respectively (Guyot *et al*., 2007).

$$\text{Total energy}\left(\frac{\text{Kcal}}{100\text{g}}\right) = (9 \times \%\text{Fat}) + (4 \times \%\text{Protein}) + (4 \times \%\text{Carbohydrate})$$

ii. *Mineral Analysis*

Calcium, magnesium, iron and zinc were determined according to the standard method of AOAC (2000) using an Atomic Absorption Spectrophotometer (Varian SAA-20 Plus). Phosphorus was determined using UV-VIS spectrometer.

iii. *Analysis of anti-nutritional factors*

Phytate content was determined using method described by Latta and Eskin (1980) and later modified by Vaintraub and Lapteva (1988).Tannin content was determined using the method of Burns (1971) as modified by Maxson and Rooney (1972).Oxalate content of sample was determined using method originally employed by Ukpabi and Ejidoh (1989).

e) *Statistical analysis*

Data for nutritional and anti-nutritional factors of yellow, white and orange sweet potato cultivars in their roots unpeeled and peeled conditions were analyzed with two-way ANOVA to evaluate the effects of variety and processing. Mean differences were statically significant at $p<0.05$ and the means of each parameter were compared using Duncan's multiple range test procedures to separate the means using SPSS, version 15.0 software.

III. Results and Discussions

a) *Proximate composition of yellow, white and orange fleshed sweet potatoes*

Table 3.1 : Proximate composition (g/100g)

Variety	Moisture*	Protein	Fat	Fiber	Ash	CHO**	Energy***
UYSP	71.73 ± 0.05^{d}	6.50 ± 0.05^{a}	0.49 ± 0.02^{d}	6.65 ± 0.00^{a}	3.49 ± 0.09^{d}	82.88 ± 0.16^{e}	361.86 ± 0.30^{d}
UWSP	72.45 ± 0.03^{c}	4.60 ± 0.10^{b}	0.53 ± 0.03^{d}	5.24 ± 0.01^{b}	4.84 ± 0.05^{a}	84.79 ± 0.22^{d}	368.12 ± 0.20^{c}
UOSP	76.97 ± 0.23^{a}	2.84 ± 0.41^{cd}	1.00 ± 0.07^{b}	4.52 ± 0.01^{c}	4.94 ± 0.04^{a}	86.72 ± 0.30^{c}	373.97 ± 1.87^{b}
PYSP	68.58 ± 0.45^{f}	4.41 ± 0.07^{b}	0.66 ± 0.00^{c}	3.59 ± 0.08^{e}	3.04 ± 0.04^{e}	88.32 ± 0.04^{ab}	376.90 ± 0.20^{a}
PWSP	70.51 ± 0.60^{e}	3.46 ± 0.01^{c}	0.72 ± 0.01^{c}	2.94 ± 0.09^{f}	4.04 ± 0.05^{c}	88.86 ± 0.14^{a}	375.65 ± 0.45^{ab}
POSP	74.84 ± 0.13^{b}	2.48 ± 0.24^{d}	1.12 ± 0.01^{a}	3.83 ± 0.06^{d}	4.33 ± 0.03^{b}	88.01 ± 0.04^{b}	373.05 ± 0.25^{b}

*Reported values are the mean ±SE (n=2). Means with different letters in the same column are significantly different (P<0.05). NB: UYSP & PYSP (Unpeeled and peeled Yellow Sweet Potato), UWSP & PWSP (Unpeeled and peeled White Sweet Potato) and UOSP & POSP (Unpeeled and peeled Orange Sweet Potato), respectively. *Wet basis, **Total Carbohydrate, *** in Kcal/100g.*

i. *Moisture content*

The moisture content of three sweet potato varieties was significantly affected ($P<0.05$) by processing and variety but their interaction did have a non significant effect. The mean values for moisture content among three sweet potato cultivars with two processing methods (Table 3.1) showed statistically significant variations; ranged from 71.73-76.97 and 68.58-74.84g/100g for unpeeled and peeled conditions, respectively. According to the result of statistical analysis, the mean moisture content of orange sweet potato variety was significantly ($P<0.05$) higher than that of both yellow and white sweet potato varieties in both unpeeled and peeled conditions. Similarly, mean moisture content of white sweet potato variety was significantly ($P<0.05$) higher compared to the mean moisture content of yellow sweet potato variety in both unpeeled and peeled conditions.

On the other hand, peeling was significantly decreased ($P<0.05$) the mean moisture content of all three sweet potato varieties. This may be higher amount of water is contained in outer skin layer than that of inner flesh layer of sweet potato roots. Results considering moisture in the present study are in the same line and comparable with works of (ENV/JM/MONO, 2010 and Purcell *et al.* 1989). The reason for the observed differences in moisture content of samples in the present study from earlier works could be attributed to the variety difference, the climate, the type of soils and others factors while the observed differences in moisture content in the current study might be contributed by variety difference.

ii. *Crude protein content*

The crude protein content of three sweet potato varieties was significantly affected ($P<0.05$) by processing, variety and their interaction. As it can be seen from statistical analysis (Table 3.1), significant differences ($p<0.05$) exist between the protein content of the three sweet potato cultivars and the value ranged from 2.84-6.50g/100g in unpeeled and 2.48-4.41g/100g in peeled conditions. The crude protein content of yellow sweet potato variety was significantly ($P<0.05$) higher than that of white and orange sweet potato varieties in both unpeeled and peeled conditions. Similarly, the mean crude protein content of white sweet potato variety was significantly ($P<0.05$) higher compared to the mean crude protein content of orange sweet potato variety in both unpeeled and peeled cases. Such observed differences in crude protein content in the current study might be contributed by cultivars or genetic difference, since all the studied varieties were collected from the same environment and soil type. These results are well agreed within the range of values (1.73 to 11.8%) that had been reported by (Purcell *et al.*, 1989). It was observed that peeling decreases the mean crude protein contents of the three sweet potato varieties; this may be higher amount of protein is accumulated in outer skin layer than that of inner flesh layer of sweet potato roots. Similar results had been reported by (William *et al.*, 1984; ENV/JM/MONO, 2010).

iii. *Crude fat content*

It was observed that the crude fat content is generally low in all investigated sweet potato cultivars; a similar idea had been reported by Boggess *et al.* (1971). The crude fat content of the three sweet potato varieties was indicated to be significantly affected (P<0.05) by processing and variety but not in their interaction. Result in Table 3.1 shows that the mean fat content of three sweet potato cultivars was significantly varied and the mean value ranged from 0.49-1.00g/100g in unpeeled and 0.66-1.12g/100g peeled conditions. The observed value of crude fat in yellow, white and orange sweet potato varieties were 0.49, 0.53 and 1.00g/100g and 0.66, 0.72 and 1.12g/100g in unpeeled and peeled roots, respectively. The mean crude fat content of orange sweet potato variety was significantly (P<0.05) higher than that of both yellow and white sweet potato varieties in their unpeeled and peeled cases. Yellow sweet potato cultivar contain lower level of mean crude fat content than that of white sweet potato cultivar in both unpeeled and peeled states but the value was not significantly different (P>0.05). This observed difference among the three sweet potato cultivars may be contributed by genetic variation, since other factors are kept constant.

On the other hand, the mean crude fat content was observed to be significantly higher (P<0.05) in peeled than that of unpeeled sweet potato root in all their corresponding varieties. This might be dietary fat more accumulated in inner flesh layer than that of outer skin layer of sweet potato roots though biological processes. This result was similar with reported value of ENV/JM/MONO (2010).

iv. *Crude fiber content*

The crude fiber content of three sweet potato varieties was significantly affected (P<0.05) by processing, variety and their interaction. It was observed that the mean crude fiber content of three sweet potato cultivars was significantly varied (Table 3.1) and the mean value ranged from 4.52-6.650g/100g for unpeeled and 2.94-3.83 g/100g for peeled roots. The mean fiber content of yellow, white and orange sweet potato varieties was 6.65, 5.24 and 4.52g/100g and 3.59, 2.94 and 3.83g/100g for unpeeled and peeled roots, respectively. The mean crude fiber content of yellow sweet potato variety was significantly (P<0.05) higher than that of both white and orange sweet potato varieties in unpeeled condition but the value was significantly (P<0.05) higher in orange sweet potato variety than that of both white and yellow sweet potato varieties in peeled condition. The result also indicated that the mean crude fiber content of white sweet potato variety was significantly (P <0.05) higher compared to the mean value of orange sweet potato variety for unpeeled and was significantly (P <0.05) lower for peeled case. On the other hand, processing conditions were indicated that the mean crude fiber value was significantly higher (P<0.05) in unpeeled sweet potato root than that of peeled sweet potato root in all their corresponding varieties. This might be more dietary fiber accumulated in outer skin layer than that of inner flesh layer of sweet potato root. A similar finding had been reported by ENV/JM/MONO (2010).

v. *Total ash content*

The mean ash value of yellow, white and orange sweet potato varieties was 3.49, 4.84 and 4.94g/100g and 3.04, 4.04 and 4.33g/100g for unpeeled and peeled roots, respectively(Table 3.1). The mean total ash content of yellow sweet potato variety was significantly (P<0.05) lower than that of both white and orange sweet potato varieties in both unpeeled and peeled roots. Orange sweet potato cultivar has the highest mean ash content than that of white and yellow sweet potato cultivars in both unpeeled and peeled conditions but significant difference was not observed in unpeeled root of orange and white sweet potato cultivars. In considering effect of processing, similar trend was observed like in fiber; the mean ash content was significantly higher (P<0.05) in unpeeled sweet potato root than that of peeled sweet potato root in all their corresponding varieties. This might be either more inorganic matter is accumulated in outer skin layer than that of inner flesh layer in storage sweet potato root or some inorganic matter that adhered the skin layer of root might be contributed during processing.

vi. *Total carbohydrate content*

The total carbohydrate content was determined by difference. The total carbohydrate content of three sweet potato varieties was significantly affected (P<0.05) by processing, variety and their interaction. All the investigated sweet potato cultivars were significantly varied (Table 3.1.) in their carbohydrate content and the mean value ranged from 82.88-86.72g/100g in unpeeled and 88.01- 88.86g/100g in peeled conditions. The mean carbohydrate content of yellow, white and orange sweet potato varieties was 82.88, 84.79 and 86.72g/100g and 88.32, 88.86 and 88.01g/100g for unpeeled and peeled roots, respectively. The mean carbohydrate content of orange sweet potato variety was significantly (P<0.05) higher than that of both yellow and white sweet potato varieties in case of unpeeled root samples while white sweet potato variety has the highest carbohydrate content in peeled condition. A similar idea had been reported by Collins and Walter (1982) that most of the dry matter (85 to 90%) of the sweet potato was carbohydrate. Effect of processing also showed that peeling was significantly increased (P<0.05) the mean carbohydrate content of three sweet potato varieties. These observed variations might be result from the difference in the protein, fat, ash and fiber content of varieties and processing.

vii. *Total energy content*

The energy content of three sweet potato varieties was found significantly influenced (P<0.05) by processing, variety and their interaction. All the investigated sweet potato cultivars were significantly varied (Table 3.1) in their energy content and the mean value ranged from 361.86-373.97Kcal/100g in unpeeled and 373.05-376.90Kcal/100g in peeled root samples. The mean energy content of orange sweet potato variety was significantly (P<0.05) higher than that of both yellow and white sweet potato varieties in unpeeled root samples while the lowest value was obtained in yellow sweet potato in the same condition. In peeled condition, the highest and lowest mean energy content was observed in yellow and orange sweet potato varieties, respectively even though significant difference was not observed between yellow and white and orange and white sweet potato cultivars.

Similarly carbohydrate, the energy contents in all investigated sweet potato cultivars were high. Thus, the principle use of sweet potato like other starchy root and tuber crops as human food and animal feed is therefore as a source of dietary energy yielding ingredients (Philip, 1991). Effect of processing also revealed that peeling was significantly increased (P<0.05) the mean energy content of all the studied sweet potato cultivars. The observed variations in energy content in variety and processing may be contributed from the difference in the protein, fat and fiber content of varieties and processes.

b) *Mineral composition of yellow, white and orange fleshed sweet potatoes*

i. *Calcium content*

The calcium content of three sweet potato varieties was significantly affected (P<0.05) by processing, variety and their interaction. All the investigated sweet potato cultivars were significantly varied (Table 3.2) in their calcium content and the mean value ranged from 7.42-47.04mg/100g and 5.28-45.54mg/100g in unpeeled and peeled root samples, respectively. The mean calcium content of orange sweet potato variety was significantly (P<0.05) higher than that of both yellow and white sweet potato varieties in both unpeeled and peeled conditions while yellow sweet potato variety contains the lowest in both unpeeled and peeled cases. This variation might be contributed by cultivar difference. A similar idea had been reported by Elkins (1979) and Lopez *et al.* (1980). In some sweet potato cultivars, high level of average calcium (78.6mg/100g) content had been reported by (Purcell *et al.,* 1989). The observed variation between average range value of calcium content in this result and earlier finding might be attributed by cultivars, climate, soil types, location and other factors (Serge, 1996).

On the other hand, effect of processing revealed that peeling was significantly decreased (P<0.05) the mean calcium content of all studied sweet potato varieties. This result is expected because higher value of average ash content was observed in the outer skin layer of sweet potato root than that of inner flesh layer during proximate study currently; hence ash is indicative of the amount of minerals contained in any food sample (Olaoye *et al.,* 2007). Moreover, there might be either more inorganic matter is accumulated in outer skin layer than that of inner flesh layer in storage sweet potato root or some minerals that are adhered with the outer layer of the root from the soil may be attributed calcium during processing.

ii. *Iron content*

The iron content of three sweet potato varieties was significantly affected (P<0.05) by processing, variety and their interaction. The mean values for iron content among three sweet potato cultivars with different processing methods (Table 3.2) showed statistically significant variations; ranged from 11.51-15.26mg/100g in unpeeled and 8.70-11.45mg/100g in peeled root samples. The mean iron content of orange sweet potato variety was significantly (P<0.05) higher than that of both yellow and white sweet potato varieties in unpeeled and peeled root samples. Similarly as calcium, yellow sweet potato variety contains the lowest iron content in both unpeeled and peeled cases. A similar finding had been reported by Elkins (1979) and Lopez *et al.* (1980). In some sweet potato varieties, low level of iron (1.72mg/100g) content had been reported by (Purcell *et al.,* 1989). This variation might be for the same reasons of calcium content that was mentioned above. The unpeeled root samples contain high level of iron content than that of peeled root samples in all investigated sweet potato cultivars; this might be for similar reasons that are mentioned in calcium content.

Table 3.2 : Mineral composition (mg/100g) of yellow, white and orange sweet potatoes

Variety	Calcium	Phosphorus	Iron	Zinc	Magnesium
UYSP	7.42 ± 0.01^{d}	19.22 ± 0.01^{e}	11.51 ± 0.02^{c}	1.14 ± 0.01^{c}	5.86 ± 0.11^{a}
UWSP	7.95 ± 0.02^{c}	24.50 ± 0.01^{a}	13.35 ± 0.01^{b}	1.97 ± 0.01^{a}	5.98 ± 0.025^{a}
UOSP	47.04 ± 0.05^{a}	22.11 ± 0.01^{b}	15.26 ± 0.02^{a}	1.30 ± 0.01^{b}	3.00 ± 0.075^{b}
PYSP	5.28 ± 0.01^{f}	15.70 ± 0.10^{f}	8.70 ± 0.01^{f}	0.68 ± 0.01^{f}	UD
PWSP	6.04 ± 0.01^{e}	21.80 ± 0.01^{c}	9.69 ± 0.01^{e}	0.79 ± 0.01^{e}	UD
POSP	45.54 ± 0.01^{b}	20.67 ± 0.01^{d}	11.45 ± 0.01^{d}	0.93 ± 0.02^{d}	UD

Reported values are the mean ±SE (n=2). Means with different letters in the same column are significantly different (P<0.05). NB: UYSP & PYSP (Unpeeled and peeled Yellow Sweet Potato), UWSP &PWSP (Unpeeled and peeled White Sweet Potato) and UOSP & POSP (Unpeeled and peeled Orange Sweet Potato), UD (undetected).

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iii. *Zinc content*

The zinc content of three sweet potato varieties was significantly affected (P<0.05) by processing, variety and their interaction. All the investigated sweet potato cultivars were significantly varied (Table 3.2) in their zinc content and the mean value ranged from 1.14-1.97mg/100g in unpeeled and 0.68-0.93mg/100g in peeled condition. White and orange sweet potato cultivars contain the highest zinc content in unpeeled and peeled conditions, respectively while yellow sweet potato variety contains the lowest zinc content in both unpeeled and peeled conditions. Zinc content is generally low in all investigated sweet potato cultivars. Similar to other minerals, peeling was significantly decreased (P<0.05) the mean zinc content of all studied sweet potato varieties even though the zinc content in both unpeeled and peeled cases can be considered low. A similar result had been reported by ENV/JM/MONO (2010) that sweet potato contains higher level of zinc in unpeeled (1.30mg/100g) condition than that of peeled (0.6–1.2mg/100g) condition.

iv. *Phosphorus content*

The phosphorus content of three sweet potato cultivars was significantly influenced (P<0.05) by processing, variety and their interaction. The mean values for phosphorus content among three sweet potato cultivars with different processing methods (Table 3.2) was indicated statistically significant variations; ranged from 19.22-24.50mg/100g in unpeeled condition and 15.70-21.80mg/100g in peeled condition. White sweet potato cultivar had the highest value of phosphorus content in both unpeeled and peeled conditions while the lowest value was observed in yellow sweet potato variety in both unpeeled and peeled root samples. A similar finding had been reported by Elkins (1979) and Lopez *et al.* (1980) that the level of phosphorus content is varied from cultivar to cultivar and the observed average value was 39.2-48.9(mg/100g). In some sweet potato cultivars, high level of average phosphorus(115.4 mg/100g) content had been reported by (Purcell *et al.,* 1989). On the other hand, peeling was significantly decreased (P<0.05) the mean phosphorus content of all studied sweet potato varieties; a similar idea was observed by ENV/JM/MONO (2010). This variation may be contributed by similar reasons that are discussed above for other minerals.

v. *Magnesium content*

The magnesium content of three sweet potato varieties was determined only in their root samples unpeeled cases (due to shortage of materials) and the mean value ranged from 3.00-5.98mg/100g. The mean magnesium content of orange sweet potato variety was significantly (P<0.05) lower than that of both yellow and white sweet potato varieties. On the other hand, white sweet potato variety contains higher level of mean magnesium value than that of yellow sweet potato variety but the value was not significantly different (P>0.05) from each other. Generally, the magnesium content of all varieties in this investigation can be considered low next to zinc among the above discussed minerals. A similar idea had been reported by Elkins (1979) and Lopez *et al.* (1980) that the level of magnesium content is varied from cultivar to cultivar and the observed average value was18.3-22.2 (mg/100g). In some sweet potato cultivars, the level of average magnisium (12.20-30.40mg/100g) content had been reported by Ukom *et al.,* (2009). The variations in magnesium content might be contributed cultivars, climate, soil types, location and other factors.

c) *Anti-nutritional factors of yellow, white and orange fleshed sweet potato cultivars*

i. *Phytate and phytate mineral molar ratio*

Results of statistical analysis show that the phytate content of three sweet potato cultivars was significantly affected (P<0.05) by processing, variety and their interaction. The mean values for phytate content among three sweet potato cultivars with different processing methods (Table 3.3) indicated statistically significant variations; ranged from 93.37-111.43mg/100g in unpeeled and 49.35-78.38mg/100g in peeled root samples. The mean phytate content of yellow sweet potato variety was significantly (P<0.05) higher than that of both orange and white sweet potato varieties in both unpeeled and peeled conditions while significantly the lowest value was observed in white sweet potato cultivar in both unpeeled and peeled conditions. This variation might be attributed by cultivar difference, since all studied sweet potato cultivars were collected from the same environment.

On the other hand, peeling was significantly decreased (P<0.05) the mean phytate content of all studied three sweet potato cultivars. This is expected because more phosphorus is accumulated in the outer skin layer of sweet potato root than that of inner flesh layer; hence phytate is natural occurring phosphorus compound.

The mean value of phytate: calcium molar ratio in the present study was 0.91, 0.90, 0.74 and 0.51 for unpeeled yellow sweet potato, peeled yellow sweet potato, unpeeled white sweet potato and peeled white sweet potato cultivars, respectively which were higher than the reported critical molar ratio (0.24) of phytate: calcium, indicating that absorption of calcium was adversely affected by phytate in these roots. But in case of both unpeeled (0.12) and peeled (0.11) orange sweet potato variety, the value was found lower than the reported critical molar ratio of phytate: calcium, indicating that absorption of calcium was not adversely affected by phytate in orange sweet potato roots. However, sweet potato root is consumed in its boiled

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state; this might reduce phytate level and enhance the bioabilability of calcium in yellow and white sweet potato varieties. All other calculated molar ratios in this study such as; Phytate: iron, phytate: zinc and [phytate x calcium]: zinc molar ratios for all sweet potato varieties in their unpeeled and peeled conditions were found less (Table 3.3) than their reported critical values, this indicates that absorption of iron and zinc from all studied sweet potato varieties were not inhibited by phytate and as a result these minerals in all roots are bioavailabile.

ii. *Oxalate content*

The oxalate content of three sweet potato cultivars was investigated only in unpeeled case (due to shortage of materials) and the mean value ranged from 3.50-8.80mg/100g (Table 3.3). The mean oxalate content of yellow sweet potato variety was significantly (P<0.05) higher than that of both orange and white sweet potato varieties. Similarly, the mean oxalate content of orange sweet potato variety was significantly (P<0.05) higher than that of white sweet potato varieties. This observed variation among three sweet potatoes might be attributed by cultivar difference. Oxalates can have a harmful effect on human nutrition and health, especially by reducing calcium absorption and aiding the formation of kidney stones (Noonan and Savage, 1999). However, the oxalate level observed in this study is low and also in recommended range for patients with calcium oxalate kidney stones if they consume up to 600g of any studied sweet potato cultivars per day; as patients are advised to limit their intake of foods with a total intake of oxalate not exceeding 50–60 mg per day (Massey *et al*., 2001).

Oxalate like phytate binds minerals such as calcium and magnesium and interfere with their metabolism. The importance of oxalate content of an individual plant product in limiting total dietary calcium availability is of significance only when the ratio of oxalate: calcium is greater than one (Frontela *et al*., 2009). Under this circumstance, the oxalate has potential to complex, not only the calcium contained in the plant, but also that derived from other food sources (Davis and Olpin, 1979). The oxalate: calcium values of YSP, WSP and OSP was 0.53, 0.20 and 0.06, respectively. These values were lower than the reported critical molar ratio (1.0) of oxalate: calcium, indicating that absorption of calcium not adversely affected by oxalate in all studied sweet potato varieties.

Table 3.3 : Anti-nutritional factors (mg/100g) and phytate mineral molar ratios of yellow, white and orange fleshed sweet potato varieties

Variety	Phytate	Oxalate	Tannin	Phy:Ca	Phy:Fe	Phy:Zn	[PhyxCa]:Zn
UYSP	111.43±0.04[a]	8.80±0.02[a]	34.38	0.91±0.001[a]	0.83±0.005[a]	9.67±0.8[b]	0.018±0.005[b]
UWSP	93.37±0.01[c]	3.50±0.04[c]	B.D.L	0.71±0.001[b]	0.59±0.00[c]	4.70±0.0[f]	0.01±0.00[b]
UOSP	95.15±0.09[b]	5.71±0.08[b]	B.D.L	0.12±0.00[d]	0.53±0.00[d]	7.39±0.19[d]	0.09±0.005[a]
PYSP	78.38±0.01[d]	UD	B.D.L	0.90±0.00[a]	0.77±0.005[b]	11.90±0.00[a]	0.015±0.005[b]
PWSP	49.35±0.03[f]	UD	B.D.L	0.51±0.005[c]	0.46±0.03[e]	6.53±0.29[e]	0.01±00[b]
POSP	77.75 ±0.01[e]	UD	B.D.L	0.11±0.005[e]	0.58±0.005[c]	8.15±0.28[c]	0.10±0.005[a]

Reported values are the mean ±SE (n=2). Means with different letters in the same column are significantly different (P<0.05). NB: UYSP& PYSP (Unpeeled and peeled Yellow Sweet Potato), UWSP&PWSP (Unpeeled and peeled White Sweet Potato) and UOSP&POSP (Unpeeled and peeled Orange Sweet Potato), UD (undetected), B.D.L (below detection levels).

iii. *Tannin content*

The mean value of tannin content was 34.38 mg/100g in unpeeled yellow sweet potato cultivar and the value was below detection level in unpeeled and peeled white sweet potato variety, unpeeled and peeled orange sweet potato variety and peeled yellow sweet potato variety (Table 3.3). This result indicates that the level of tannin content is absent or insignificant in three investigated sweet potato cultivars except unpeeled condition of yellow sweet potato variety. It was also observed that tannin is accumulated in the outer skin layer of yellow sweet potato variety and it was removed by peeling with the outer skin layer of the root (Table 3.3). The presence of tannin only in yellow sweet potato variety might be contributed by the presence of polyphenolic compound such as flavonoids (quercetin, $C_{15}H_{10}O_{7}$) which found in yellow sweet potato varieties (Guan *et al.,* 2006) and the absence of tannin in white and orange sweet potato varieties might be lack of these compounds in their roots.

The beneficial or anti-nutritional property of tannin depends on its amount in the diet. The toxicity effects of the tannin may not be significant since the total acceptable tannic acid daily intake for a man is 560 mg (Anonymous, 1973). The current result shows that if a man daily consumes up to 1900 grams of unpeeled yellow sweet potato roots and any amount of unpeeled and peeled white sweet potato, unpeeled and peeled orange sweet potato and peeled yellow sweet potato roots, the level of tannin in these roots will not cause the toxicity effect to man.

IV. Conclusion and Recommendations

a) Conclusion

This study has covered information on the nutritional and anti-nutritional status of yellow, white and orange fleshed sweet potato cultivars in their raw roots unpeeled and peeled conditions. The result showed that the nutritional and anti-nutritional contents of three sweet potato varieties were significantly varied due to cultivar variation, processing conditions and their interactions. Orange sweet potato variety contains the highest level of moisture, fat, ash, carbohydrate, energy, calcium and iron in unpeeled condition and fiber, moisture, fat, ash, calcium, iron and zinc in peeled condition. The protein content was least in orange sweet potato cultivar in both conditions. Yellow sweet potato variety contains the highest level of protein, phytate, phytate: calcium, Phytate: iron and Phytate: zinc molar ratios in both unpeeled and peeled conditions while fiber, oxalate and tannin value was highest in unpeeled condition. White sweet potato variety contains the highest and lowest levels of phosphorus and phytate in both unpeeled and peeled conditions and it was found in intermediate position for other nutrients. On the other hand, peeling was decreased the levels of moisture, protein, fiber, ash, carbohydrate, calcium, phosphorus, iron, zinc and phytate and increased the other parameters such as fat, carbohydrate and energy contents in their corresponding varieties. Among three sweet potato cultivars, this result has indicated that orange sweet potato variety is potentially good source of nutrients compared to other sweet potato varieties.

b) Recommendations

- Since orange sweet potato variety is potentially good source of nutrients among three sweet potato varieties, more emphasis should be given for its cultivation in agricultural sectors as well as farmers land.
- It is highly recommended that sweet potato roots should be consumed in its unpeeled state provided that peeling of sweet potato roots removes most of nutrients that are important to human health.

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