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ASSESSMENT ON NUTRITIONAL AND PHYTOCHEMICAL FACTORS OF EXTRUDED PRODUCT BLENDS FROM CASSAVA, SWEET POTATO, AND PLANTAIN FORTIFIED WITH *MORINGA OLEIFERA* LEAVES

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Abstract
Orange fleshed sweet potato (OFSP) and yellow root cassava (YRC) were harvested from National Root Crop Research Institute Umudike, while moringa leaves was sourced from Micheal Okpara University of Agriculture, Umudike (MOUAU) and plantain from Umuahia market. They were processed into flour and used to form a blend, and processed into extruded baked snacks fortified with *Moringa oleifera* leaves powder at constant ratio (5%). The vitamin C value for the snacks varied from 23.66µg/100g to 32.76µg/100g. Vitamin C content increased as the proportion of cassava increased from sample A (31.43µg/100g) to E (32.76µg/100g), while sample H (95% OFSP with 5% *Moringa oleifera* leaves powder) had the least (0.13 – 93.75µg/100g). Vitamin B_1, B_2, B_3 were less than 1%, and ranged from 0.45µg/100g (G) to 0.75µg/100g (E) for vitamin B_1, 0.07µg/100g (F) to 0.34µg/100g (A) for vitamin B_2 and B_3 from 0.41µg/100g (A) to 0.64µg/100g (E). Vitamin A level increased with plantain ration which was observed in sample A (31.35µg/100g) and B (31.02µg/100g). It was observed that calcium, potassium and sodium levels increased with percentage of yellow root cassava. There was a decrease in iron content, which ranged from 0.43mg/100g for F, to 3.12mg/100g for G as the percentage of *Moringa oleifera* leaves powder added was constant. Sodium content from the table increased with percentage of biofortified cassava (UMUCASS 45) ranging from 10.22mg/100g to 17.14mg/100g. No significant difference (P>0.05) was observed among samples C (13.06mg/100g), D (13.09mg/100g) and E (13.21mg/100g), A (12.05mg/100g) and B (12.20mg/100g).

Keywords: Yellow root, Orange fleshed, Plantain, Production, extruded baked snacks, vitamins, minerals and phytochemicals

Introduction
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, increasing demand of consumers for better quality foods and increasing new uses for 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 are as 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, processes and raw material development issues, improvement achieved in nutritional delivery of cassava foods, progress made in the storage, presentation, packaging, etc., of cassava foods. Extruders minimize the operating costs and higher productivity than other cooking process, combining energy efficiency and versatility. Cassava and corn meal is a major ingredient for extruded foods, such as ready-to-eat breakfast cereals and snacks (Jozinovic *et al.,* 2012). The market share of "ready-to-eat" food, "snack" food and breakfast cereals are growing almost everywhere in the world (Brncic *et al*., 2006). Snack foods are prepared from natural ingredients or components to yield products with specified functional properties (Reid *et al*., 1998). Snacks can be used as a vehicle for incorporating nutrients that have health benefits (Zazueta-Morales *et al*., 2001). Food extrusion has been widely used to produce ready to-eat cereals and snack foods. Physical

characteristics of an extruded snack product such as expansion, hardness and density are important parameters in terms of the consumer acceptability and as functional properties of the final product. Extruded snack products are predominantly made from cereal flour because of their good expansion characteristics. However, extruded food products produced from cereals tend to be low in protein and have a poor biological value because of their limited essential amino acid contents (Iqbal *et al.,* 2006). Many snack foods have low nutrient densities and are often fortified with proteins (Tangkanakul *et al*., 1999). As a carbohydrate source, maize is extensively used in the production of snack food by extrusion technology. Extrusion has become a very important role in food processing operation. Today, the food extruders are used to produce pasta, ready-to eat cereals, snacks, confectionery products, modified starch for soup, baby food and instant foods, beverage bases and texturized vegetable proteins. Extrusion cooking technology is a high temperature short time processing for the development of new innovative products. It minimizes energy, time and cost (Vijayarani *et al.,* 2012). The demand for bakery products and importation of wheat are increasing (CSA 2011), replacing relative proportion of flours from OFSP/ biofortified cassava/ plantain fortified with *moringa* leaves powder could have an advantage on the nutritional and economic aspects. Therefore, the aim of this study was to develop pro-vitamin A and energy rich extruded snacks from blends of yellow root cassava (TMS/07/0593)/ OFSP/ Plantain fortified with *Moringa oleifera* leaves powder by altering the blend ratio. Nutritional composition (mineral and vitamins) analyses and anti-nutritional properties were conducted to support the objectives of this study.

Materials and Methods

Sample preparation

OFSP (*Ipomoea batatas*) and yellow root cassava (*Manihot esculenta* Crantz) variety (TMS/07/0593) and *Moringa oleifera* leaves were collected from National Root Crop Research Institute Umudike, while plantain was purchased from Umuahia main market, processed into flour at the factory (NRCRI) Experiment A. Ingredients like mixed spices, salt and butter were purchased from Umuahia local market. The matured and sorted OFSP tubers, YRC, Plantain were cleaned and washed with tap water to remove any adhering soil, dirt and dust. The tubers were then peeled off with knife. YRC and OFSP were chipped, while plantain was sliced into 2 mm thickness with knife to facilitate drying and milling. The sliced plantain, chipped YRC and OFSP were oven dried. The material were then dried in solar drier (Alvant blanch, Withshier, England) for 24 h at 50-60^{o}C till it reached 12% moisture and ground with a miller (Thomas-Wiley laboratory mill, ILCA 5789, Philadelphya PA, USA) on 500 µm screen. The flour sample was packed in airtight black HDPE plastic using impulse sealer (HM3000 Polythene heat sealer, hulmemartin, UK) and kept at 15 - 18°C until use (these samples were not stored too long and the use of the samples was immediate after the day of preparation).

Technological treatments

Snack food preparation: Procedures were carried out as preliminary steps towards preparing the formulated food mixtures. Five blends were formulated and fortified with *Moringa oleifera* leave powder (5%), in addition to another one, the TMS/07/0593 (5% *Moringa oleifera* leaves powder + 95% biofortified cassava), (OFSP 95% + 5%moringa leave powder) and (95% Plantain + 5% *Moringa oleifera* leaves powder). Total weight of each blend was about 20-25 kg. The five experimental blends were prepared according to the percentages of constituent ingredients given in Table 1, and each blend was named according to its constituent ingredient.

Table 1: Flour Blends of Yellow Root Cassava (YRC) (TMS/07/0593), Orange-fleshed sweet potato (OFSP), Plantain and *Moringa oleifera* Leaves

Sample number	YRC%	OFSP%	Plantain %	*Moringa oleifera leaves* powder %
A	65	10	20	5
B	70	10	15	5
C	75	10	10	5
D	80	5	10	5
E	85	5	5	5
F	95	-	-	5
G	-	95	-	5
H	-	-	95	5

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

The table shows the blends of raw material (composite flour): plantain flour, orange fleshed sweet potato, yellow root cassava and *Moringa oleifera* leaves powder were blended using a Hobert mixer in the ratio which shows blend formula of eight (8) equal combinations. This composite flour, baked products were packaged in polyethylene bags and stored at room temperature.

Preparation of extruded baked snacks

The method described by Yiu (2006), with slight modification was used for the production of puffed snacks. For the production of extruded baked snacks made from blends of yellow root cassava flour, orange fleshed sweet potato flour, unripe plantain flour with *Moringa oleifera* leaves powder (used as fortification), the dough for the extruded blends was first prepared by mixing 100g of cassava flour, orange fleshed sweet potato flour, unripe plantain flour and *Moringa oleifera* leaves powder, 1g of salt and 1g of mixed spices, with 150ml of water in a bowl. After which the flour was thoroughly mixed to obtain malleable dough at temperature of 37°C. The dough was formed into cylindrical rolls of 5cm in diameter, and the cylindrical dough was filled in an extruder which was piped on a greased tray. The greased tray with the extruded product was baked in a hot oven (Gallenkamp Co. Ltd. London, England) at 100°C for 30 minutes to the required moisture content (12%). The blend baked snacks were allowed to cool on kitchen paper and stored in air tight containers prior to various analyses. Snack extrusion was made in single-screw extruder (locally fabricated single screw extruder) with cold extrusion. Each blend was mix-fed to the extruder at room temperature (37°C) at 30% moisture content on a greased pan. The extruder was operated for 3 mins for each set of sample.

Physicochemical analyses

Vitamin A was determined by the method as described by Delia *et al*. (2004, while thiamine (vitamin B_1) was determined by the method as described by Onwuka (2003). Riboflavin (vitamin B_2), niacin (vitamin B_3), ascorbic acid (vitamin C), tocophenol (vitamin E) were determined by the method as described by AOAC (2010). Minerals such as ; calcium, potassium, iron and magnesium were carried out using Atomic Absorption Spectophotometer (AAS) as described by AOAC (2010). Sodium and potassium were carried out using flame photometry as described by Onwuka (2003). Phytochemical determination such as flavonoid, phytate, oxalate, tannin, alkaloid, hydrogen cyanide, haemaglutinin and phenols were determined by the method as described by AOAC (2010). All the analysis were carried out in triplicates.

Results and Discussion

The results in Table 2 shows the Vitamin composition of the extruded baked product from cassava, sweet potatoes and plantain blend with *moringa oleifera* leaves. The vitamin C values for the snacks varied from 23.66µg/100g to 32.76µg/100g. Vitamin C content increases as the proportion of cassava increases for sample A (31.43µg/100g) to E (32.76µg/100g), while sample H which is 95% OFSP with 5% *Moringa Oleifera* leaves powder had the least (0.13 – 93.75µg/100g), and lower than that of orange fleshed sweet potato juice reported by Tarika *et al.* (2014). The vitamin C values of snacks of sample A (31.43µg/100g), B (31.67µg/100g), C (31.88µg/100g) and F (31.11µg/100g) were significantly the same. Sample E contain the highest vitamin C content. The reduction of vitamin C in sample H which is 95% OFSP blend with 5% *Moringa oleifera* leaves powder could be due to the processing method used during baking. Though, no ascorbic acid was added as reported in Tarika *et al.* (2014) which may be the course of the increment of vitamin C in the juice product. As shown in Table 2, the result of vitamin B_1, B_2, B_3 were less than 1%, which ranged between 0.45µg/100g in sample G to 0.75µg/100g in sample E for vitamin B_1, 0.07µg/100g in sample F to 0.34µg/100g in sample A for vitamin B_2 and 0.41µg/100g in sample A to 0.64µg/100g in sample E for vitamin B_3. As shown in Table 2, vitamin A level increases with increase in plantain ration which was observed in sample A (31.35µg/100g) and B (31.02µg/100g). Sample H was the blend of 95% OFSP with 5% *Moringa oleifera* leaves powder which had the highest vitamin A value. The high vitamin A content of sample H corroborates the claim, traditionally and medically that it improves eyesight. This may probably be a result of a dense concentration of OFSP. Consequently, in Africa, where vitamin deficiencies are common occurrences, baked OFSP was considered an important vitamin A supplement of diets (Bassir, 1968). The thiamin level increased with increase proportion of yellow root cassava in samples A (0.52µg/100g), B (0.55µg/100g), C (0.62µg/100g), D (0.69µg/100g) and E (0.75µg/100g) which recorded the highest vitamin B_1. Among the 95% level, sample F (0.58µg/100g) had the highest thiamin value which is the blend of 95% YRC with 5% *Moringa oleifera* leaves powder, while samples G and H were 95% plantain and OFSP with 5% *Moringa oleifera* leaves powder are significantly the same (0.45µg/100g). As indicated also, increase in plantain ratio increased the vitamin B_3 content presented in sample A (0.34µg/100g) and B (0.31µg/100g), while sample F (0.07µg/100g) was the least among the 95% blends. Vitamin B_3 increased with cassava ratio as observed among sample A (0.41µg/100g), B (0.44µg/100g), C (0.50µg/100g), D (0.57µg/100g) and E (0.64µg/100g). Sample F (95% YRC with 5% *Moringa oleifera* leaves powder) (0.62µg/100g) had the highest vitamin B_3 content as compared to 0.57µg/100g in sample G (95% plantain with 5% *Moringa oleifera* leaves powder) and 0.48µg/100g in sample H (95% OFSP with 5% *Moringa oleifera* leave powder). Vitamin E as indicated in the Table 2 showed no significant difference (P>0.05) among samples A (2.96µg/100g), B (2.95µg/100g), C (2.95µg/100g), D (2.93µg/100g), E (2.87µg/100g), F (2.88µg/100g), G (2.66µg/100g) and H (2.99µg/100g) which ranged from 2.66µg/100g in sample G to 2.99µg/100g in sample H, while sample H had the highest vitamin E content. Consumption of 100 – 200g of OFSP requires achieving around 20% - 25% RDA of vitamin E. However, the OFSP is not considered as the best source of α-tocopherol because less concentration of fats was reported in OFSP. So supplementation of vitamin E foods, such as oil seeds is very important for the consumers of OFSP as second staple vitamin E represented eight isomers of fat-soluble compounds (α, β, γ, δ tocopherol and tocoterienol) metabolized in plants (Netscher, 2007), which are available in various concentrations in fat-rich foods (edible oils and seeds). Reboul *et al*., (2006) indicated anti-inflammatory and liver protection. Galli *et al*. (2017) reported that tocophenol helps to synthesis new red blood cells and widens blood vessels, potentially lowering risk of developing blood clots (Krem and Cera, 2002). Some of the vitamins are loss during the extrusion process, but most of it takes place during drying (removal of water), about 50% most of the vitamins are also lost in the process. There is a 90% loss of thiamin, riboflavin niacin, 50% loss in vitamin E and 50% vitamin A and C retained in the baked snacks.

Results of some essential minerals including calcium (Ca), phosphorus (P), magnesium (mg), iron (Fe), potassium (K) and sodium (Na) for the extruded baked snacks are presented in Table 3. Tabulated results showed no significant difference (P>0.05) among samples C (12.07mg/100g), D (12.95mg/100g), E (12.98mg/100g) and F (12.96mg/100g), while samples B (11.56mg/100g), G (11.24mg/100g) and H (11.93mg/100g) were significantly the same. Among the flour samples with 5% *Moringa oleifera* leaves powder (samples F, G and H), the 95% yellow root cassava had the highest calcium content of 12.96mg/100g.(Obasi and Chukwuma, 2015) on evaluation of crackers from yellow root cassava (UMUCASS 36 and 38) reported 2.02mg/100g and 2.61mg/100g, which are lower than 12.96mg/100g obtained from UMUCASS 45 blend with 5% *Moringa oleifera* leaves powder, but similar to 1.02 to 15.46μg/100g on composition of gari analog produced from cassava and cocoyam tuber as reported by Oluwaseun *et al.* (2014). A little variation might be because cocoyam is richer in mineral composition than in cassava. Calcium is essential for bone formation in children. Calcium plays a major role in muscle function, formation and strengthening of bones, teeth, conducting nerve impulses, blood clothing, and maintaining a normal heartbeat (Zemel, 2009). Humans within the age range of 18-50 require 1,000mg of calcium per day as recommended daily allowance (RDA). Individuals younger than 18years need superior concentration (1,300mg) of calcium for development of bones and teeth (Wosje and Specker, 2009). The calcium content of 24.40 – 45.54mg/100g was observed in OFSP, which were higher than 11.93mg/100g indicated in this study for sample H which was the 95% OFSP. These variations in the calcium concentration are attributed to varietal and agro-geological conditions (Sanoussi *et al*., 2016).

Sample F (89.17mg/100g) magnesium, and Potassium (289.62mg/100g) scored the highest as compared to other samples, while sample G recorded highest in sodium and iron (17.14mg/100g) and (3.12mg/100g) respectively. Obasi and Chukwuma (2015) on evaluation of crackers from yellow root cassava (UMUCASS 36 and 38) reported magnesium level of 0.24mg/100g each, sodium level of 2.87mg/100g each, which are lower than the magnesium (89.17mg/100g), and sodium level of 10.22mg/100g from UMUCASS 45 with 5% *Moringa oleifera* leaves powder. But 0.56mg/100g and 0.63mg/100g for UMUCASS 36 and 38 respectively, were similar to (0.43mg/100g) iron from UMUCASS 45 reported from this study. It has been documented by Sehecie and Dragojevic (2005) on biscuits as source of calcium, magnesium, sodium and potassium in nutrition that calcium and magnesium contents in different kinds of biscuit ranged from 204.3 to 879.2 μg g^{-1} and 172.9 to 595.3 μg g^{-1} respectively were higher than the values obtained from this study. Rania *et al*. (2016) on effect of *Moringa oleifera* leaves on pan bread indicated calcium (28.42mg/100g) as higher than calcium content reported from this result, magnesium (5.50mg/100g), lower than 33.21 – 89.17mg/100g and iron (3.82mg/100g) similar to 0.43 – 3.12mg/100g obtained from this study.

The data showed that potassium content gradually increased from 217.18mg/100g in sample G to 279.71mg/100g for sample C. Using of *Moringa oleifera* leaves powder raised the potassium level. Potassium is the major mineral in most root crops particularly variable in the diet of patients with high blood pressure who have to restrict their sodium intake. In such cases, the high potassium to sodium ratio may be an additional benefit (Meneely and Battarblee, 1976). Also in Table 3, there was a decrease in iron content, which ranged from 0.43mg/100g for F, to 3.12mg/100g for G, as the percentage of *Moringa oleifera* leaves powder added was constant. Sodium content from the table increased with increase in the percentage of biofortified cassava (UMUCASS 45), as it ranged from 10.22mg/100g to 17.14mg/100g were no significant difference (P>0.05) was observed among samples C (13.06mg/100g), D (13.09mg/100g), and E (13.21mg/100g); among samples A (12.05mg/100g) and B (12.20mg/100g). Humans acquires sodium from food and drink and losses through sweat and urine. Kidneys play a crucial role in sodium-level adjustments (Reynolds *et al*., 2006). RDA of sodium is 1.500mg, less concentrations of the sodium in food source may not have any health problem, because the addition of sodium in form of table salt is a common practice in human food preparations for the sake of taste. In general, the magnesium content of sample F (89.17mg/100g) was highest, followed by sample H (81.57mg/100g), which is the blend of 95% OFSP and G (33.21mg/100g) recorded the least 95% plantain with 5% *Moringa oleifera* leaves powder.

Magnesium is one of the six important key macro minerals and essential minerals in >300 metabolic functions and important for strong bones, appropriate cardiac temperature (Saris *et al*., 2000). The RDA of Mg of men and women is 420 and 320mg/100g respectively. The magnesium concentration of 3 - 37mg/100g was reported by Endrias *et al*. (2016) in OFSP, which was lower than 81.51mg/100g in sample H (95% OFSP). This variation may be attributed to the varietal and agro-climatic conditions. Staple cereals are good sources of the magnesium than OFSP. The magnesium rich food supplementation is highly recommended for consumers of OFSP to meet RDA of magnesium. It was observed that calcium, potassium and sodium levels increased with increase in percentage of yellow root cassava. Concerning the recommendation of FAO (2001) eating about 100g of sample F (95% UMUCASS 45) will provide adequate nutrient for adults. It could be observed that all processed snacks were superior in potassium and magnesium. About 6% of iron in humans is present in certain proteins, which are crucial for respiration and energy metabolic processes, and implicated in the amalgamation of collagen and certain neurotransmitters (Bashiri *et al.,* 2003). Iron deficiency is known as crythropoiesis and worst iron deficiency leads to anemia (Abbaspour *et al.,* 2014). The RDA of iron is 1.8mg in adults and merely 10%-30% of the iron in diet is bioavailable (Endrias *et al*., 2016). OFSP was reported to be 0.63- 15.26mg/100g of iron (USDA, 2015) and therefore as a good source for providing the RDA of iron.

The phytochemical content of the snacks and extruded product are represented in Table 4. The mean values of phytochemicals of the baked snacks produced from yellow root cassava, orange fleshed sweet potato and plantain fortified with *Moringa oleifera* leaves powder with different ratio are shown in table 4. Tannin, oxalate, phytate, HCN, alkaloid, flavonoid, phenol and heamaglutin were evaluated. For all the samples, sample F had the most abundance of tannin (2.41mg/100g), phytate (0.03mg/100g), HCN (1.58mg/100g), alkaloid (0.96mg/100g) and heamaglutin (7.60mg/100g). It was also observed that tannin, oxalate, phytate, hydrogen cyanide and alkaloid levels increased as the percentage of yellow root cassava increases which ranged from sample A to E. Among the 95% blends, sample G had the highest of phenol content of (0.47mg/100g). Though, a significant difference ($P<0.05$) did not occur in phenol content which ranged from (0. 12 - 0.47mg/100g). No significant difference also occurred among the sample in oxalate, phytate and alkaloid which ranged from (0.00 – 0.01mg/100g), (0.01 - 0.03mg/100g) and (0.62 - 0.96mg/100g). The residual cyanide remaining in the cassava plants after being processed, the cassava roots were classified according to their potential toxicity to human and animals as non-toxic (less than 50mg HCN Kg^{-1} in fresh roots) moderately toxic (50 100mg HCN Kg^{-1} in fresh roots) and dangerously toxic (above 100mg HCN Kg^{-1} in fresh roots) (Delange *et al*., 1984). The lethal dose of cyanide in humans has been reported by several authors as ranging between 50 to 300mg HCN Kg^{-1} body weights (Akiyama *et al.,* 2006). The residual cyanide level among the extruded snacks ranged from (0.25 – 1.58mg/100g) with UMUCASS 45 blend with 5% *Moringa oleifera* leaves powder having the highest cyanide level among the baked snacks investigated while the blend of 95% plantain with 5% *Moringa oleifera* leaves powder had the least. This variation can be attributed to the improvement in lowering hydrogen cyanide content to an acceptable ratio. Hydrogen cyanide is volatile and processing methods used in the production of baked product (grating and oven drying) helped to lower the cyanide content as reported to reduce the cyanide content of cassava (Bradbury, 2004). The implication is that consumption of these baked snacks may not confer any toxic effect to the consumers. It was observed in table 4 that hydrogen cyanide content increased as the concentration of cassava increases. Therefore, the low cyanide content of the snacks falls within the acceptable limits of 10mg HCN equivalent/kg dry weight recommended by FAO/WHO (1998) for safe cassava products. Tannin is one of the important secondary metabolites which reduces the risk of coronary heart disease. From table 4, it was observed that sample F (2.41mg/100g) had the highest tannin level. The implication of the baked snacks investigated showed that low levels of anti-nutrient are free for human consumption. Therefore, the toxic compound hydrogen cyanide and anti-nutrients were found below the permissible level (1%) indicating that these samples are safe for consumption.

Conclusion

In conclusion, the implication of the baked snacks investigated showed low levels of anti-nutrient which indicates that the snacks are free for human consumption. Therefore, the toxic compound hydrogen cyanide and anti-nutrients were found below the permissible level (1%) indicating that these samples are safe for consumption. Also, they contain some minerals and vitamins which are therefore a good source for providing the RDA of iron and other minerals.

Table 2: Vitamin composition of the extruded baked product from cassava, sweet potatoes, and plantain blend with *moringa oleifera* leaves

Sample	Vitamin A(mg/100g)	Vitamin B_1(mg/100g)	Vitamin B_2(mg/100g)	Vitamin B_3(mg/100g)	Vitamin C(mg/100g)	Vitamin E (mg/100g)
A	31.35^{b}±0.02	0.52^{e}±0.01	0.34^{a}±0.01	0.41^{d}±0.01	31.43^{e}±0.01	2.96^{ab}±0.01
B	31.02^{c}±0.02	0.55^{de}±0.01	0.31^{a}±0.01	0.44^{d}±0.01	31.67^{d}±0.01	2.95^{ab}±0.01
C	30.44^{d}±0.02	0.62^{c}±0.02	0.25^{b}±0.02	0.50^{c}±0.01	31.88^{c}±0.02	2.95^{ab}±0.02
D	29.85^{e}±0.01	0.69^{b}±0.01	0.19^{c}±0.01	0.57^{b}±0.01	32.22^{b}±0.01	2.93^{bc}±0.02
E	28.72^{f}±0.01	0.75^{a}±0.01	0.16^{c}±0.01	0.64^{a}±0.01	32.76^{a}±0.02	2.87^{cd}±0.02
F	26.12^{g}±0.03	0.58^{cd}±0.01	0.07^{e}±0.01	0.62^{a}±0.02	31.11^{f}±0.01	2.88^{cd}±0.01
G	15.27^{h}±0.02	0.45^{f}±0.02	0.12^{d}±0.01	0.57^{b}±0.02	26.57^{g}±0.02	2.66^{e}±0.04
H	38.58^{a}±0.01	0.46±0.01^{f}	0.09^{de}±0.01	0.48±0.01^{c}	23.66^{h}±0.01^{h}	2.99^{a}±0.12

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 3: Mineral composition of the extruded baked snacks from cassava, sweet potatoes, plantain blend with *moringa oleifera* leaves (mg/100g)

Sample	**Magnesium** (mg/100g).	**Calcium** (mg/100g).	**Potassium** (mg/100g).	**Sodium** (mg/100g).	**Iron** (mg/100g).
A	46.42^{c}±0.29	10.36^{d}±0.08	258.67^{e}±0.77	12.05^{f}±0.06	0.89^{c}±0.01
B	45.52^{d}±0.02	11.56^{bc}±0.63	258.74^{e}±0.78	12.20^{e}±0.01	0.94^{b}±0.01
C	43.66^{e}±0.64	12.07^{b}±0.08	279.71^{b}±0.64	13.06^{d}±0.50	0.97^{b}±0.01
D	38.66^{f}±0.07	12.95^{a}±0.02	276.68^{c}±0.69	13.09^{cd}±0.50	0.76^{d}±0.50
E	36.84^{g}±0.64	12.97^{a}±0.02	268.71^{d}±0.74	13.21^{c}±0.04	0.71^{d}±0.01
F	89.17^{a}±0.08	12.96^{a}±0.04	289.62^{a}±0.69	10.22^{g}±0.01	0.43^{f}±0.01
G	33.21^{h}±0.03	11.24^{cd}±0.10	217.18^{f}±1.42	17.14^{a}±0.03	3.12^{a}±0.01
	81.57^{b}±0.78	11.93^{b}±0.08	276.54^{c}±0.78	16.23^{b}±0.00	0.50^{e}±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 .

Table 4: Phytochemical Analysis of the Extruded Baked Snacks from Cassava, Sweet Potatoes, Plantain Blend with *Moringa oleifera* Leaves

Samples	Tannin mg/100g	Oxalate mg/100g	Phytate mg/100g	HCN mg/100g	Alkaloid Mg/100g	Flavonoid Mg/100g	Phenol Mg/100g	Heamaglutin Mg/100g
A	$1.90^{c}\pm0.01$	$0.01^{a}\pm0.00$	$0.02^{a}\pm0.01$	$0.73^{e}\pm0.01$	$0.64^{e}\pm0.01$	$4.52^{a}\pm0.01$	$0.37^{b}\pm0.01$	$6.19^{f}\pm0.01$
B	$1.92^{bc}\pm0.01$	$0.00^{b}\pm0.04$	$0.02^{a}\pm0.01$	$0.74^{de}\pm0.01$	$0.72^{d}\pm0.01$	$3.85^{b}\pm0.01$	$0.33^{c}\pm0.01$	$6.36^{e}\pm0.01$
C	$1.93^{bc}\pm0.01$	$0.00^{b}\pm0.00$	$0.02^{a}\pm0.00$	$0.76^{cde}\pm0.02$	$0.78^{c}\pm0.01$	$2.92^{d}\pm0.01$	$0.26^{d}\pm0.01$	$6.61^{d}\pm0.01$
D	$1.94^{b}\pm0.01$	$0.00^{b}\pm0.00$	$0.02^{a}\pm0.01$	$0.78^{cd}\pm0.01$	$0.82^{ab}\pm0.03$	$2.22^{e}\pm0.03$	$0.20^{e}\pm0.00$	$6.83^{c}\pm0.01$
E	$1.94^{b}\pm0.01$	$0.00^{b}\pm0.00$	$0.03^{a}\pm0.01$	$0.79^{d}\pm0.01$	$0.94^{a}\pm0.02$	$2.04^{g}\pm0.01$	$0.18^{f}\pm0.01$	$7.15^{b}\pm0.01$
F	$2.41^{a}\pm0.01$	$0.00^{b}\pm0.00$	$0.03^{a}\pm0.00$	$1.58^{a}\pm0.02$	$0.96^{a}\pm0.01$	$2.09^{f}\pm0.01$	$0.14^{g}\pm0.01$	$7.60^{a}\pm0.01$
G	$0.68^{e}\pm0.01$	$0.00^{b}\pm0.00$	$0.02^{a}\pm0.01$	$1.25^{b}\pm0.01$	$0.62^{e}\pm0.02$	$3.56^{c}\pm0.01$	$0.47^{a}\pm0.01$	$5.66^{g}\pm0.01$
H	$0.57^{f}\pm0.02$	$0.00^{b}\pm0.00$	$0.01^{a}\pm0.00$	$0.87^{c}\pm0.02$	$0.87^{b}\pm0.02$	$2.62^{e}\pm0.02$	$0.12^{n}\pm0.01$	$5.02^{n}\pm0.02$

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

References

Akiyama, H., Toida, T., Sakai, S., Amakura, Y., Kondo, K., Sugita-Kunishi, Y. and Maitani, T. (2006). Determination of cyanide and thiocyanate in Sugihiratake mushroom using HPLC method with fluorometric detection. *Journal of Health Sci.*, 52: 73-77.

Abbaspour, N., Hurrell, R. and Kelishadi, R. (2014). Review on iron and its importance for human health. *Journal of Research in Medical Sciences*, 19 (2): 164– 174.

AOAC (2010). Association of Official Analytical Chemists. Official Methods of Analysis of the Association of Official Analytical Chemists.

Bashiri, A., Burstein, E., Sheiner, E. and Mazor, M. (2003). Anemia during pregnancy and treatment with intravenous iron: Review of the literature. *European Journal of Obstetrics Gynecology and Reproductive Biology*, 110 (1): 2– 7.

Bassir, O. (1968). Some Nigerian Wines. *W. Afr. Journal. Biol. Chem.*, (10): 42-45.

Bolhuis, G. G. (1954). The toxicity of cassava roots. *Neth. Journal of Agric. Sci*., 2: 176-185

Bradbury J. H. (2004). Wetting method to reduce cyanide content of cassava flour. Cassava Cyanide Diseases Network News, 4: 3-4.

Brncic, M., Tripalo, B., Jezek, D., Semenski, D., Drvar, N. and Krainczyk, M. (2006). Effect of twin-screw extrusion parameters on mechanical hardness of direct-expanded extrudates. *Sadhana,* 31 (1): 527–536.

CSA (2011). Central Statistical Agency of Ethiopia. Report on large and medium scale manufacturing and electricity industries survey.seasofchange.net/wp-content/.../Food-processing-in-Ethiopia.web.

Delange, F., Iteke, F.B., Ermans, A. M. (1982). Nutritional Factors Involved in the Goitrogenic Action of Cassava. International Development Research Centre, Ottawa, ON, Canada. 100pp.

Delia, B., Rodriguez-Amayal, E., Evelyn, B. and Amaya-Farfanl, J. (2004). Advances in Food Carotenoid Research: Chemical and Technological Aspects, Implications in Human Health. *Journal of Nutr*. 12(1): 101-121.

Endrias, D., Negussie, R., Gulelat, D. (2016). Comparison of three sweet potato (*Ipomoea Batatas* (L.) Lam) *varieties on nutritional and anti-nutritional factors. Global Journal of Science Frontier Research: D Agriculture and Veterinary*, 16(4): 1920– 11.

FAO (2001). Food and Agriculture Organization. FAOSTAT data base results. Food and Agriculture Organization of the United Nations. Rome. Italy

FAO/WHO (1998). Food and Agriculture Organization/ World health organization. Human vitamin and mineral requirements, report of a joint FAO/WHO Expert Consultation, Bangkok, Thailand. Rome, Italy: Food and Agriculture Organization of the United Nations. Available at: http://www.fao.org/DOCREP/004/Y2809E/y2809e00.htm. Accessed March 21 2015.

Galli, F., Azzi, A., Birringer, M., Cook-Mills, J.M., Eggersdorfer, M., Frank, J. and Özer, N.K. (2017). Vitamin E: Emerging aspects and new directions. *Free Radical Biology and Medicine*, 102:16-36.

Iqbal, A., Khalil, I.A., Ateeq, N. and Khan, M. S. (2006). Nutritional quality of important food legumes. *Food Chem*. 97: 331–335.

Jozinovic, A., Subaric, D., Durdica, A., Babic, J., Mirela, P., Pavokovic, M. and Marijana, B. (2012). Effect of screw configuration, moisture content and particle size of corn grits on properties of extrudates. *Croatian Journal of Food Sci. Technol.*, 4 (2): 95-101.

Krem, M. M. and Cera, E. D. (2002). Evolution of enzyme cascades from embryonic development to blood coagulation. *Trends in Biochemical Sciences*, 27(2): 67– 74.

Reid, I., Laronne, J.B. and Powell, D. M. (1998). Flash-flood and bedload dynamics of desert gravel-bed streams. *Journal of Food Sci*., 58(2): 9–20.

Meneely, G. R. and Battarblee, H.D. (1976). Sodium and potassium. *Nutr. Rev*., (34): 225-235.

Netscher, T. (2007). Synthesis of vitamin E. *Vitamins and Hormones,* 76 (7):155– 202.

Obasi, N. E. and Chukwuma C. S (2015). Quality Evaluation of Cassava Crackers Made From Yellow Root Cassava (*Manihot esculenta*). *Journal of Environmental Science, Toxicology and Food Technology,* 9(1):93-101.

Oluwaseun, B., Femi, G.O., Basirat, A.O. and Beatrice, F. (2014). Nutritional composition of gari analog produced from cassava (*Manihot esculenta*) and Cocoyam (*Colocasia esculenta*) tuber. Food Science and Nutrition 2(6): 49-53.

Onwuka, G.I. (2005). Food Analysis and Instrumentation. Theory and Practice, Naphthali prints, a division of HG Support Nig. Ltd, Lagos. Pp. 68-139

Reboul, E., Richelle, M., Perrot, E., Desmoulins-Malezet, C., Pirisi, V. and Borel, P. (2006). Bio-accessibility of carotenoids and vitamin E from their main dietary sources. *Journal of Agricultural and Food Chemistry*, 54(23): 8749– 8755.

Rania. E., Shady, M. E. and Gehan, A. G. (2016). Effect of moringa leaves powder (Moringa oleifera) on some chemical and physical properties of pan bread. *J. Food and Dairy Sci., Mansoura Univ.*, 7(7): 307 – 314.

Reynolds, R. M., Padfield, P. L. and Seckl, J.R. (2006). Disorders of sodium balance. *British Medical Journal,* 332(7543): 702– 705.

Saris, N.E.L., Mervaala, E., Karppanen, H., KhawajaJA, Lewenstam A (2000). Magnesium: An update on physiological, clinical and analytical aspects. *Clinica Chimica Acta,* 294(12):1920– 1945

Sanoussi, A.F., Adjatin, A., Dansi, A., Adebowale, A., Sanni, L.O. and Sanni, A. (2016). Mineral composition of ten elites sweet potato (*Ipomoea batatas* [L.] Lam.) Landraces of Benin. *International Journal of Current Microbiology and Applied Sciences,* 5(1): 103– 115.

Sehecie, B., Dragojevic, I.V. (2005). Biscuits as source of calcium, magnesium, sodium and potassium in nutrition. *Deutsch. Lebensmittel. Rundsch.* (101): 392-397.

Tangkanakul, P., Tungtrakul, P. and Mesomya, W. (1999). Nutrient contents of commercial snack food products. *Kasetsart Journal of Nat. Sci.* 33: 270–276.

Tariku, Z. M., Abadi, G. M. and Abebe, H. (2014). Development of Orange-Fleshed Sweet Potato (*Ipomoea batatas*) Juice: Analysis of Physico-Chemical, Nutritional and Sensory Property. *International Journal of Food Science and Nutrition Engineering*, 4(5): 128-137

USDA (2015). Food and Nutrition Information Center Food Guide Pyramid. Steps to a Healthier You

Vijayarani, D., Ponnalaghu, S. and Rajathivya, J. (2012). Development of Value Added Extruded Product Using Spirulina. *International Journal of Health Sciences and Research*, 2 (4): 42-47

Wosje, K. S. and Specker, B. L. (2000). Role of calcium in bone health during childhood. *Nutrition Reviews*, 58 (9):253– 268.

Yiu, H. H. (2006). Extruded Snacks. Handbook of Food Science, Technology, and Engineering. CRC Press. (4): 168-8.

Zazueta-Morales, J.J., Martínez-Bustos, F., Jacobo-Valenzuela, N., Ordorica-Falomir, C., Paredes-López, O. (2001). Effect of the addition of calcium hydroxide on characteristics of extruded products from blue maize (*Zeamaiz L.*) using response surface methodology. *Journal of the Science and Food Agriculture*. 14 (81):1379-1386.

Zemel, M. B. (2009). Proposed role of calcium and dairy food components in weight management and metabolic health. *Physician and Sports Medicine*, 37(2): 29– 39.