

Sweet potato varietal evaluation trial for food nutritional values

Abstract:

Aim: To explore the nutrient, mineral, beta carotene and total carotenoid capabilities of five varieties of sweet potato.

Study design: The sweet potato vines at six week stage were cut into 1.2m each and transplanted in parallel lines on the same 1.2m by 2.6m bed, spaced about 0.52m from each other in Dukumah Garden. There were five such beds and vine cuttings were transplanted in the same order on each bed. **Study Site:** The study, which took four months, was conducted in Dukumah Garden in Bolgatanga Municipality (10.7875° N, 0.8580° W) of the Upper East Region of Ghana.

Methodology: The sweet potatoes were harvested after four months after transplanting on the same day. Samples of the various varieties were taken, parceled, appropriately labelled and hand delivered to the Food Chemistry laboratory of Kwame Nkrumah University of Science and Technology for the following analysis:

- i. Proximate analysis in percentages (%).
 - ii. Total carotenoids and beta carotene in milligrams per gram (mg/g) and
 - iii. Concentration of the minerals Magnesium (Mg), Sodium (Na), Potassium (K), Calcium (Ca) Iron (Fe) and Zinc (Zn) in milligrams per kilogram (mg/kg).
- Results:** All five

varieties of sweet potato are nutritious. Protein content ranges from 3.82% in Agric white variety to 0.11% in Agric orange flesh. Fat, from 4.84% in orange flesh variety to 1.74% in red skin. Crude fibre content was between 1.77% in Agric orange flesh and 0.10% in T.U. purple. Total carbohydrate, from 23.2% in Agric orange flesh variety to 15.8% in Agric white one. Moisture is high in all the varieties, ranging from 75.78% in Agric white variety to 71.04% in Orange flesh one. The orange flesh variety has the highest ash content of 1.56%.

27 All the varieties contain high concentrations of Mg but low concentrations of Na and K. The
 28 highest concentration of Ca (8250.70 ± 0.062 mg/kg) was recorded by T.U. purple. The
 29 concentrations of Fe in the sweet potato varieties decreases in the order: T.U. purple>Red
 30 skin>Orange flesh>Agric orange flesh>Agric white. The highest Zn concentration of
 31 123.12 ± 0.004 mg/kg in orange flesh variety and lowest (33.10 ± 0.002 mg/kg) in Agric white
 32 was observed. The concentration of beta carotene (mg/kg) in five sweet potato varieties
 33 increases in the order Agric orange flesh<<Agric white<Red skin<Orange flesh<T.U. purple.
 34 **Conclusion:** The five varieties of sweet potato are rich in proteins, total carbohydrates and
 35 fats. They are observed with variability in macro- and micronutrients, beta carotene and total
 36 carotenoids. T.U. purple variety was identified with richest source of Ca and beta carotene.
 37 The varieties of sweet potato may thus be of considerable importance in ameliorating
 38 nutrient, mineral as well as beta carotene malnutrition in resource poor areas of developing
 39 countries.
 40 **Key words:** sweet potato varieties, nutrient, minerals, beta carotene.

41 1.0 Introduction

42 Varieties of *Ipomea batatas*, commonly called sweet potatoes, are recognizable by the
 43 different skin colors of white, cream, yellow, orange, pink, red or purple and / or flesh colors
 44 of white or cream, yellow, orange or purple ([1]; [2]). The vegetable tuber crop, sweet potato
 45 ranks among the top five most important staple food crops in the world, including rice, wheat,
 46 maize and cassava. Sweet potatoes are rich not only in the major minerals such as potassium
 47 (K), sodium (Na), calcium (Ca), magnesium (Mg), Sulphur (S) and Phosphorus (P) which are
 48 associated with carbohydrates, proteins and fats but also in vitamins A and C, and the trace
 49 elements; zinc (Zn), manganese (Mn), iron (Fe), Copper (Cu) and Iodine (I) ([3]; [4]; [1]; [5];
 50 [6]; [7]; [8]; [2]). Sweet potato was also known to contain many valuable phytochemicals

51 like phenol-related chlorogenic acid, anthocyanins; antioxidants; anti-cancer chemicals and
52 carotenoids ([9]; [10]).

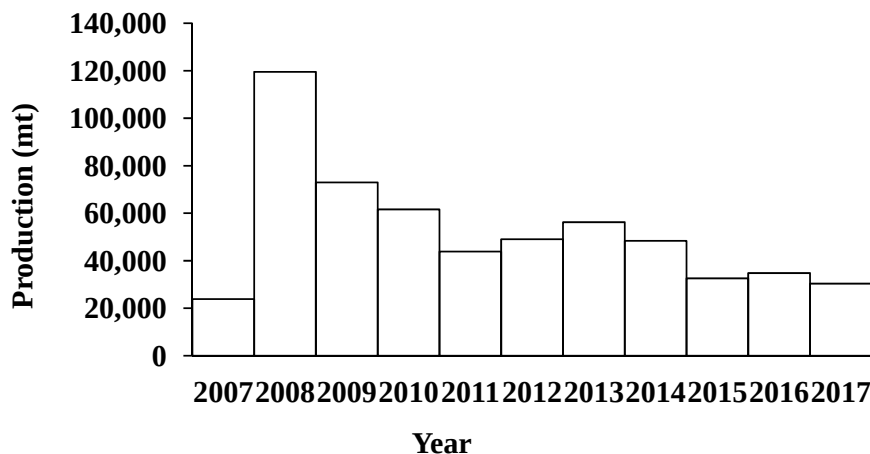
53 Studies have shown that the nutrient or chemical content of crops stem from the soil on which
54 they grow ([1]; [5]; [6]; [7]; [2]). It has also been found out that even when cultivars of the
55 same crop are cultivated adjacent each other under the same edaphic conditions, the
56 concentrations of these nutrients and chemicals still vary in the different varieties. This
57 suggests that the genetic constitution of crops play a role in their nutrient and chemical
58 enrichment [11]

59 According to Mitra [12], sweet potatoes can help to heal from liver injury. They are one
60 among the cheapest biofortified food resources, easily accessed by the average person that
61 help ameliorate nutrient deficient conditions in humans. Their versatility and relative ease of
62 cultivation, impregnation with vitamin A precursors, vitamin C and minerals coupled with
63 rich sources of proteins and carbohydrates enabled their cultivation in more than a hundred
64 countries in the world, though appreciable tonnage is produced in China and other developing
65 countries ([1]; [5]; [6]; [7]; [8]; [12]; [2]; [9]; [10]).

66 Recent world statistical data [13] reported China as the lead producer of sweet potatoes
67 accounting to 70,526,000 metric tons per year, which constitute far more than half (68.6%) of
68 the total global production. Tanzania and Nigeria follow in that order with 3,470,304 metric
69 tons and 3,450,000 metric tons respectively, each sharing a proportion of 3.3% of world's
70 production. Indonesia and Uganda are fourth and fifth in the world in terms of sweet potato
71 cultivation, contributing a combined 4% of total production.

72 Ghana produced 143,111 tons of sweet potatoes in 2016 from an area covering 76,594 ha of
73 land. This constituted a share of 0.1% of total potato production in the world during 2016 and
74 ranked Ghana at number 37 in the world with respect to sweet potato production [14]. The
75 data shows that the production of the crop in Ghana has increased in a decade, given that

76 earlier records, posted a production of 90,000 tons from an area of 65,000 ha ([13] [15]).
77 Bidzakin and co-workers [15] said the Ministry of Food and Agriculture (MoFA) field survey
78 in 2012 reported that in Ghana, upper east is the region with the highest sweet potato
79 cultivation, producing 46,000 metric tons, with 34.9% total production in Ghana, from an
80 area of land covering 5,550 ha, which is 57.7% of total land used for the crop production in
81 Ghana. Northern and upper west regions follow in that order with respect to both the area of
82 land devoted to potato production and the tonnage produced per annum.
83 However, the data from the upper east regional office of the MoFA showed a steady decline
84 in the production of sweet potatoes from 2008 to 2017, after a steep rise in production from
85 2007 to 2008 (Figure 1).



86
87 **Figure 1: Annual production of sweet potatoes in metric tons (mt) from 2007 to 2017.**
88

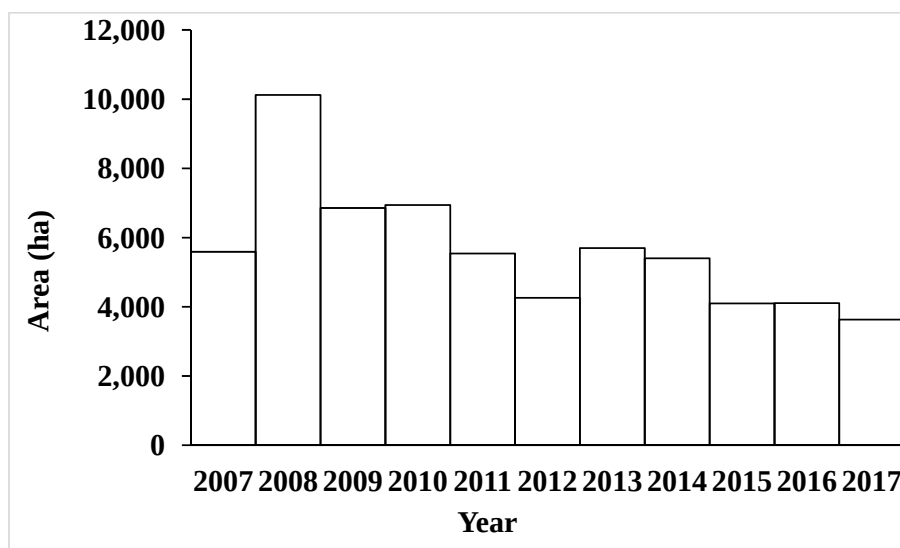


Figure 2: Area of land (ha) used in the production of sweet potatoes from 2007 to 2017

The data also show that farmers progressively devoted less land for cultivation of the crop (Figure 2). Farmers in this region reported lack of planting materials (sweet potato seeds/slips), farm inputs, implements and a ready market to purchase their farm produce to have increased productivity from sweet potato cultivation [15]. This may account for the loss of interest in cultivating this crop. Though provision of above inputs may improve the production, the nutrients available in the crop may encourage the consumption of the crop produced, a major determining factor to increase the demand for the crop thereby enhancing market and increasing sweet potato production. The nutrient contents of different varieties of the crop were investigated and reported by various scientists. However, it has been an established fact that the type and concentration of macro- or micronutrients as well as other phytochemicals in any given crop is dependent on the respective availability and concentration of the same in the soil on which the crop is grown ([1]; [5]; [16]; [6]; [7]; [2]). Thus the same crop grown in different geographic regions may be biofortified with different concentrations of the same or different elements all together. Therefore it is necessary for crops grown in different geographic locations to be analysed to ascertain their nutrient worth

and biofortification with vitamins or minerals which have health benefits. However, the nutrient content of different varieties of a crop can be compared when they are cultivated at the same location with similar soil conditions. The study seeks to find out the proportions of food substances such as crude protein, carbohydrates and fat; total carotenoids and beta carotene as well as some major and minor minerals that reside in the sweet potatoes grown in parts of the upper east region.

2.0 Methodology

2.1 The study site:

The Bolgatanga Municipality (10.7875° N, 0.8580° W) is a developing city (Figures 3 and 4) with a total population of 131,550, more than half (52.3%) of which is females with males constituting 47.7% of the population. About half (50.2%) of the population in the Municipality is rural [17].

The Municipality experiences a longer dry season from October to May and a shorter rainy season which may begin in June or July to end in October. The mean annual rainfall ranges between 600mm and 1400mm. The mean temperature is about 21°C which can rise to 45°C in March or April. The municipality has “upland soil” originating from granite rocks. It is shallow, generally not very fertile in terms of humus enrichment and largely coarse in texture. However, some places on lowlands possess sandy loamy soils with high organic matter content. The effect of these conditions is a natural vegetation comprising mainly of guinea savannah woodland. Plant species are deciduous trees widely spaced and a ground flora, which gets spent due to the scorching by the sun and animal grazing during the long dry season. Eighty percent (80%) of the economically active population engage mainly in subsistent agriculture cultivating maize, millet, guinea-corn, sorghum, rice, groundnuts, beans

of vine cuttings, each line being a variety of sweet potato spaced about 0.52m from each other so that their performance with respect to nutrient content can be compared. Vine cuttings were transplanted in the same order in all five beds. The sweet potatoes were transplanted on 22nd June 2017. Organic manure obtained from Dukuma Garden, prepared by fermenting together rice straw, ground nuts plants parts and cattle dander in a pit over a two year period, was applied evenly to all lines on the same day. Dukumah Garden has sandy loamy soil. No synthetic fertilizer was applied.

2.4 Harvesting and nutrient analysis of sweet potato varieties:

The sweet potatoes were harvested after four months of transplanting, on 22nd October, on the same day. Samples of the various varieties were taken from only one bed, parcelled, appropriately labelled and hand delivered to the Food Chemistry laboratory of Kwame Nkrumah University of Science and Technology for the following analysis ([18] [19]):

i. Proximate analysis in percentages (%):

Moisture content and total solids: oven drying method

5g of each variety sample was transferred to labelled, previously dried and weighed dishes. The latter were placed in an oven thermostatically controlled at 105 degrees for 5 hours. Dishes were removed and placed in a desiccator to cool to room temperature and weighed. They were dried again for 30 minutes, cooled and weighed. Drying, cooling and weighing were repeated until a constant weight was reached. Alternatively, samples were dried in a thermostatically controlled oven for at least 8 hours where a constant weight would be achieved. The determination at least duplicated and the averages found.

Calculations

$$\% \text{moisture (wt/wt)} = \frac{\text{wt H}_2\text{O in sample}}{\text{Wt of wet sample}} \times 100$$

$$\% \text{moisture (wt/wt)} = \frac{\text{wt of wet sample} - \text{wt of dry sample}}{\text{Wt of wet sample}} \times 100$$

177

$$\% \text{total solids (wt/wt)} = \frac{\text{wt of dried sample}}{\text{Wt of wet sample}} \times 100$$

$$\% \text{total solids (wt/wt)} = \frac{\text{wt of dried sample}}{\text{Wt of wet sample}} \times 100$$

180

$$\% \text{total solids (wt/wt)} = \frac{\text{wt of dried sample}}{\text{Wt of wet sample}} \times 100$$

$$\% \text{total solids (wt/wt)} = \frac{\text{wt of dried sample}}{\text{Wt of wet sample}} \times 100$$

183

184 **Ash content:**

185 5g of each variety sample was weighed into a tarred crucible. Samples were pre-dried.

186 Crucibles were placed in cool muffle furnace. Tongs, gloves and protective eyewear

187 were used when the muffle furnace was warm. Test samples were ignited for 2 hours

188 at about 600°C. Muffle furnace Turn off and opened only after the temperature has

189 dropped to at least 250 °C. The door was carefully opened to avoid losing ash that may

190 be fluffy. Using safety tongs, crucibles were quickly transferred to a desiccator with a

191 porcelain plate and desiccant. Desiccator was closed and crucibles allowed to cool

192 prior to weighing.

193 **Calculations**

194

$$\% \text{Ash} = \frac{\text{wt of ash}}{\text{Wt of sample}} \times 100$$

$$\% \text{Ash} = \frac{\text{wt of ash}}{\text{Wt of sample}} \times 100$$

197

$$\% \text{Ash} = \frac{(\text{wt of crucible} + \text{ash}) - \text{wt of empty crucible}}{(\text{wt of crucible} + \text{sample}) - \text{wt of empty crucible}} \times 100$$

$$\% \text{Ash} = \frac{(\text{wt of crucible} + \text{ash}) - \text{wt of empty crucible}}{(\text{wt of crucible} + \text{sample}) - \text{wt of empty crucible}} \times 100$$

Fat content: soxhlet extraction

A 250ml, previously dried (air oven at 100°C) round bottom flask was accurately weighed. 5.0g of dried sample was weighed to 22 ×80mm paper thimble or a folded filter paper. A small piece of cotton or glass wool was placed into the thimble to prevent loss of the sample. 150ml of petroleum spirit B.P 40-60°C was added to the round bottom flask and the apparatus assembled. The condenser was connected to the soxhlet extractor and refluxed for 4 - 6 hours on the heating mantle. After extraction, thimble was removed and solvent recovered by distillation. The flask and fat/oil was heated in an oven at about 103°C to evaporate the solvent. Flask and contents were cooled to room temperature in a desiccator. Flask was weighed and weight of fat/oil collected was determined.

$$\% \text{ FAT (dry basis)} = \frac{\text{fat/oil collected} \times 100}{\text{Weight of sample}}$$

$$\% \text{ FAT (dry basis)} = \frac{(\text{wt of flask + oil}) - \text{wt. of flask} \times 100}{\text{Weight of sample}}$$

Crude fibre determination

2.g sample from crude fat determination was weighed into a 750ml Erlenmeyer flask. 200ml of 1.25% H₂SO₄ was added and flask was immediately set on hot plate and connected to condenser. The contents came to boil within 1 minute of contact with

solution. At the end of 30 minutes, flask was removed and immediately filtered through linen cloth in funnel and washed with a large volume of water. Filtrate (containing sample from acid hydrolysis) was washed back into flask with 200ml 1.25% NaOH solutions. Flask condenser was connected and boiled for exactly 30 minutes. It was then filtered through Fischer's crucible and washed thoroughly with water and 15ml 96% alcohol added. Crucible and contents were dried for 2 hour at 105 °C, cooled in desiccator and weighed. Crucible ignited in a furnace for 30 minutes, cooled and reweighed.

$$\% \text{ Crude fibre} = \frac{\text{weight of crude fibre} \times 100}{\text{Weight of sample}}$$

$$\% \text{ Crude fibre} = \frac{\text{wt of crucible + sample (before - after) ashing} \times 100}{\text{Weight of sample}}$$

Protein determination

Digestion

To the digestion flask, was added 2g of sample and a half of selenium –based catalyst tablets and a few anti-bumping agents. 25ml of concentrated H₂SO₄ was added and the flask shaken so that entire sample is thoroughly wet. Flask placed on digestion burner and heated slowly until boiling ceased and the resulting solution was clear. It was cooled to room temperature. Digested sample solution was transferred into a 100ml volumetric flask and made up to the mark.

Distillation

To flush out the apparatus before use, Distilled water was boiled in the steam generator of the distillation apparatus with the connections arranged to circulate through the condenser, for at least 10 minutes. If the tip of the condenser was beneath the surface of the distillate, the receiving flask was lowered and heating continued for 30 seconds in order to carry over all liquid in the condenser.

25 ml of 2% boric acid was pipetted into 250ml conical flask and 2 drops of mixed indicator added.

The conical flask and its contents were placed under the condenser in such a position that the tip of the condenser is completely immersed in solution. 10ml of the digested sample solution was measured into the decomposition flask of the Kjeldahl unit, fixed and excess of 40% NaOH (about 15-20ml) added to it. The ammonia produced was distilled into the collection flask with the condenser tip immersed in the receiving flask till a volume of about 150ml– 200ml is collected. Before distilling another sample and on completion of all distillations, the apparatus was flushed as stated above. Steam was passed only until 5ml of distillate was obtained.

Titration

The distillate was titrated with 0.1N HCL solution. The acid was added until the solution was colorless. If additional acid was added, the solution turned pink. The nitrogen content, was determine at least in duplicates, and a blank determination run using the same amount of all reagents as used for the sample. The blank corrected for traces of nitrogen in the reagents and including digestion as well as distillation.

Calculation:

$$\% \text{ total nitrogen} = \frac{100 \times (V_a - V_b) \times N_A \times 0.01401 \times 100}{W \times 10}$$

V_a- volume in ml of standard acid used in titration

V_b- volume in ml of standard acid used in blank

N_A- normality of acid

W- Weight of sample taken

Nitrogen free extract (NFE)

Calculation

$$\text{NFE (\%)} = 100 - (\% \text{ moisture} + \% \text{ fat} + \% \text{ crude fibre} + \% \text{ protein} + \% \text{ ash})$$

Carbohydrate

Calculation

$$\text{Carbohydrate (\%)} = \% \text{ crude fibre} + \% \text{ NFE}$$

Or

$$\text{Carbohydrate (\%)} = 100 - (\% \text{ moisture} + \% \text{ fat} + \% \text{ protein} + \% \text{ ash})$$

296

297

298

299 **Carotenoids estimation**

300 The estimation of carotenoids content according to the method, Mackinney
301 (1941) and Maclachan and Zalick (1963), respectively.

302 50mls of acetone was added to about 100mg of the fresh sample in a separating
303 funnel. Mixture was swirled a little and 10ml petroleum ether quantitatively
304 added. The usual liquid – liquid extraction procedure was carried out. The flask
305 was positioned upright in the ring clamp and the stopper removed till there was
306 partitioning. The lower layer was discarded as the upper layer was transferred
307 into a glass test tube.

308 The optical densities (O.D) were read at wavelengths with the help of a UV
309 spectrophotometer.

310 The carotenoids contents were expressed in mg/g fresh sample and calculated
311 according to the formulae given below:

312

313

314 Beta carotene

315
$$= \frac{0.216(OD.663nm) - 0.304(OD.505nm) + 0.452(OD.453) \times V}{d \times 1000 \times W}$$

316
$$d \times 1000 \times W$$

317 Total carotenoids
$$= \frac{7.6(OD.480nm) - 1.49(OD.510nm) \times V}{d \times 1000 \times W}$$

318
$$d \times 1000 \times W$$

319 where,

320 V= final volume of the extract.

321 d= length of light path

322 W= fresh weight of sample

323 O.D= optical density of a given wavelength

324 Concentrations of the minerals; Magnesium (Mg), Sodium (Na), Potassium (K), Calcium

325 (Ca) Iron (Fe) and Zinc (Zn) in milligrams per kilogram (mg/kg) were determined using

326 atomic absorption spectrophotometer, AAS Model Nov AA 400p.

327

328 The five sweet potatoes varieties were coded as follows: Agric Orange flesh (AO), Red Skin

329 (RS), Agric White (AW), Orange flesh (OF) and T.U. Purple (TP).

330

331

332 **2.5 Data analysis Analysis:**

333 **Each treatment (variety)** samples were analysed in duplicates and the average values recorded
334 with standard deviations (SD).

335

336

337 **3.0 Results**

338 **3.1 Colours of the different varieties:**

339 The colours of the five different varieties of sweet potatoes (shown with their vines in plates
340 1 to 5), grown in the Bolgatanga Municipality which have been analysed **are described as**
341 follows: Three varieties **had coloured flesh**. They include Agric orange flesh and Orange
342 flesh which are much alike, having both skin and flesh **in orange** colour and T.U. purple
343 whose skin and flesh are purple. The remaining two varieties are Agric white that has white
344 skin and flesh **while the Red** skin has a red skin but a white flesh.



Plate 1: Agric orange flesh

345



Plate 2: Agric orange flesh

346



Plate 3: Red skin variety

347

348

349



Plate 4: Orange flesh variety

350



Plate: T.U. purple variety

351

352

353



Plate 1: Agric orange flesh



Plate 2: Agric white



Plate 3: Red skin



Plate 4: Orange flesh



Plate 5: T.U. purple

3.2 Proximate analysis:

The proximate composition of the various varieties is shown in Table 1. The results reveal that the Agric white (AW) variety has the highest moisture of 75.79%, protein content of 3.82% and the lowest total carbohydrate content of 15.80%, being 15.69% nitrogen free extract (NFE) and 0.11% crude fibre. The Agric orange flesh (AO) variety, on the other hand, has the lowest protein content of 0.11% but the highest total carbohydrate percentage of 23.20%, being 1.77% crude fibre and 21.43% NFE. The orange flesh variety has the second highest protein proportion of 1.53% after AW, while the latter **also has** the second highest

370 composition of fat (3.37%), after the former (OF), which has the highest lipid composition of
 371 4.84%.

372 **Table 1: Proximate analysis of five varieties of sweet potatoes**

SPV	% Moisture	%Ash	%Crude fibre	%Protei n	%Fat	%NFE	%TC
AO	73.38± 0.65	0.10± 0.00	1.77± 0.04	0.11± 0.03	3.22± 0.40	21.43± 1.03	23.20± 1.07
RS	73.84± 0.45	0.83± 0.00	0.99± 0.03	0.62± 0.04	1.74± 0.10	21.98± 0.48	22.96± 0.51
AW	75.78± 4.30	1.23± 0.01	0.11± 0.00	3.82± 0.03	3.37±0.5 8	15.69± 4.9	15.80± 4.93
OF	71.04± 0.06	1.56± 0.00	0.64± 0.00	1.53± 0.04	4.84± 0.95	20.39± 0.84	21.03± 0.84
TP	74.42± 0.43	0.76± 0.00	0.10± 0.00	0.68±0. 04	2.76±0.6 2	21.29± 1.09	21.38± 1.09

373 SPV: Sweet potato variety, AO: Agric orange flesh, RS: Red skin, AW: Agric white, OF: Orange flesh, TP: T.U. purple

374 NFE: nitrogen free extract, TC: total carbohydrates.

375

376 **Table 2: Mineral composition of the five sweet potato varieties.**

	Concentration in mg/kg					
SPV	Mg	Na	K	Ca	Fe	Zn
AO	13322.4 4±0.10	2810.54 ±0.05	4444.77 ±0.03	6282.49± 0.20	38.47± 0.01	36.49±0. 00
RS	9651.17 ±0.02	1887.24 ±0.10	3711.48 ±0.19	3944.48± 0.13	85.91± 0.01	105.16± 0.00

AW	12253.9 9±0.10	1786.77 ±0.07	4882.07 ±0.08	4704.79± 0.08	7.71±0. 00	33.10±0. 00
OF	13713.4 4±0.07	1669.88 ±0.05	5265.03 ±0.02	4707.05± 0.02	47.62± 0.01	123.12± 0.00
TP	10788.3 1±0.07	2073.07 ±0.10	4382.20 ±0.08	18250.70 ±0.06	101.33 ±0.01	66.35±0. 01

SPV: Sweet potato variety, AO: Agric orange flesh, RS: Red skin, AW: Agric white, OF: Orange flesh, TP: T.U. purple

3.3 Mineral composition of the five sweet potato varieties

Concentrations of four major minerals: magnesium (Mg), sodium (Na), potassium (K), calcium (Ca) and two minor ones: iron (Fe) and zinc (Zn) were presented in Table 2. All five varieties of sweet potatoes contain these elements in varying concentrations in milligrams per kilogram (mg/kg). All the five sweet potato varieties contain Mg in appreciably high concentrations and T.U. purple recorded the highest concentration of Ca (18250.70±0.062 mg/kg) than the other varieties. The rest of the varieties recorded moderate concentrations of Ca. Again, all the varieties contained low concentrations of Na and K. The varieties TP, RS and OR contained comparatively higher concentrations of the two minor minerals (Fe and Zn) than varieties AO and AW.

The variety OF has the highest concentration of Mg (13713.44±0.069 mg/Kg), K (5265.03±0.023mg/kg) and Zn (123.12±0.004 mg/Kg) but has the lowest concentration of Na (1669.88±0.051 mg/kg). The variety RS has the second highest concentration of the minor minerals, Fe (85.91±0.007mg/Kg) and Zn (105.18±0.001mg/Kg) while the variety AO has a concentration of 13322.44±0.098 mg/Kg of Mg and 6282.49±0.200 mg/Kg of Ca. On the other hand, the AW variety has the second highest concentration of K (4882.07±0.078 mg/Kg). The variety TP has the highest concentration of Fe (101.33±0.007 mg/Kg) and Ca

(18250.70±0.062 mg/Kg). The AW variety was observed with the lowest concentration in mg/kg of the trace elements: Fe (7.71±0.003) and Zn (33.10±0.00) while the lowest concentrations in mg/kg of Mg (9651.17±0.017), K (3711.48±0.191) and Ca (3944.48±0.126) were recorded in the variety RS.

3.4 Total carotenoids and Beta carotene

Figures 5 and 6 illustrates the beta carotene and total carotenoids concentration in milligrams per gram (mg/g), respectively found in the five sweet potato varieties. The OF variety recorded the highest concentration of total carotenoids (1.6454) while TP contained the highest concentration of beta carotene (0.0130). The lowest concentrations of total carotenoids and beta carotene were recorded in the RS (0.1097) and AO (0.0009) respectively.

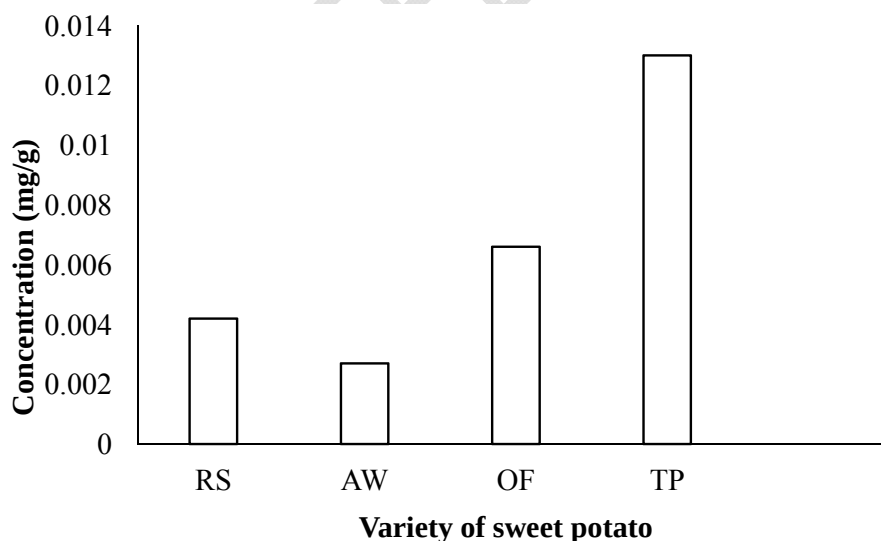


Figure 5: Beta carotene concentration (mg/g) in varieties of sweet potatoes

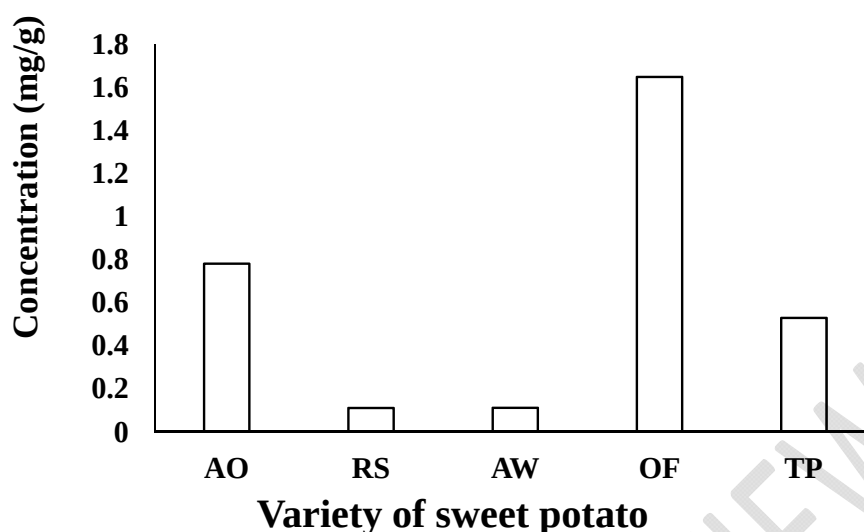


Figure 6: Total carotenoids concentration (mg/g) in varieties of sweet potatoes

4.0 Discussion

The research aimed to grow the varieties of sweet potato together on the same farm and under the same edaphic conditions so that their respective nutrient, mineral, beta carotene and total carotenoid capabilities could be explored. The findings show that all five varieties of sweet potato are nutritious, with protein content ranging from the highest of 3.82% in the AW variety to the lowest of 0.11% in the AO. This finding is different from that reported in Benin [20], which suggested that white fleshed sweet potato local varieties contain less protein than the coloured flesh ones. The range of protein content observed from the current study was found similar to the range of 3.3% to 1.2% reported from five varieties in Sri Lanka [21]. It is however, much higher than the range of 0.91% to 0.05% reported by Rwanda [6]. The observed protein range is lower than the range of protein content (4.16% to 3.28) recorded in Nigeria [22], China (6.53% to 4.86%) [23] and Benin (4.09 to 1.97%)[20]. The AW variety, with its high protein content, may thus be of importance in the amelioration of protein malnutrition in resource poor areas of developing countries.

431 All five varieties of sweet potato contain considerable percentage of fat, ranging from 4.84%
432 in the orange flesh (OF) variety to 1.74% in the red skin (RS) one. The content of fat in the
433 five varieties increases in the order of RS<TP<AO<AW<OF. A much higher range of fat
434 content ($8.88\pm0.30\%$ to $0.54\pm0.13\%$) was recorded in Benin [20]. Given the importance of
435 lipids as a component of lipopolysaccharide in the plasma membranes of cells, the
436 considerable fortification of some of the sweet potato varieties with fat may help to improve
437 the health-status of the rural poor. On the other hand, the moderate fat content in the other
438 varieties, especially RS and TP, makes them useful food for people who are concerned about
439 consuming high fatty foods.

440 Crude fibre content was found to range between 1.77% in the AO and 0.10% in TP in this
441 study, much higher than the range of 0.14% to 0.11% reported earlier in Rwanda [6]; but
442 much lower than the range (2.35% -1.85%) reported in China [8]; the range (13.60% to
443 2.10%) observed in Sri Lanka [21]; the range of 5.40 to 3.30% recorded in Martinique [24]
444 and the range of 3.00 to 1.81% [20] in Benin. Foods rich in crude fibre may reduce the
445 likelihood of one experiencing various sicknesses such as those related to the digestive
446 system; sugar related health issues and heart problems ([6]; [25]).

447 Total carbohydrate content in the varieties of sweet potato studied was as ranging from 23.2% in
448 the AO variety to 15.8% in AW one, which is lower than the range (38.92 ± 0.04 to
449 $14.46\pm0.07\%$) reported in Benin [20]. Thus, sweet potato cultivating rural folks of developing
450 countries have access to cheap but good source of calories from this crop.

451 A moisture content ranging from 75.78% in the AW variety to 71.04% in the OF one, was
452 observed higher than the finding of a range between 64.34% and 62.58% in Rwanda [6] and
453 70.0% to 61.00% in Nigeria [22]. This shows that the five sweet potato varieties have very
454 high moisture content. This may have impact on the taste when freshly harvested sweet
455 potatoes are cooked immediately. The average high moisture content in the five varieties may

456 account for the general low ash content, given that the OF variety which recorded the lowest
 457 moisture of 71.04% has the highest ash content of 1.56%. According to Ingabire and
 458 Vasanthakaalam [6], high moisture in sweet potatoes is the cause of their low ash content.
 459 The study revealed varying concentrations of Mg, Na, K, Ca, Fe and Zn in sweet potato
 460 varieties tested. The highest concentration of Mg (13713.44 ± 0.069 mg/kg) was found in the
 461 OF variety whereas its lowest concentration (9651.17 ± 0.017 mg/kg) was recorded in the RS
 462 variety. Mg was observed at higher concentrations in all five varieties of sweet potato in this
 463 study. Thus any of the five varieties is a good source of this major mineral. A recent study
 464 with Ten Elites Sweet Potato cultivars in Bennin [26] reported a lower concentration range of
 465 Mg (2540.00 to 2130.00 mg/kg) than that of the current study.
 466 Of the four major minerals studied, Na concentration is the lowest recorded in all five sweet
 467 potato varieties with an average of 2044.29 mg/kg. This concentration of Na is lower than the
 468 range of 3400.00 to 2900.00 mg/kg reported in Bennin [26].
 469 The concentration of K is low in all five sweet potato varieties, averaging 4537.11 mg/kg,
 470 though this is more than twice the average concentration of Na. Thus, these sweet potato
 471 varieties may not be rich sources of K and Na, more so, the latter. This low range of K
 472 concentration is much lower than that reported in Western Kenya (16838.00-1040.00 mg/kg)
 473 [2] and in Bennin (32867.00 to 30867.00 mg/kg) [26]. The TP variety, by virtue of its
 474 richness in concentration (mg/kg) of Ca (18250.70 ± 0.062), is the richest source of Ca, out of
 475 the five varieties. On the other hand, the concentrations of Fe in the sweet potato varieties
 476 decreases in the order: TP>RS>OF>AO>AW. The Ca concentrations recorded in this work is
 477 much higher than that recorded by Senanayake et al. in Sri Lanka for Ca (590.00 to 210.00
 478 mg/Kg) [21]. However, the previously reported Fe concentration (630.00 to 420.00 mg/Kg),
 479 was much higher than that was observed from the current research work. In a similar way, the
 480 Ca concentration recorded in the current study is much higher than the concentration range of

2735.00 to 1850.00 mg/kg in varieties of sweet potato reported in Western Kenya [2] while their Fe concentration of (140.00-103.00 mg/kg) is higher than that was recorded by the varieties used in this study. Again, the current finding shows a higher concentration ranges of these minerals than that found in Bennin [26] between 2997.00 and 2304.00 mg/kg for Ca and 73.00 to 53.00 mg/kg for Fe.

The trace element, Zn recorded highest in concentration of 123.12 ± 0.004 mg/kg in the orange flesh (OF) variety and lowest (33.10 ± 0.002 mg/kg) in the Agric white (AW) variety. Similarly, the concentrations of Zn in the sweet potato varieties decreases in the order: OF>RS>TP>AO>AW. This concentration range of Zn is much higher than the range of 27.00 to 23.00 mg/kg recorded in Benin recently [26].

The concentration of beta carotene (mg/kg) in the five sweet potato varieties increases in the order AO<<AW<RS<OF<TP, where the highest concentration of 0.0130 mg/kg was recorded in the T.U. purple variety while the lowest concentration of 0.0009 mg/kg was recorded in the Agric orange flesh variety. An earlier study [22] reported beta carotene content ranging from 0.0071 to 0.0060 mg/kg in Nigeria, which is within the current values recorded. The white coloured varieties (AW) contained 0.0027 mg/kg and the red skinned and white fleshed variety (RS) recorded 0.0042 mg/kg of beta carotene, contrasting differently from earlier findings of no beta carotene at all in white sweet potato varieties ([6]; [2]). In this study, T.U. purple (TP) is the variety that may be recommended as a beta carotene supplementary food, followed by the orange flesh (OF) variety.

However, in keeping of view of the earlier reports ([6]; [2]), the two white fleshed varieties (AW and RS) recorded the lowest concentration of total carotenoids of 0.11 mg/kg each while the Orange flesh (OF) variety has the highest content of 1.6454 mg/kg.

Given that all the varieties were cultivated on the same beds with the same loamy soil type, soil nutrient content and moisture, their levels of nutrient fortification can be attributed solely to the variety of sweet potato and not variation in the soil type ([1]; [5]; [16]; [6]; [7]; [2]).

4.1 Conclusion

The five varieties of sweet potato are not only rich in varying degrees of proteins, carbohydrates, and fats contents and oils, but are also impregnated with both macro- and micronutrients, beta carotene and total carotenoids. The highest sources of protein and fat are Agric white and orange flesh varieties respectively whereas the Agric orange flesh variety contains the greatest proportions of both total carbohydrate and crude fibre. All varieties contain high amounts of Mg. The T.U. purple variety is the richest source of Ca and beta carotene, compared to the rest. All the varieties of sweet potato contain moderate to low concentrations of K and Na respectively. The varieties of sweet potato may thus be of considerable importance in the amelioration of nutrient, mineral and beta carotene malnutrition in resource poor areas of developing countries.

4.2 Recommendation

A follow up study to assess the nutrient status of other varieties of sweet potato in the area and other factors such as phytochemicals, vitamins or their precursors will provide a full picture of the nutrient worth of the varieties of sweet potato grown in the study location.

4.0 References

1. Abubakar HN, Olayiwola IO, Sanni SA, Idowa MA. Chemical composition of sweet potatoes (*Ipomoea batatas* L am) dishes as consumed in Kware state, Nigeria. International Food Research Journal. 2010; 17:411- 416.

2. Aywa AK, Nawiri MP, Nyambaka HN. Nutrient variation in coloured varieties of *Ipomea batatas* grown in Vihiga County, Western Kenya. International Food Research Journal. 2013; 20(2):819-825.
3. Oduro I, Ellis WO, Owusu. Nutritional potential of two leafy vegetables: *Moringa oleifera* and *Ipomea batatas* leaves. Scientific Research and Essay. 2008;3:57-60.
4. Ofori G, Oduro I, Ellis WO, Dapaah H. Assessment of vitamin A content and sensory attributes of new sweet potato (*Ipomea batatas*) genotypes in Ghana. African Journal of Food Science. 2009; 3(7):184-192.
5. Meludu NT. Proximate analysis of sweet potato toasted granules. African Journal of Biomedicine. 2010; 13:89-91.
6. Ingabire MR, Vasanthakalam H. Comparison of the nutrient composition of four sweet potatoes varieties cultivated in Rwanda. American Journal of Food and Nutrition. 2011; 1(1):34-38.
7. Ukom AN, Ojimekwe PC, Alamu EO. All trans-cis β -carotene content of selected sweet potato (*Ipomea batatas* (L) Lam) varieties as influenced by different levels of nitrogen fertilizer application. African Journal of Food Science. 2011; 5(3):131-137.
8. Hue SM, Boyce AN, Chandran S. Antioxidant activity, phenolic and flavonoid contents in different varieties of sweet potato (*Ipomea batatas*). Australian Journal of Crop Science. 2012; 6(3):375-380.
9. Tierno R, Hornero-Méndez D, Gallardo-Guerrero L, López-Pardo R, Ruiz de Gallareta JI. Effect of boiling on the total phenolic, anthocyanin and carotenoid concentrations of potato tubers from selected cultivars and introgressed breeding lines from native potato species. Journal of Food Composition and Analysis. 2015; 41:58–65.

10. Lachman J, Hamouz K, Orsák M, Kotíková Z. Carotenoids in potatoes – a short overview. *Plant Soil Environment*. 2016; 62(10):474–481.
11. Shubhendu S, Divya M, Alak KBT, Subhra C. Comparative analysis of phytochemicals and nutrient availability in two contrasting cultivars of sweet potato (*Ipomoea batatas* L.). *Food Chemistry*. 2015; 173: 957–965. DOI: 10.1016/j.foodchem.2014.09.172. Source: PubMed.
12. Mitra S. Nutritional status of orange-fleshed sweet potatoes in alleviating vitamin A malnutrition through a food-based approach. *Journal of Nutrition and Food Science*. 2012; 2:160. doi:10.4172/2155-9600.1000160.
13. FAOSTAT. 20016. Statistic database (online) available online at <http://apps.fao.org>
14. FAOSTAT. 20017. Statistic database (online) available online at <http://apps.fao.org>
15. Bidzakin JK, Acheremu K, Carey E. Needs assessment of sweet potato production in northern Ghana: implications for research and extension efforts. *ARNP Journal of Agricultural and Biological Science*. 2014; 9(9):315-319.
16. Sunette ML. Agronomic performance, consumer acceptability and nutrient content of new sweet potato varieties in South Africa. PhD thesis, University of Free state, South Africa. 2010; 13-56.
17. Ghana Statistical Service (GSS). Population and housing census, Bolgatanga Municipality. 2010; 1-75.
18. Association of official analytical chemist (AOAC). Official method of analysis, 16th edition, Washington DC; 2005.
19. Association of official analytical chemist (AOAC). Official method of analysis, 16th edition, Washington DC; 2008.

20. Aweke A, Roba B. Evaluation of proximate composition of sweet potato [*Ipomoea batatas* (L.) Lam] for better utilization through agro-food processing chain. Global Journal of Animal Breeding and Genetics. 2016; 4 (4):248-255.
21. Senanayake SA, Ranaweera KKDS, Gunaratne A, Bamunuarachchi A. Comparative analysis of nutritional quality of five different cultivars of sweet potatoes (*Ipomoea batatas* (L) Lam) in Sri Lanka. Food Science and Nutrition. 2013; 1(4):284– 291.
22. Ukom A.N., Ojmelukwe P.C. and Okpara D.A. Nutrient composition of selected sweet potato [*Ipomoea batatas* (L) Lam] varieties as influenced by different levels of nitrogen fertilizer application. Pakistan Journal of Nutrition. 2009; 8(11):1791-1795.
23. Hua J, Haixin Z, Hongtao L, Yunchao L. Analysis on the nutrition composition and antioxidant activity of different types of sweet potato cultivars. Food and Nutrition Sciences. 2015; 6:161-167. <http://dx.doi.org/10.4236/fns.2015.61017>.
24. Ellong EN, Billard C, Adenet S. Comparison of physicochemical, organoleptic and nutritional abilities of eight sweet potato (*Ipomoea batatas*) varieties. Food and Nutrition Science. 2014; 5(2):196-211.
25. Trinidad PT, Sagum RS, Mallillin AC, Borlagdan MS, de Leon MP, Aviles T. Sweet potato and cassava can modify cholesterol profile in humans with moderately raised serum cholesterol levels. Food Nutrition Science. 2013; 4(5):491-495.
26. Sanoussi AF, Adjatin A, Dansi A, Adebawale A, Sanni LO, Sanni A. Mineral composition of ten elites sweet potato (*ipomoea batatas* [L.] lam.) landraces of Benin. International Journal of Current Microbiology of Applied Science. 2016; 5(1):103-115.