Asian Journal of Advances in Agricultural Research

12(2): 7-19, 2020; Article no.AJAAR.54120
ISSN: 2456-8864

Evaluation of Nutritional and Anti Nutrition Factors of Orange-fleshed Sweet Potato, Yellow Root Cassava and Plantain Flour Blends Fortified with *Moringa oleifera* Leaves

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Authors' contributions

This work was carried out in collaboration among all authors. Authors LNU and EAM designed the study. Author LNU performed the statistical analysis. Authors LNU and EAM wrote the protocol and wrote the first draft of the manuscript. Authors LNU and ANK managed the analyses of the study and managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJAAR/2020/v12i230075
Editor(s):
(1) Prof. Oguz Dolgun, Department of Plant and Animal Production, Adnan Menderes University, Sultanhisar Vocational College, Turkey.
Reviewers:
(1) O. Okpo, Ngozi, Federal College of Agricultural Produce Technology, Nigeria.
(2) Charles Afriyie-Debrah, CSIR-Crops Research Institute, Kumasi, Ghana.
Complete Peer review History: http://www.sdiarticle4.com/review-history/54120

Original Research Article

Received 28 November 2019
Accepted 02 February 2020
Published 08 February 2020

ABSTRACT

Aim: The aim of this study is to produce flour from different blend ratio of orange fleshed sweet potato, yellow root cassava (YRC) and Plantain fortified with *Moringa oleifera* leaves powder and to determine the nutritional composition (vitamin and mineral) and phytochemical content of the composite flour.
Introduction: Orange-fleshed sweet potato (OFSP) is a promising root crop due to its high β-carotene content which could help to reduce vitamin A deficiency (VAD). However, it is a less utilized perishable crop. Therefore, in other to improve it utilization in processing and bakery products the incorporation with other flours should be considered. In order to use OFSP tubers, incorporation with other flours in processing and baked products can be considered.
Study Design: The physicochemical analysis was carried out at the biochemistry laboratory of

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National Root Crop Research Institute (NRCR1) while part of the analysis was done at International Institute of Tropical Agriculture Ibadan (IITA). Study lasted for 6 months.
Methodology: Orange-fleshed sweet potatoes (OFSP), yellow roots cassava (YRC) were all sourced from National Root Crops Research Institute Umudike, while the plantain and *Moringa oleifera* leaves were gotten from Umuahia market and Michael Okpara University of Agriculture Umudike (NRCRI) respectively. The samples were processed into flour and used to form a blend. The flour blend constitute of yellow root cassava, orange fleshed sweet potato and plantain which were fortified with *Moringa oleifera* leaves at constant portion of 5% while the YRC, OFSP and plantain were varied at different concentration of 65%, 70, 75, 80, 85, 95 and 5, 10, 95 and 5, 10, 15, 25 and 95% I.e. Sample A, B, C, D, E, F, G, H respectively.
Results: The result obtained indicated among the mineral content determined that sample G which serves as the control with 95% Plantain and 5% *Moringa oleifera* leaves powder exhibited highest in calcium having 13.26 mg/100 g, magnesium 88.06 mg/100 g, potassium 287.70 mg/100 g and iron 2.69 mg/100 g as compared to other composite flour. The phytochemical content of sample F (95% YRC with 5% *Moringa oleifera* leaves powder) has the highest in alkaloid, tannin and hemagglutinin content as 4.22 mg/100 g 2.26 mg/100 g and 12.43 mg/100 g respectively. The result also indicated that increase in the YRC and decrease in the OFSP caused an appreciable increase in the Vitamin B1, B3 C and D content.
Conclusion: The vitamins, mineral and phytochemical content of the products were enhanced and can be of nutritional benefit to the public.

Keywords: Orange-fleshed sweet potato; yellow root cassava; plantain; moringa leave powder; blends; vitamin; mineral.

1. INTRODUCTION

Vitamin A deficiency (VAD) is a widespread nutritional disorder in low-income countries and is still a public health concern worldwide. The insufficient intake over a long period of time causes xerophthalmia that may lead to irreversible blindness Bokanga [1]. Furthermore, subclinical deficiency can aggravate diseases such as diarrhea and other infectious processes [2]. Cassava (*Manihot esculenta* Cranz) has been processed into food products worldwide for several hundreds of years. The traditional methods of processing cassava roots into food have been adapted to suit the attributes of the plant such as root yield, spoilage, cyanide content, nutrient content, and process-ability. With increasing population, increase demand of consumers for better quality foods and increase new use of cassava, indigenous methods of cultivation and processing of cassava have been transformed by modern scientific knowledge for use in industrial operations. Cassava is basically made into fermented and unfermented products. Fermented products include cassava bread, fermented cassava flour, fermented starch, fufu, lafun, akyeke (or attieke), agbelima, and gari, whereas the unfermented products include tapioca, cassava chips and pellets, unfermented cassava flour and starch. New food uses of cassava include flour in gluten free or gluten-reduced products (e.g., bread, biscuits, etc.). This review highlights progress made in the utilization of cassava for food; challenges, process and raw material development issues and improvement achieved in nutritional delivery of cassava foods. Also, progress made in the storage, presentation, packaging, etc., of cassava foods. Plantain is gluten-free though lower in protein [3] which is essential for those of gluten intolerance. Plantain have been reported to contain low quantities of minerals [4].

2. MATERIALS AND METHODS

Pounds of unripe (green) plantain (*Musa paradisiaca normalis*) was purchased from a local market in Umuahia, Abia State. Yellow root cassava (*Manihot esculenta* Cranz) tuber variety UMUCASS 45 and Orange-fleshed sweet potatoes (OFSP) (*Ipomoea batatas* L. Lam) was obtained from the experimental / commercial farm of the National Root Crop Research Institute (NRCRI) Umudike. *Moringa oleifera* leaves were obtained from Michael Okpara University of Agriculture, Umudike (MOUAU) which was sprayed on a tray to dry under natural air (not sundried). The dried moringa was milled into powder, sieved and packaged in polyethylene bag, sealed and store at room temperature (30±1°C) until used. The flow chart for the production of Yellow root cassava, Orange-fleshed sweet potato and Plantain are shown in Figs. 1 and 2 respectively.

Picture A. Orange- fleshed sweet potato

Picture B. Shredded orange fleshed sweet potato

Picture C. Yellow root cassava

Picture D. Bunch of unripe plantain

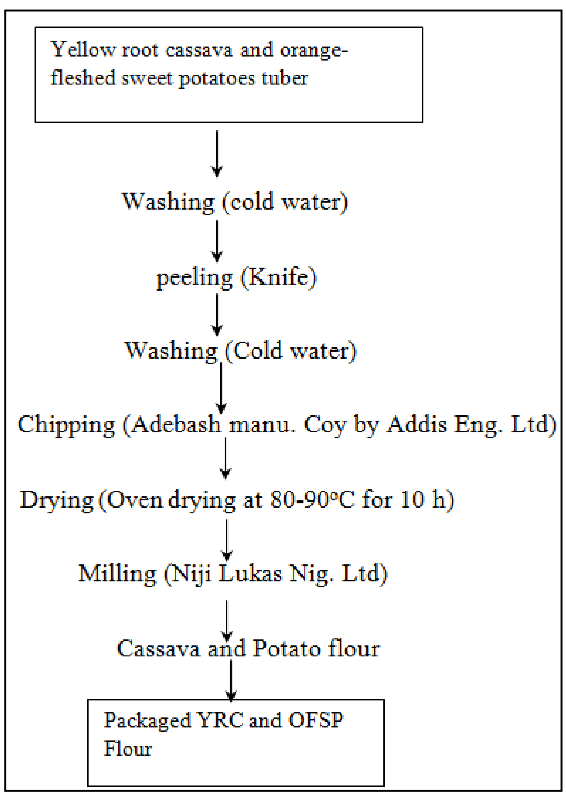

Fig. 1. Flow chart for the production of food quality yellow root cassava and orange fleshed sweet potato

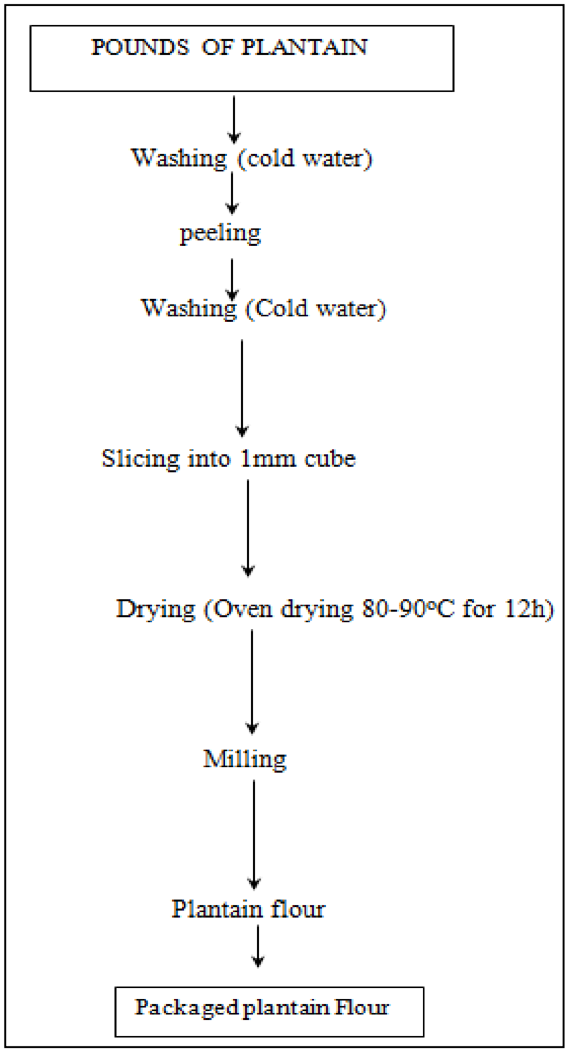

Fig. 2. Flow chart for the production of quality plantain

Table 1. Flour blends of Yellow Root Cassava (YRC) (TMS/07/0593), Orange-fleshed sweet potato (OFSP), plantain and *Moringa oleifera*

YRC%	OFSP%	Plantain %	Moringa leaves powder%
65	10	20	5
70	10	15	5
75	10	10	5
80	5	10	5
85	5	5	5
95	-	-	5
-	95	-	5
-	-	95	5

YRC- Yellow root cassava, OFSP – Orange-fleshed sweet potato

Blending of Raw Materials (Flour): Plantain flour, Orange-fleshed sweet potatoes, Moringa leaves powder and Cassava flour was blended using a Hobart mixer in the ratio shown below. Table 1, shows the formula for blends of raw flour into eight (8) equally spaced combinations. It showed the impact of cassava flour addition at equal proportions to orange-fleshed sweet potato flour, plantain and Moringa leaves powder. The flour blends were packaged in polyethylene bags and stores at room temperature.

2.1 Mineral Analysis

Determination of calcium, potassium, iron and magnesium by Atomic Absorption Spectro-photometer (AAS) while sodium and potassium Flame photometry was done as described by Onwuka [5].

2.2 Phytochemical Content Analysis

Determination of flavonoid, Phytate, tannin, alkaloid, hydrogen cyanide, Hemagglutinin, Phenols content were done by method as described by Onwuka [5].

2.3 Vitamin Content

Thiamine (vitamin B_1), Riboflavin (vitamin B_2), Niacin (vitamin B_3), Ascorbic acid (vitamin C), Tocopherol (vitamin E) were done by method described by AOAC [6].

3. RESULTS AND DISCUSSION

Moringa oleifera leaves powder, yellow root cassava (TMS/07/0593 or UMUCASS 45), orange fleshed sweet potatoes and plantain flour were chemically analyzed, and obtained results were summarized in Table 2. Minerals serve as prosthetic groups or cofactors to vitamins functioning as coenzymes in enzyme catalyzed bioreactions. Minerals are equally required for the right composition and proportion of body fluids, formation of blood and bones and the creation and maintenance of healthy nerve functions [7]. Above all, the higher potassium than sodium levels make them ideal diuretic diet for the prevention of the onset of certain health conditions including hypertension. Generally, minerals and vitamins are functional ingredients of food which impact positively on human health and well-being beyond mere nutrition. For all the samples, sample G which serves as the control (95% Plantain with 5% *Moringa oleifera* leaves powder) exhibited highest in calcium (13.26 mg/100 g), magnesium (88.06 mg/100 g), potassium (287.70 mg/100 g) and iron (2.69 mg/100 g) as compared to other composite flour. Potassium and sodium perform important biochemical functions as in acid-base balance, nerve impulse mediation and cell membrane sodium (Na) and potassium (K) channels and pumps. However, compelling evidence has replicated high dietary sodium intake in the development of cardiovascular disease, importantly hypertension and that increased intake of dietary potassium is beneficial in relation to blood pressure control [8]. Currently, results are inconclusive as to whether potential adverse effects are associated with low intake of sodium [8]. Meanwhile sodium intake of <1.5 g or <2.3 g per day is recommended in dietary guidelines [9]. Potassium level ranged from (244.62 mg/100 g to 287.70 mg/100 g) with significant differences within the samples (P<0.05). Sample G had the highest potassium level which is similar to (264.75 mg/100 g) as reported by Oko, et al. [10] on Nbipaul plantain cultivar variety. It has been reported that plantain is low in sodium and higher in potassium and calcium as evidenced in the result. Potassium was present in about 15 times as sodium. The value of composite flour of 95% plantain with 5% *Moringa oleifera* leaves powder (sample G) was (9.26 mg/100 g) which is lower than (27.78 mg/100 g) as reported by Oko, et al. [10]. Therefore, consumption of plantain flour may dispose of populace to hypernatremia or high blood pressure respectively.

Magnesium level indicated a significant difference (P<0.05) which ranged between (28.10 mg/100 g to (88.06 mg/100 g) for sample A and G respectively. Iron content investigated showed that samples A (1.04 mg/100 g) and G (2.69 mg/100 g) had iron content more than 1%. While other samples had less than 1% which did not significantly differ from each other as shown in Table 2. The results are an indication of the usefulness of plantain in increasing the mineral composition of the composite flour. Plantain can be considered a good source of calcium, magnesium, potassium and iron while sample H (95% OFSP with 5% *Moringa oleifera* leave powder) indicated rich in sodium. The calcium is comparatively more abundant among samples G (13.26 mg/100 g) while sample D (12.86 mg/100 g) did not significantly (P>0.05) differ from E (12.87 mg/100 g) and F (12.17 mg/100 g). It was observed that the values increased with increase ratio of biofortified cassava (UMUCASS 45) for calcium as observed among samples A, B, C, D and E (10.60 mg/100 g), (10.77 mg/100 g), (11.60 mg/100 g), (12.86 mg/100 g) and (12.87 mg/100 g). Low intake of calcium in children may induce rickets, growth retardation and biochemical signs of hyper parathyroidism that normalize after calcium supplement [11].

The results of the anti-nutritional content of composite flour produced from yellow root cassava, orange fleshed sweet potato and plantain fortified with *Moringa oleifera* leaves powder were presented in Table 3. The anti-nutritional factors determined were Tannin, Phytate, Oxalate, HCN, Alkaloid, Flavonoid, Phenol and Hemagglutinin. The result indicated sample F had the highest amount of all the anti-nutritional factors tested except in phytate, flavonoid and phenol. No significant difference (P>0.05) was observed among A (2.02 mg/100 g), B (2.16 mg/100 g), C (2.17 mg/100 g), D

(2.20 mg/100 g), E (2.23 mg/100 g) and F (2.26 mg/100 g) while samples G (1.07 mg/100 g) and H (1.98 mg/100 g) are significantly the same. Sample F contained the highest, blend of 95% yellow root cassava with 5% *Moringa oleifera* leaves powder. The next abundance in anti-nutritional was sample E except in alkaloid, flavonoid and phenol. This variation may be due to the processing method used which required heat. Ojo and Akande, [12] reported that different processing methods such as cooking, autoclaving and soaking have an influence in reducing the anti-nutritional factors of foods. The oxalate and phytate levels found in the flour were similar to (0.01 to 0.04 mg/100 g) and (0.00 to 0.01 mg/100 g) by Oluwaseun, et al. [13] but tannin level was higher ranging from (1.07 to 2.26 mg/100 g) than the tannin level from this work (0.02 to 0.05 mg/100 g) found in a work on composite flour from cocoyam and cassava by Oluwaseun, et al. [13].

Increase percentage of yellow root cassava, increased the values of HCN, alkaloid, phytate and tannin level while decrease in yellow root cassava increased in phenol and flavonoid content. Flavonoid functions to protect against allergies, inflammation, free radicals, platelet aggregation, microbes, ulcers, tumor etc [14].

Flavonoid occurred in higher quantities in 65% yellow root cassava + 10% orange fleshed sweet potato + 20% plantain with 5% *Moringa oleifera* leaves powder (sample A) (5.01 mg/100 g) followed by sample B (4.76 mg/100 g) which is 70% yellow root cassava + 10% orange fleshed sweet potato + 15% plantain with 5% *Moringa oleifera* leaves powder. This showed that flavonoid content increased with increased plantain and decreased in yellow root cassava content. Looking at sample G (4.15 mg/100 g) 95% plantain with 5% *Moringa oleifera* leaves powder contained more flavonoid than sample F (95% yellow root cassava with 5% Moringa leaves powder) was an indication that caused the increase in the blend of A and B.

Generally, the alkaloid, tannin and hemagglutinin content for sample F (95% YRC with 5% *Moringa oleifera* leaves powder) were (4.22 mg/100 g), (2.26 mg/100 g) and (12.43 mg/100 g) which recorded highest that caused the increment among the flour blends that is from sample A to E, while sample G, contained the least of alkaloid (2.74 mg/100 g) and (1.07 mg/100 g) for tannin.

The phytate, oxalate, cyanogenic glucoside content presented in Table 4 ranged from (0.04-0.08 mg/100 g), (0.00-0.01 mg/100 g) and (1.05-2.72 mg/100 g) is lower than (0.36-0.69 mg/100 g), (31.60-48.05 mg/100 g) and (16.80-32.53 mg/100 g) on cassava flour as reported by Oluwaniyi and Oladipo [15] Alkaloid and heamagletin content existed in large proportions in this work which ranged from (2.74–4.22 mg/100 g) and (8.41-12.43 mg/100 g). A high amount of oxalate and phytate was observed (163.00 mg/100 g) in sweet potato and (38.00 mg/100 g) in cassava leaves and in phytate level of (235.00 mg/100 g) in cassava leaves and (1.05 mg/100 g) in sweet potato leaves, (235.00 mg/100 g) on phytochemical and antinutrient constituents of cassava and sweet potato reported by Anbuselvi and Balamurugan, [16]. The residual cyanide levels in the flour of all blends investigated ranged from (1.05 mg/100 g) for sample H to (2.72 mg/100 g) for sample H which is 95% yellow root cassava with 5% *Moringa oleifera* leaves powder. It was observed that the flour blends increases in hydrogen cyanide as the percentage of yellow root cassava increases in the blends ranging between sample A (2.55 mg/100 g) to sample E (2.63 mg/100 g), while sample G (95% plantain and 5% *Moringa oleifera* leaves powder) and H (95% orange fleshed sweet potato) presented the least were significantly the same (P>0.05). Comparing (2.72 mg/100 g) from UMUCASS 45 blend with 5% Moringa leaves powder to (2.43 mg/100 g) for UMUCASS 37 were similar but TMS 98/0505 (3.40 mg/100 g) is higher as reported by Eleazu and Eleazu, [17]. Work by Obasi and Chukwuma, [18] presented hydrogen cyanide content (2.07 mg/100 g) for UMUCASS 36 and (2.11 mg/100 g) for UMUCASS 38 which is similar to cyanide content obtained from this work (2.72 mg/100 g).

Moringa oleifera leaves powder, yellow root cassava, plantain and orange fleshed sweet potato composite flour were chemically analyzed, obtained results were summarized in Table 4. Roots and tubers are not rich sources of fat-soluble vitamins. However, provitamin A is present as the pigment beta-carotene in the leaves of root crops, some of which are edible [19]. Most roots and tubers contain only negligible amounts of beta carotenes with the exception of selected varieties of sweet potato. Deep coloured varieties are richer in carotenes than white cultivars. In the orange variety "Goldrush", the pigment is made up of about 90 percent beta carotene and in "Centennial" the corresponding figure is 88 percent. This is one of the nutritional advantages of sweet potato because sufficient and regular ingestion of sweet potato leaves, together with the tubers of high

Table 2. Mineral composition of the flour of yellow root cassava, orange fleshed sweet potatoes, plantain blend with *Moringa oleifera* leave (mg/100 g)

Samples	Calcium	Potassium	Magnesium	Sodium	Iron
A	10.60^{g}±0.71	28.10^{d}±0.01	244.62^{f}±0.68	9.35^{g}±0.02	1.04^{b}±0.03
B	10.77^{f}±0.03	36.14^{bcd}±0.04	252.11^{e}±0.00	11.93^{e}±0.01	0.99^{c}±0.07
C	11.60^{d}±0.01	38.37^{bcd}±0.02	251.62^{e}±0.00	12.15^{d}±0.14	0.97^{c}±0.01
D	12.86^{b}±0.04	43.30^{bc}±0.28	275.65^{b}±0.69	12.87^{c}±0.03	0.91^{cd}±0.01
E	12.87^{b}±0.00	45.47^{b}±14.11	273.66^{c}±0.71	13.11^{b}±0.78	0.71^{d}±002
F	12.17^{c}±0.03	35.85^{bcd}±0.05	262.16^{d}±0.71	11.23^{f}±0.50	0.62^{e}±0.01
G	13.26^{a}±0.04	88.05^{a}±0.08	287.70^{a}±0.58	9.26^{g}±0.50	2.69^{a}±0.01
H	11.24^{e}±0.10	3.16^{cd}±0.01	276.11^{b}±0.00	15.16^{a}±0.50	0.49^{f}±0.01

Mean values are of duplicate and expressed as mean ± SD. Values with the same superscripts in the same column are not significantly different (p>0.05); YRC = Yellow Root Cassava, OFSP= Orange Fleshed Sweet Potato; A= 65% YRC + 10% OFSP + 20% Plantain + 5% Moringa leaves powder, B = 70% YRC + 10% OFSP + 15% Plantain + 5% Moringa leaves powder, C = 75% YRC + 10% OFSP + 10% Plantain + 5% Moringa leaves powder, D = 80% YRC + 5% OFSP + 10% Plantain + 5% Moringa leaves powder, E = 85% YRC + 5% OFSP + 5% Plantain + 5% Moringa leaves powder, F = 95% YRC + 5% Moringa leaves powder, G= 95% Plantain + 5% Moringa leaves powder, H = 95% OFSP + 5% Moringa leaves powder

Table 3. Phytochemical analysis of the composite flour of yellow root cassava, orange fleshed sweet potatoes, plantain blend with *Moringa oleifera* leave

Samples	Tannin mg/100 g	Oxalate mg/100 g	Phytate mg/100 g	HCN mg/100 g	Alkaloid mg/100 g	Flavonoid mg/100 g	Phenol mg/100 g	Heamaglutin mg/100 g
A	2.02^{e}±0.01	0.00^{b}±0.00	0.04^{b}±0.01	2.55^{d}±0.01	3.11^{g}±0.01	5.01^{a}±0.01	0.61^{b}±0.01	10.53^{f}±0.01
B	2.16^{d}±0.01	0.00^{b}±0.04	0.05^{a}±0.01	2.59^{c}±0.01	3.24^{f}±0.01	4.76^{b}±0.01	0.50^{d}±0.00	10.97^{e}±0.01
C	2.17^{cd}±0.01	0.01^{a}±0.00	0.05^{a}±0.00	2.61^{bc}±0.01	3.36^{e}±0.01	3.51^{e}±0.01	0.53^{c}±0.01	11.32^{d}±0.01
D	2.20^{bc}±0.01	0.00^{b}±0.00	0.06^{a}±0.00	2.62^{bc}±0.01	3.45^{d}±0.02	3.23^{f}±0.01	0.44^{e}±0.00	11.79^{c}±0.01
E	2.23^{ab}±0.01	0.00^{b}±0.00	0.07^{a}±0.01	2.63^{b}±0.01	3.57^{c}±0.02	2.85^{g}±0.01	0.41^{f}±0.01	12.05^{b}±0.01
F	2.26^{a}±0.01	0.00^{b}±0.00	0.07^{a}±0.01	2.72^{a}±0.01\	4.22^{a}±0.02	2.54^{h}±0.01	0.35^{g}±0.00	12.43^{a}±0.01
G	1.07^{g}±0.01	0.00^{b}±0.00	0.08^{a}±0.02	1.09^{e}±0.01	2.74^{h}±0.01	4.15^{c}±0.01	0.83^{a}±0.01	10.31^{g}±0.01
H	1.98±0.01^{f}	0.01±0.00^{a}	0.06±0.01^{a}	1.05±0.02^{f}	3.91±0.01^{b}	3.78±0.01^{d}	0.28±0.01^{h}	8.41±0.01^{h}

Mean values of duplicate and expressed as mean ± SD. Values with the same superscripts in the same column are not significantly different (p>0.05); YRC = Yellow Root Cassava, OFSP= Orange Fleshed Sweet Potato; A= 65% YRC + 10% OFSP + 20% Plantain + 5% Moringa leaves powder, B = 70% YRC + 10% OFSP + 15% Plantain + 5% Moringa leaves powder, C = 75% YRC + 10% OFSP + 10% Plantain + 5% Moringa leaves powder, D = 80% YRC + 5% OFSP + 10% Plantain + 5% Moringa leaves powder, E = 85% YRC + 5% OFSP + 5% Plantain + 5% Moringa leaves powder, F = 95% YRC + 5% Moringa leaves powder, G= 95% Plantain + 5% Moringa leaves powder, H = 95% OFSP + 5% Moringa leaves powder

Table 4. Vitamin composition of the flour of yellow root cassava, orange fleshed sweet potatoes, plantain blend with *Moringa oleifera* leaves

Samples	A(mg/100 g)	B_1(mg/100 g)	B_2(mg/100 g)	B_3(mg/100 g)	C(mg/100 g)	E (mg/100 g)
A	31.72^{b}±0.01	0.61^{d}±0.01	0.49^{a}±0.01	0.52^{e}±0.01	36.22^{b}±0.02	3.12^{b}±0.01
B	31.42^{c}±0.03	0.66^{c}±0.01	0.45^{b}±0.01	0.57^{d}±0.01	36.42^{b}±0.02	3.13^{b}±0.01
C	30.87^{d}±0.02	0.71^{b}±0.01	0.36^{c}±0.01	0.62^{c}±0.02	36.36^{b}±0.72	3.14^{b}±0.01
D	30.28^{e}±0.02	0.75^{ab}±0.02	0.27^{d}±0.01	0.68^{b}±0.01	37.43^{a}±0.01	3.13^{b}±0.02
E	29.17^{f}±0.02	0.78^{a}±0.01	0.21^{e}±0.01	0.73^{a}±0.01	37.71^{a}±0.01	3.13^{b}±0.02
F	26.47^{g}±0.01	0.65^{c}±0.01	0.09^{g}±0.01	0.74^{a}±0.01	35.42^{c}±0.03	3.13^{b}±0.01
G	15.64^{h}±0.02	0.51^{e}±0.01	0.17^{f}±0.02	0.63^{c}±0.002	30.74^{d}±0.01	3.07^{c}±0.01
H	38.96^{a}±0.02	0.58^{d}±0.02	0.13^{f}±0.01	0.56^{d}±0.01	27.87^{e}±0.01	3.18^{a}±0.01

Mean values of duplicate and expressed as mean ± SD. Values with the same superscripts in the same column are not significantly different (p>0.05); YRC = Yellow Root Cassava, OFSP= Orange fleshed Sweet Potato; A= 65% YRC + 10% OFSP + 20% Plantain + 5% Moringa leaves powder, B = 70% YRC + 10% OFSP + 15% Plantain + 5% Moringa leaves powder, C = 75% YRC + 10% OFSP + 10% Plantain + 5% Moringa leaves powder, D = 80% YRC + 5% OFSP + 10% Plantain + 5% Moringa leaves powder, E = 85% YRC + 5% OFSP + 5% Plantain + 5% Moringa leaves powder, F = 95% YRC + 5% Moringa leaves powder, G= 95% Plantain + 5% Moringa leaves powder, H = 95% OFSP + 5% Moringa leaves powder beta-carotene varieties can meet the consumer's daily requirement of vitamin A and hence prevent the dreadful disease of xerophthalmia, which is responsible for nutritional blindness in many countries like Nigeria [20]. The dessert type of sweet potato is even higher in beta-carotene and it has been estimated that an intake of 13 g/day will be sufficient to meet the vitamin A requirement. Other sources of beta-carotene include the deep orange varieties of banana. The concentration, however, decreases from 1.04 mg per 100 g when green (unripe) to 0.66 mg when ripe [21]. Plantain contains very little beta-carotene. Vitamin A is an essential nutrient needed in small amounts by human for the normal functioning of the visual system, growth and development, maintenance of epithelial cellular integrity, immune function and reproduction. These dietary needs for vitamin A are normally provided for as performed retinol and provitamin A carotenoids [22]. Vitamin A equivalency of β-carotene (VEB) is defined as the amount of ingested β-carotene in µg that is absorbed and converted into 1 µg retinol vitamin A in the [23] and the VEB for a mixed vegetable diet was estimated to be 6 µg β-carotene to 1 µg retinol. This VEB of 6:1 for a mixed diet is referred to as the retinol equivalents and is used in many food compositions tables. Estimates for the vitamin A recommended safe intakes for male and female adults are 600 µg and 500 µg retinol daily respectively [22]. As indicated in Table 4, vitamin A content of the flour samples ranged from 15.64 µg/100 g to 38.96 µg/100 g for sample G and H respectively. No significant difference (P>0.05) was observed among samples A (31.72 µg/100 g), B (31.42 µg/100 g), C (30.87 µg/100 g), and D (30.28 µg/100 g) while sample H (38.96 µg/100 g) presented the highest in vitamin A content which is the 95% OFSP + 5% *Moringa oleifera* leaves powder. Expectedly, the significant difference in vitamin A contents of the sample H flour might be due to deep colour of the potato. Consequently, the vitamin A content of the composite flour increased as the proportion of orange fleshed sweet potato increased, this is due to the minerals and vitamin A content of OFSP is higher than that of yellow root cassava and plantain. When compared to the daily requirements, the blend can contribute to some extent [11].

A study with biofortified cassava porridge in Colombia reported VEB of 2.80 µg β-carotene to 1 µg retinol [24]. Another study with biofortified cassava porridge in the USA determined a VEB of 4:2:1 provided with added oil and a VEB of 4:5:1 when provided without added oil [25]. Considering a VEB of 2.80 µg β-carotene to 1µg retinol and an intake of 600µg retinol daily, the consumption of 380 g of β-carotene will contribute to health.

As indicated on Table 4, all the composite flour samples contained thiamin (vitamin B_1), riboflavin (vitamin B_2) and niacin (vitamin B_3) content less than 1%. Vitamin B_2 range between (0.09 µg/100 g) for sample F which was the flour blend of 95% yellow root cassava + 5% Moringa leave powder to (0.49 µg/100 g) for sample A (65% YRC + 10% OFSP + 20% Plantain + 5% Moringa leave powder). Among the composite flour, it was indicated that sample G (0.17 µg/100 g), the blend from 95% plantain and 5% *Moringa oleifera* leave powder presented high vitamin B_2 than samples F and H (0.09 µg/100 g) and (0.13 µg/100 g) which was 95% YRC and 95% OFSP with 5% *Moringa oleifera* leave powder. Vitamin B_1 and B_3 ranged from (0.51 µg/100 g) in sample B to (0.78 µg/100 g) in sample E and (0.52 µg/100 g) in sample A to (0.74 µg/100 g) in sample F. It was observed that the levels of thiamin and niacin increased as the proportion of yellow root cassava increases. Among the 95% blend, sample F contained the highest thiamine and niacin contents of (0.65 µg/100 g) and (0.74 µg/100 g). A good review of simple technologies for root crop processing provided by the United Nations Development Fund for Women publication, Root crop processing [26]. The first step in processing any root crop is usually peeling. This may remove nutrients if it is not done carefully. Cooking losses can be reduced by retaining the skin to minimize leaching and to protect the nutrients. It is sometimes advisable to peel after boiling, and to make use of the cooking water in order to conserve water-soluble nutrients [27]. Processing methods used during production might be the cause of reduction in thiamine, riboflavin and niacin content.

Most of the root crops contain small amounts of the vitamin B group, sufficient to supplement normal dietary sources. The B-group of vitamins acts as a co-factor in enzyme systems involved in the oxidation of food and the production of energy. These vitamins are found mainly in cereals, milk and milk products, meat and green vegetables, including the leaves of roots and tubers [27] For every 1000 kcal of carbohydrate ingested about 0.4 mg of vitamin B_1 (thiamine) is needed for proper digestion. Sweet potato contains about double this required amount of vitamin B_1 (0.8-1.0 mg/1000 kcals). Villareal [28] has estimated that a hectare of land planted with sweet potato will provide about eight times as much vitamin B_1 (thiamin) and 11 times as much vitamin B_2 (riboflavin) as a hectare planted with rice. Similarly, it has been estimated by the Nutrition Food Survey Committee, that in the United Kingdom Irish potato supplied 8.7 percent of the riboflavin, 10.6 percent of the niacin (vitamin B_3), 12 percent of the folic acid, 28 percent of the pyridoxine (vitamin B_6) and 11 percent of the panthothenic acid [29].

Ascorbic acid, also known as vitamin C, is a water-soluble vitamin. It naturally occurs in plant tissues, primarily in fruits and vegetables. Ascorbic acid occurs in considerable quantities in several root crops. However, the level could be reduced during cooking of roots unless skins and cooking water are utilized. Root crops, if carefully prepared, can make a significant contribution to the vitamin C content of the diet. As reported by the Nutritional Food Survey Committee [30], Irish potatoes serve as a principal source of vitamin C in British diets, providing 19.4% of the total requirement. The vitamin C content of Irish potatoes is very similar to those of sweet potatoes and cassava. The concentration of ascorbic acid varies with the species, location, crop year, maturity at harvest, soil, and nitrogen and phosphate fertilizers. Vitamin C is the most thermolabile vitamin and is also easily leached into cooking water or canning syrup. Elkins [31] reported complete retention of vitamin C in freshly canned sweet potato but the vitamin content dropped to 60 percent of its original value after storage for 18 months. The concentration of the canning syrup did not affect vitamin retention [32]. Air drying of thin slices of sweet potato leads to only slight losses of vitamin C. The vitamin C content as shown in Table 4 ranged from (27.87 µg/100 g) in sample H to (37.71 µg/100 g) for sample E. No significant difference (P>0.05) occurred among samples A (36.22 µg/100 g), B (36.42 µg/100 g) and C (36.36 µg/100 g) respectively.

Boiling may result in a 20 to 30 percent loss of vitamin C from unpeeled roots and tubers. If peeled before boiling the loss may be much higher, up to 40 percent. Swaminathan and Gangwar [33] estimated that 10 to 21 percent of the loss is due to leaching into the cooking water and the rest is destroyed by heat. Work by Ashokkumar, et al. [34] had thiamin level of (80.0 µg/100 g), riboflavin (40.0 µg/100 g), niacin (60.0 µg/100 g) and vitamin C of (20.0 µg/100 g) on yellow root cassava which is higher than the result obtained from this work. Baking losses of vitamin C in unpeeled potato are about the same as in boiling but roasting results in higher losses, while making into crisps seems to be slightly better in terms of vitamin retention. Frying results in the loss of 50 to 56 percent compared to 20-28 percent on boiling unpeeled [35]. Streghtoff, et al. [36] reported a 28 percent loss during baking and only a 13 percent loss when boiled after peeling. The difference may be that the higher temperature of baking leads to greater destruction of the vitamin. The vitamin C content of potato is very similar to those of sweet potato, cassava and plantain, but the concentration varies with the species, location, crop year, maturity at harvest, soil, nitrogen and phosphate fertilizers [37]. One hundred grams of potato boiled with the skin is sufficient to provide about 80 percent of the vitamin C requirement of a child and 50 percent of that for an adult. According tothe Cook, et al. [38] potato was a principal source of vitamin C in British diets, providing 19.4 percent of the total requirement. McCay, et al. [7] estimated that in the United States of America potato provided as much vitamin C (20 percent) as did fruits (18 percent). Study on vitamin E (tocophenol) reported by Oki, et al. [39] ranged (2.61–8.48 mg/100 g) on OFSP which were little higher than (3.13 mg/100 g) on sample F which was the 95% OFSP blend with 5% Moringa leave powder.

4. CONCLUSION

Sweet potatoes are an essential nutritious staple crop in Nigeria. Above all, the higher potassium than sodium levels make them ideal diuretic diet for the prevention of the onset of certain health conditions including hypertension. Generally, minerals and vitamins are functional ingredients of food which impact positively on human health and wellbeing beyond mere nutrition. For all the samples tested, sample G which serves as the control (95% Plantain with 5% *Moringa oleifera* leave powder) exhibited highest in calcium (13.26 mg/100 g), magnesium (88.06 mg/100 g), potassium (287.70 mg/100 g) and iron (2.69 mg/100 g) as with composite flour. Potassium and sodium perform important biochemical functions as in acid-base balance, nerve impulse mediation and cell membrane sodium (Na) and potassium (K) channels and pumps. However, compelling evidence have replicated high dietary sodium intake in the development of cardiovascular disease, importantly hypertension and that increased intake of dietary potassium is beneficial in relation to blood pressure control [8]. Currently, results are inconclusive as to whether potential adverse effects are associated with low intake of sodium [8]. Meanwhile sodium intake of <1.5 g or <2.3 g per day is recommended in dietary guidelines [9]. Potassium level ranged from (244.62 mg/100 g to 287.70 mg/100 g) with significant differences within the samples (P<0.05). Sample G had the highest potassium level which is similar to (264.75 mg/100 g) reported by Oko, et al. [10] on Nbipaul plantain cultivar variety. Plantains are reported to be low in sodium and higher in potassium and calcium which is confirmed in this result. Potassium was present in about 15 times as sodium. The value of composite flour of 95% plantain with 5% *Moringa oleifera* leaves powder (sample G) was (9.26 mg/100 g) which is lower than (27.78 mg/100 g) as reported by Oko, et al. [10]. Therefore, consumption of plantain flour may be disposed populace to hypernatremia or high blood pressure respectively. The calcium is comparatively more abundant among samples G (13.26 mg/100 g) while sample D (12.86 mg/100 g) did not significantly (P>0.05) differ from E (12.87 mg/100 g) and F (12.17 mg/100 g). Generally, the alkaloid, tannin and heamaglutinin content for sample F (95% YRC with 5% *Moringa oleifera* leave powder) were (4.22 mg/100 g), (2.26 mg/100 g) and (12.43 mg/100 g) which recorded highest that caused the increment among the flour blends therefore, from sample A to E, while sample G, contained the least of alkaloid (2.74 mg/100 g) and (1.07 mg/100 g) for tannin. Plantain contains very little beta-carotene Consequently, the vitamin A content of the composite flour increased as the proportion of orange fleshed sweet potato increased, this is due to the minerals and vitamin A content of OFSP is higher than that of yellow root cassava and plantain. When compared to the daily requirements, the blend can contribute to some extents. This study also revealed that composite flour blends of OFSP, YRC, Plantain fortified with *Moringa oleifera* leave powder are rich in carotenoids and also assumed to be rich in β-carotene, which is a precursor of vitamin A, and can play an important role in the alleviation of VAD in the children of developing countries. While the production of other sweet potato varieties is encouraged, the study findings suggest the consumption of OFSP to address nutrient deficiencies. With the findings of this research work is therefore, recommended that the consumption of OFSP, YRC and plantain fortified with *Moringa oleifera* leaves should be brought to the public, medical profession, consumers and producers due to it beneficial role.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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