Journal of Advances in Microbiology

20(2): 35-47, 2020; Article no.JAMB.54971
ISSN: 2456-7116

Effect of Yellow Root Cassava, Orange Flesh Sweet Potato and Plantain Fortified with *Moringa oleifera* Leave on the Functional and Proximate Composition of Extruded Product

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Authors' contributions

This work was carried out in collaboration among all authors. Authors LNU, EAM and NO designed the study. Authors LNU and NAK performed the statistical analysis. Authors LNU and EAM wrote the protocol and wrote the first draft of the manuscript. Authors LNU, EAM and NO managed the analyses of the study. Authors LNU and NAK managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JAMB/2020/v20i230218
Editor(s):
(1) Dr. Niranjalie Perera, Wayamba University of Sri Lanka, Sri Lanka.
Reviewers:
(1) Ibidapo Olubunmi Phebean, Federal Institute of Industrial Research Oshodi, Nigeria.
(2) Jorge Isaac Castro Bedriñana, Universidad Nacional del Centro del Perú, Peru.
(3) Marcos Flores, Universidad Santo Tomás, Chile.
Complete Peer review History: http://www.sdiarticle4.com/review-history/54971

Original Research Article

Received 18 December 2019
Accepted 24 February 2020
Published 10 March 2020

ABSTRACT

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. In order to use OFSP tubers, incorporation with other flours in processing and baked products can be considered. The aim of this study is to determine the functional properties of the composite flour, development of extruded snacks using locally fabricated extruder from flour of different blend ratio of OFSP, YRC, Plantain fortified with moringa leaves powder and to determine the proximate composition of the fresh of orange fleshed sweet potato, yellow root cassava, plantain, the flour and the extruded baked snacks.

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Keywords: Functional properties; proximate and extruded baked snacks from orange-fleshed sweet potato; yellow root cassava; plantain fortified with moringa leaves powder.

1. INTRODUCTION

Carotenoids are among the most widespread natural pigments with yellow, orange, and red colors in plants. The carotenes are hydrocarbons soluble in nonpolar solvents such as hexane and petroleum ether. The oxygenated derivatives of carotenes, xanthophylls, dissolve better in polar solvents such as alcohols [1]. Vitamin A deficiency is common in sub-Saharan Africa. In Nigeria, it affects about 20% of pregnant women and 30% of children under five [2]. It can impair immune systems and vision which could cause blindness and, in some cases, death [3]. Yellow cassava contains high levels of β-carotene, which is a precursor to vitamin A. Cassava is also a major source of carbohydrates, 80% of which are starches [4]. The new, yellow cassava can provide up to 25% of daily recommended Vitamin A intake [5]. Since cassava is a major part of many people's diets, introducing cassava bio-fortified with Vitamin A is an excellent innovation to improve health on a large scale [6]. It is normally risky to change the colour of a staple crop because colour preference can negatively affect consumer adoption rates. Although, this is not the case with yellow cassava [7]. Since local consumers often add palm oil to white cassava flour in their foods, they are normally accustomed to the golden colour [8]. Therefore, the yellow colour has been shown not to defer consumers [9]. Orange-fleshed sweet potato are frequently consumed as a family meal in different countries by boiling, steaming, roasting, and drying [10]. Traditional sweet potato products are having significant role in income generation in small-scale businesses and entrepreneurs run by women. In developing nations such as Uganda and other countries, dehydrated and minimally processed foodstuffs from orange-fleshed sweet potato have been recognized as significant for domestic utilization and for small-scale commerce in domestic markets [11]. Orange-fleshed sweet potato and their products are highly promoting the different African countries such as Kenya, Uganda, Ethiopia, Mali by local governments with the help of International research organizations [12]. Report showed that semi processed products from Orange-fleshed sweet potato have been extensively studied in some countries such as Kenya was reported. Complementary food in form of porridge by Orange┼fleshed sweet potato flour was highly accepted by the assessors [13]. Researchers are concentrated on the methods to develop retention of the carotenes by the processing and are trying to develop the traditional foods by incorporating Orange-fleshed sweet potato such as bread [14], cookies [15], juices [16], and porridge [17]. The *Moringa oleifera* leaves are the most commonly use and nutritious part of the plant, being a significant source of vitamins like A beta-carotene, B, C, K, manganese, and protein, among other essential nutrients [18]. When compared with common foods particularly high in certain nutrients per 100 g fresh weight, cooked moringa leaves are considerable sources of these same nutrients [19]. Some of the calcium in moringa leaves is bound as crystals of calcium oxalate [20] though at levels 1/25th to 1/45th of that found in spinach, which is a negligible amount. The leaves are cooked and used like spinach and are commonly dried and crushed into a powder used in soups and sauces [21]. *Moringa l*eaves helps in treatment of asthma, heart burn, pneumonia, scurvy, headaches, malaria, bronchitis, skin disease, eye and skin infections [22]; [22]. Also reduces blood pressure, cholesterol and acts as an anticancer, antioxidant, antimicrobial and antidiabetic agents [23]. Therefore, production of extruded product will go a long way in reducing food scarcity, improve food security and produce a new product in the market.

2. MATERIALS AND METHODS

2.1 Sample Preparation

OFSP (*Ipomoea batatas*) and yellow root cassava (*Manihot esculenta Crantz*) variety TMS/07/0593 and *Moringa oleifera* leaves was collected from National Root Crop Research Institute Umudike and 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 by with knife. YRC and OFSP were chipped and plantain was sliced to 2 mm thickness with knife to facilitate drying and milling. The sliced plantain and chipped YRC and OFSP were oven dried. The material was then

Table 1. Product formulation of the flour blends of Yellow Root Cassava (YRC), Orange-fleshed Sweet Potato (OFSP), plantain and *Moringa oleifera* leaves

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	-
Fresh root			
100	-	-	-
-	100	-	-
-	-	100	-

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

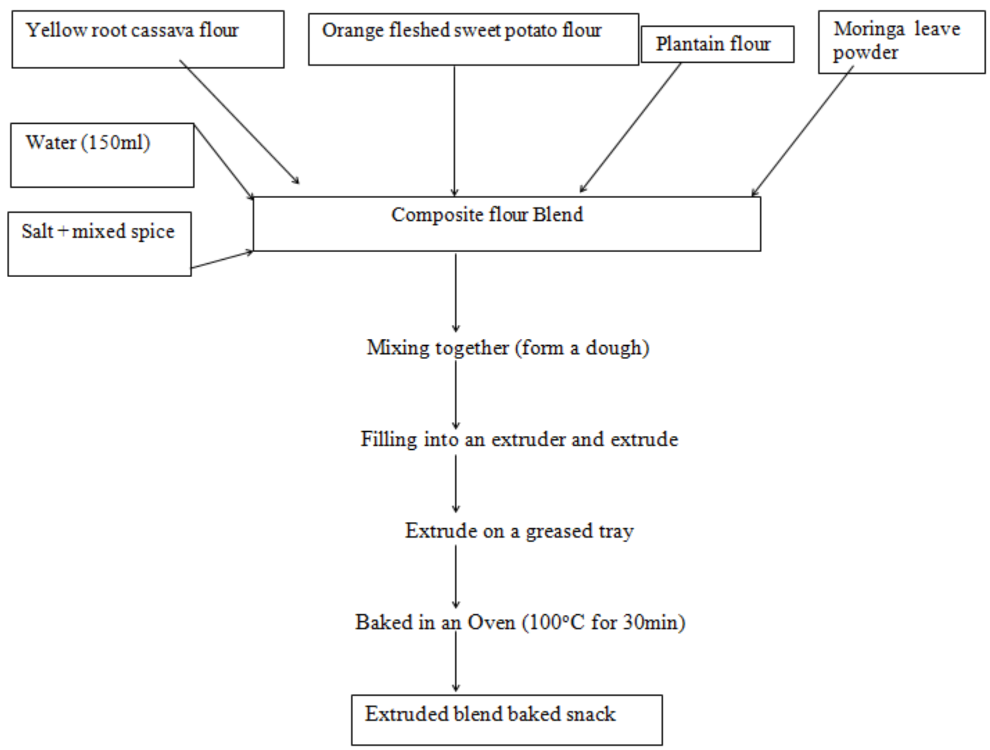

Fig. 1. Flow chart for production of extruded blend snacks

dried in solar drier (Alvant blanch, Withshier, England) for 24 h at 50-60°C till it reached 12% moisture and grounded by miller (Thomas-Wiley laboratory mill, ILCA 5789, Philadelphya PA, USA) with 500 µm screen. The flour sample was packed in airtight black high-density polyethylene 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).

2.2 Preparation of Extruded Snacks Made from a Blend of Yellow Root Cassava Flour, Orange Fleshed Sweet Potato Flour, Plantain Flour and *Moringa oleifera* Leaves Flour

The method described by Yiu [24], for the production of puffed snacks was used with a modification. 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* leaves powder (used as a fortificant), the dough for the extruded blends was first prepared by mixing 100 g of cassava flour, orange fleshed sweet potato flour, unripe plantain flour and moringa leaves powder, 1 g of salt and 1 g of mixed spices, with 150 ml of water in a bowl. The composite flour was thoroughly mixed to the consistency to obtain malleable dough at temperature of 37°C. The dough formed into cylindrical rolls of 5cm in diameter, after which 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 baked snacks were allowed to cool on kitchen paper and stored in air tight containers prior to various analyses.

2.3 Functional Properties Analysis

Determination of bulk density (BD), swelling index (SI). Water absorption capacity (WAC), foam capacity and Oil absorption capacity (OAC) was carried out using the method of AOAC (2010).

2.4 Proximate Composition Analysis

Determination of moisture content and crude protein carried out by the method of AOAC Association of Official Analytical Chemists, [25] while determination of carbohydrate, fat content, crude fiber, ash content, was carried out by the method described by Onwuka [26].

3. RESULTS AND DISCUSSION

The result of the functional properties of yellow root cassava, orange fleshed sweet potato and plantain composite flour fortified with moringa leaves powder were presented in Table 2. Functionality of foods is the characteristics of food ingredient other than nutritional quality which has a great influence on its utilization [27]. There was no significant difference on bulk density of composite flour which ranged from (0.71 – 0.79%). The bulk density from this research was in agreement with the findings (0.87 – 0.99%) reported by Aminu et al., [28] and it is also in line with the results (0.25 g/ml) as reported by Ajatta et al., [29] on wheat-breadfruit-cassava composite flour which ranged (0.82 g/ml to 0.85g/ml) which is contrary to a report made by Fagbemi, [30] which showed that bulk density increased as a result of blanching/ heat treatment prior to drying. Karuna et al., [31] indicated that bulk density is influenced by particle size and starch polymers structure because loose structure of the starch polymers could result in low bulk density. Therefore, the reduction in bulk density of this composite flour is desired and advantageous as it's contributes to lower dietary bulk, ease of packaging, storage and transportation [32]. This is usually affected by the particle size and density of the flour and very important in determining the packaging requirement, materials handling and application in wet processing in the food industry.

Water absorption capacity is the ability of a product to associate with water under a water limiting condition. The higher water absorption capacity of the composite flour could be attributed to the presence of higher amount of carbohydrate (starch) and fiber in the flour where no significant difference (P>0.05) was observed among the samples in water absorption capacity which ranged from (2.31% to 2.51%) higher than (1.65 to 2.15%) reported by Aminu et al. [28] and lower than (240-275% g/g as reported by Ajatta et al. [29] on composite flour from wheat- African breadfruit. Probably, the variation might be due to influenced of wheat- breadfruit flour which contain protein where there is presence of hydrophobic amino acids which interferes with the ability of the breadfruit starch to absorb water [33]. A desired characteristic of composite starches is the absorption of water during mixing in dough [34]. It was observed that water absorption capacity increased with decrease in oil absorption capacity which ranged between (0.09 g/ml) to (0.44 g/ml) whereby no significant difference (P>0.05) was observed among the samples which was lower than (0.50 – 1.25 g/ml) reported by Appiah et al., 2011 [35] and (125.5 – 158.1mg/g) on wheat- breadfruit flour as reported by Ajatta et al. [29]. This variation might be due to effect of the wheat-breadfruit flour which was part of the composite flour. Oil absorption capacity is the flavor retaining capacity of flour which is very important in food formulations [36].

Swelling index power is an indication of the absorption index of the granules during heating (Loos et al., 1981). A significant difference exists among the samples which increases in swelling index as the proportion of cassava increases which ranged from (1.04 g/ml – 2.12 g/ml). Sample A had the lowest swelling index of (1.04 g/ml) ie a blend 65% YRC + 10% OFSP + 20% Plantain + 5% *Moringa* leaves powder while the highest was presented in sample E (2.12 g/ml) ie a blend 85% YRC + 5% OFSP + 5% Plantain + 5% Moringa leaves powder. There was no significant difference among samples A (1.04 g/ml), B (1.06 g/ml), C (1.12 g/ml) and G (1.90 g/ml) also among samples D (2.10 g/ml), E (2.12 g/ml), F (2.01 g/ml) and H (2.02 g/ml).

Foam capacity of this work ranged from (8.72 g/ml) to (15.26 g/ml). There was no significant difference (P>0.05) among samples A (11.89 g/ml), B (11.67 g/ml), C (11.37 g/ml), D (11.32 g/ml), E (11.26 g/ml) and F (11.12 g/ml). Sample G (15.26 g/ml) happened to show highest in foam capacity which was the blend of 95% Plantain + 5% *Moringa* leaves powder followed by sample H (8.72 g/ml), the blend of 95% OFSP + 5% *Moringa* leaves powder. All the composite flours displayed stronger affinity for water than oil. In general, water absorption index among the composite flours did not differ significantly and has implications for viscosity. It is also essential in bulking and consistency of products as well as in baking application [37]. Oil absorption index was important since oil acts as flavor retainer and increases the mouth feel of foods, improvement of palatability and extension of shelf life particularly in bakery or meat products where fat absorptions are desired [38].

Table 3 showed the proximate composition of composite flour of yellow root cassava, plantain and orange fleshed sweet potato and moringa leave powder as a fortified product The table revealed that significant difference (P<0.05) exist between the samples. The dry matter content of the composite flour ranged from H (90.75%) to E (94.89%) were sample E recorded the highest and H the least. Result from Wasiu et al., [39] on the yellow root cassava blend with wheat flour of (96.80 - 96.84%) was in agreement with this research work on dry matter content. The moisture composition ranged from (5.88%) for sample A which is 65% YRC + 10% OFSP + 20% Plantain + 5% Moringa leaves powder to sample H (9.25%) which is 95% OFSP + 5% Moringa leaves powder. The moisture content of this research work was in line with work reported by Arisa et al. [29] on plantain composite flour of (5.16% - 6.27%) also agreed with work by Abegunde et al. [40] on biscuit blends with wheat and cocoyam that ranged from (8.43% to 5.86%) but lower than the values from Ubbor and Akobundu, [41] who reported higher moisture content of (19.51% - 21. 47%). It was observed that protein content ranged (6.71%) to (3.66%). A significant difference (P<0.05) occurred among the sample. Samples F (6.20%) and H (6.71%) had no difference which were the 95% YRC and 95% OFSP, among samples A (5.31%) and D (5.34%) which were composite flour of 65% YRC + 20% Plantain + 10% OFSP + 5% *Moringa* leaves powder and 80% YRC + 10% Plantain + 5% OFSP + 5% *Moringa* leaves powder and among samples B (4.98%), C (4.82%) and E (4.79%) which were of 70% YRC + 15% Plantain + 10% OFSP + 5% Moringa leaves powder, 75% YRC + 10% Plantain + 10% OFSP + 5% *Moringa* leaves powder and 85% YRC + 5% Plantain + 5% OFSP + 5% Moringa leaves powder while G (3.66%) 95% Plantain + 5% *Moringa* leaves powder was the least.

Table 2. Functional properties of the flour of yellow root cassava, orange fleshed sweet potatoes, plantain blend with *Moringa oleifera* leaves

Samples	Bulk density (g/ml)	WAC (g/ml)	OAC (g/ml)	Foam capacity (g/ml)	Swelling index (g/ml)
A	0.75^{bc}±0.00	2.51^{a}±0.01	0.09^{c}±0.00	11.89^{d}±0.01	1.04^{e}±0.01
B	0.75^{bc}±0.00	2.49^{b}±0.01	0.09^{c}±0.00	11.67^{c}±0.02	1.06^{e}±0.01
C	0.76^{b}±0.00	2.31^{c}±0.01	0.09^{c}±0.00	11.37^{d}±0.01	1.12^{d}±0.01
D	0.77^{b}±0.00	2.41^{b}±0.01	0.18^{b}±0.00	11.32^{e}±0.02	2.10^{a}±0.01
E	0.79^{a}±0.00	2.41^{b}±0.01	0.44^{a}±0.00	11.26^{f}±0.02	2.12^{a}±0.01
F	0.79^{a}±0.00	2.31^{c}±0.01	0.18^{b}±0.00	11.12^{g}±0.01	2.01^{b}±0.01
G	0.75^{bc}±0.00	2.51^{a}±0.01	0.18^{b}±0.00	15.26^{a}±0.01	1.90^{c}±0.01
H	0.71^{c}±0.00	2.51^{a}±0.01	0.44^{a}±0.00	8.72^{h}±0.02	2.02^{b}±0.02

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 PotatoA= 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

Ash content is considered among the chemical characteristics that defined quality of flour [42]. There was a significant difference (P<0.05) within the samples for ash content which ranged from (2.51 – 5.82%) except for samples C (2.91%), D (2.83%), E (2.77%), F (2.73%) and G (2.51%) respectively which was significantly the same. According to Maziya et al. [43], the ash content ranged from (0.77 - 1.43%) and (0.05 to 2.3%) by Kent and Ever, [42] which were lower than the ash content gotten from this work. Thus, almost all the samples do not comply with the regulatory standard of not more than 1.5% as content [44]. It was observed that ash content increased as percentage of plantain increases which indicated highest in (Sample G) as showed in Table 3. The protein content from Arisa et al., [45] was similar to protein content of this research but higher than (1.71 – 5.53%) reported by Maziya *et al.,* [43] on high quality cassava flour. This increment may be from *moringa* leaves powder which was added as a fortificant. Sample G (3.66%) was in agreement with (4.27%) on the protein content of plantain flour reported by Arisa [45]. No significant difference (P>0.05) was observed in fat content among the composite flour which ranged from sample F (1.05%) to G (1.58%). When compared the fat content as reported by Arisa et al., [45] on the composite flour of wheat and plantain (1.40 – 2.75%) were lower. Crude fiber is one of the non-digestible carbohydrates which provides the fecal bulkiness, less intestinal transit, role in cholesterol level reduction and trapping dangerous substances like cancer-causing agents and encourages the growth of natural microbial flora in gut [46]. The crude fiber ranged from (2.37 – 10.43%) which indicated sample G having the highest crude fiber content. As shown in the table, sample G is the 95% plantain flour which showed highest among the 95% blends, also as the proportion of plantain ratio increases, the crude fiber content of the composite flour increases as indicated in sample A (4.87%) and B (4.85%).

Green plantain contains starch which is in the range of 21 to 26%. The starch in the unripe plantain is mainly amylase and amylopectin and this is replaced by sucrose, fructose and glucose during ripening due to the hydrolysis of the starch Marriott et al. [47]. The carbohydrate content reduced to between 5 to 10% when ripe. The sugar content is between 0.9 to 2.0% in the green fruit but becomes more predominant in the ripe state. The plantain therefore has a high carbohydrate content (31 g/100 g) and low-fat content of (0.4g/100g) [48] which happened in Sample G (69.35%) ie 95% plantain contain high content of carbohydrate with low content of fat (1.58%). The result of carbohydrate content is in line with (63.83%) obtained from Arisa et al. [45] on effect of plantain but low in fat content from this work (1.58%) lower than (7.52%). There was a significant difference (P<0.05) within the composite flour for carbohydrate content which ranged from (69.35 – 81.76%). Sample A presented highest while G was the least in carbohydrate content. Samples A (81.76%), B (81.26%) and F (81.24%) are significantly the same also among samples C (79.59%) and D (79.72%).

The proximate composition of the extruded blend snacks produced from yellow root cassava, orange-fleshed sweet potato and plantain with *Moringa oleifera* leaves powder was present in Table 4. Significant difference among the samples (P<0.05) was observed. The moisture content of extruded snacks ranged from O (1.52%) to N (1.01%). The values from this research were lower as compared with the (9.77 – 11.72%) reported by Igbabu et al. [49]. The lower moisture content of the extruded baked product goes a long way in suggesting advantage for reduction of microbial growth and confers higher shelf life because higher moisture favours the development of contaminating microorganisms whose growth and activities causes spoilage in foods [50]. Low moisture content in *moringa* leaves powder used in the baked blends might have effective implications in extruded processed. The percentage moistures contents of the samples (dry basis) as observed in Table 4 whose moisture content does not differ from each other indicated low moisture content, which is a good attribute for storage. In addition, lower moisture content of sample compared indicated longer storage and if well packed and stored.

The dry matter content of the baked snack relates to good cooking quality ranged from (90.39 – 94.22%) ie M – O. As indicated in the table, the plantain level increased in samples I (93.18%) and J (92.86%) while among the 95% blends, sample O (94.22%) had the highest dry matter, no significant difference (P>0.05) existed between samples N (93.63%) and P (93.73%). The result from this work is higher than (54.00 – 67.47%) obtained from Wasiu et al., [39] on the blend of Yellow root cassava and wheat in the production of baked bread. This variation might be from the blend used as sample O (94.22%)

which is 95% plantain + 5% moringa leaves powder had the highest dry matter. High dry matter content of all the extruded baked snacks analysed in Table 4 differed significantly from each other (P<0.05) suggesting better cooking qualities and extruded storage lives. Plantain flour analysed with other blends in this study showed a good quality binders and composite flour in food and baking industries due to low moisture content.

As shown in the table, ash content of sample O (10.35%) was highest as compared with other samples which were higher than (0.55 to 2.53%) as reported by Oko et al. [51]. However, Shodehinde and Oboh [52] have reported significantly the same value in roasted and boiled plantain. Crude fiber consists of largely cellulose and lignin and some mineral matter. Values obtained in all the samples analyzed indicated significant difference in samples investigated (P<0.05). Sample M (9.61%) was significantly higher in crude fiber content (P<0.05) than other samples while sample I (6.82%) which did not differ significantly (P>0.05) from the crude fiber content of sample N (6.37%) and P (6.26%) respectively while sample O (5.78%) recorded the least. The total fat content of these snacks shows sample N (5.76%) presented highest. These values are lower than daily reference intake's (DRI) acceptable macronutrient distribution range (AMDR) range from 25 – 30% total fats for adults [53]. Fat serves as a source of energy and insulation for the body. In addition, it is needed for growth and development as solvent for some vitamins including A D E and K, maintenance of cell membrane, provide taste and consistency of foods. However, caution should be taken in order to avoid saturated and trans-fats in diets considering their dangerous health effects. A significant difference (P<0.05) was observed in fat content of the extruded baked snacks which ranged from sample O (2.45%) to N (5.76%). Samples J (2.85%), K (2.77%), L (2.71%), M (2.71%) and O (2.45%) are significantly the same and also between samples I (3.09%) and P (3.15%). The lower level of fat in samples gave a higher probability of a longer shelf-life in terms of onset of rancidity [54]. According to Oko et al. [51], fat content of boiled plantain ranged from (2.05 – 4.07%) which agreed with sample O (2.45%) (95% Plantain + 5% *Moringa* leaves powder).

A significant difference occurred in crude fiber on the snacks which range between (5.78 to 9.61%) from sample O (95% Plantain + 5% *Moringa* leaves powder) to sample M (85% YRC + 5% Plantain + 5% OFSP + 5% *Moringa* leaves powder).

The protein content ranged from sample O (3.52%) to P (5.92%) with sample P having the highest value which significantly differ (P<0.05) in protein and O the least. Work on biscuit snacks had protein content of (4.27 - 6.04%) reported by Arisa et al., [45] which agreed with the protein content of this research work. Many studies have reported lower protein content than (6.71%, 6.20%) as shown in this study. However, they cannot supply protein needs to human as a healthy adult requires about 0.75 g/kg per day Arisa et al., [45]. Crude protein composition of the snacks was within the lower limit of the recommended daily reference intake's (DRI) acceptable macronutrient distribution range (AMDR) of 10 – 35% protein for adults [53]. Though, comparatively, these different agricultural produce of (Yellow root cassava, orange-fleshed sweet potato and plantain) are not good source of protein. Proteins play very essential roles in healthy diets and nutrition. Carbohydrate content ranged from (76.38 – 80.71%) with significant difference (P<0.05) within the sample means. High amounts of carbohydrates are an alternative source of fiber in food and constitutes important energy source once included in [55]. Carbohydrate content on extruded snack ranged from (76.38 – 80.71%) except for samples I (79.29%) and J (79.09%), also among samples K (77.88%), L (77.14%) and M (77.14%) and among samples N (80.49%) and P (80.71%) respectively were significantly the same.

The main nutrient supplied by roots and tubers is dietary energy provided by carbohydrates. Cassava protein is lower in total essential amino acid than the other root crops but recently Adewusi et al. [56] found that cassava flour used as a component in animal feeding trails was a more effective replacement for wheat than either maize or sorghum. To some extent, the protein content of root crops is influenced by variety, cultivation practice, climate growing season and location [57]. Addition of nitrogen fertilizer increases the protein content of some root and tuber [58]. The protein content is low (1–2%) and almost all root crop proteins as in legume, proteins, sulphur- containing amino acids. Roots and tubers are deficient in most other vitamins and minerals but contain significantly amounts of dietary fiber. The moisture content of the raw fresh sample ranged from (0.45 – 2.24%)

Table 3. Proximate composition of the flour of yellow root cassava, orange fleshed sweet potatoes, plantain blend with moringa leaves powder

Samples	Dry matter (%)	Moisture content (%)	Crude fiber (%)	Ash (%)	Fat (%)	Protein (%)	Carbohydrate (%)
A	$92.12^{d}\pm0.01$	$5.88^{g}\pm0.01$	$4.87^{b}\pm0.01$	$3.27^{gb}\pm0.01$	$1.55^{a}\pm0.01$	$5.31^{c}\pm0.42$	$81.76^{a}\pm3.73$
B	$93.73^{bc}\pm0.01$	$5.91^{g}\pm0.01$	$4.85^{b}\pm0.01$	$3.15^{c}\pm0.01$	$1.51^{b}\pm0.01$	$4.98^{d}\pm0.04$	$81.26^{ab}\pm0.04$
C	$93.47^{d}\pm0.01$	$6.11^{f}\pm0.01$	$4.71^{c}\pm0.01$	$2.91^{d}\pm0.01$	$1.45^{c}\pm0.01$	$4.82^{d}\pm0.09$	$79.59^{abc}\pm0.12$
D	$94.09^{b}\pm0.01$	$6.53^{d}\pm0.01$	$4.62^{d}\pm0.01$	$2.83^{e}\pm0.01$	$1.38^{d}\pm0.01$	$5.34^{d}\pm0.07$	$79.72^{abc}\pm0.10$
E	$94.89^{a}\pm0.01$	$7.27^{c}\pm0.01$	$4.03^{e}\pm0.01$	$2.77^{f}\pm0.01$	$1.24^{e}\pm0.01$	$4.79^{d}\pm0.06$	$78.24^{ab}\pm0.06$
F	$93.59^{c}\pm0.01$	$6.41^{e}\pm0.01$	$2.37^{g}\pm0.01$	$2.873^{g}\pm0.01$	$1.05^{g}\pm0.01$	$6.20^{b}\pm0.02$	$81.24^{ab}\pm0.00$
G	$90.83^{e}\pm0.01$	$9.17^{b}\pm0.01$	$10.43^{a}\pm0.01$	$5.82^{a}\pm0.001$	$1.58^{a}\pm0.01$	$3.66^{e}\pm0.91$	$69.35^{d}\pm0.12$
H	$90.75^{e}\pm0.01$	$9.25^{a}\pm0.01$	$2.95^{f}\pm0.01$	$2.51^{h}\pm0.01$	$1.16^{f}\pm0.01$	$6.71^{a}\pm0.13$	$77.43^{c}\pm0.16$

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 4. Proximate composition of snacks from blends of yellow root cassava, orange fleshed sweet potatoes, plantain blend with moringa leaves powder

Samples	Dry matter (%)	Moisture content (%)	Crude fiber (%)	Ash (%)	Fat (%)	Protein (%)	Carbohydrate (%)
I	$93.18^{d}\pm0.01$	$1.47^{b}\pm0.01$	$6.82^{e}\pm0.01$	$4.79^{b}\pm0.01$	$3.09^{b}\pm0.01$	$4.48^{b}\pm0.02$	$79.29^{b}\pm0.99$
J	$92.86^{e}\pm0.01$	$1.43^{c}\pm0.01$	$7.14^{d}\pm0.01$	$4.77^{b}\pm0.01$	$2.85^{bc}\pm0.01$	$4.42^{b}\pm0.99$	$79.09^{b}\pm0.06$
K	$91.77^{f}\pm0.01$	$1.37^{d}\pm0.01$	$8.23^{c}\pm0.01$	$4.63^{c}\pm0.01$	$2.77^{bc}\pm0.01$	$4.41^{b}\pm0.78$	$77.88^{c}\pm0.49$
L	$91.48^{g}\pm0.01$	$1.36^{d}\pm0.01$	$8.52^{b}\pm0.01$	$4.54^{d}\pm0.01$	$2.71^{c}\pm0.69$	$3.93^{cd}\pm0.44$	$77.14^{d}\pm0.02$
M	$90.39^{h}\pm0.01$	$1.18^{e}\pm0.01$	$9.61^{a}\pm0.01$	$3.95^{e}\pm0.01$	$2.71^{c}\pm0.01$	$3.94^{cd}\pm0.19$	$77.14^{d}\pm0.57$
N	$93.63^{c}\pm0.01$	$1.01^{g}\pm0.01$	$6.37^{f}\pm0.01$	$2.27^{g}\pm0.01$	$5.76^{a}\pm0.01$	$4.10^{bc}\pm0.42$	$80.49^{a}\pm0.01$
O	$94.22^{a}\pm0.01$	$1.52^{a}\pm0.01$	$5.78^{h}\pm0.01$	$10.35^{a}\pm0.01$	$2.45^{d}\pm0.01$	$3.52^{d}\pm0.02$	$76.38^{e}\pm0.28$
P	$93.74^{b}\pm0.01$	$1.12^{f}\pm0.01$	$6.26^{g}\pm0.01$	$2.85^{f}\pm0.01$	$3.15^{b}\pm0.01$	$5.92^{a}\pm0.12$	$80.71^{a}\pm0.12$

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 I= 65% YRC + 10% OFSP + 20% Plantain + 5% Moringa leaves powder, J = 70% YRC + 10% OFSP + 15% Plantain + 5% Moringa leaves powder, K = 75% YRC + 10% OFSP + 10% Plantain + 5% Moringa leaves powder, L = 80% YRC + 5% OFSP + 10% Plantain + 5% Moringa leaves powder, M = 85% YRC + 5% OFSP + 5% Plantain + 5% Moringa leaves powder, N = 95% YRC + 5% Moringa leaves powder, O= 95% Plantain + 5% Moringa leaves powder, P = 95% OFSP + 5% Moringa leaves powder

Table 5. Proximate composition of yellow root cassava, orange fleshed sweet potatoes and plantain on fresh basis

Samples	Dry matter (%)	Moisture content (%)	Crude fiber (%)	Ash (%)	Fat (%)	Protein (%)	Carbohydrate (%)
Q	38.09 ^{b}±0.01	2.24 ^{a} ±0.01	61.91^{b}±0.01	2.18 ^{b} ±0.01	2.28 ^{a}±0.01	0.36 ^{b}±0.02	31.04 ^{b} ±0.02
R	48.58 ^{a}±0.01	1.54 ^{b}±0.01	51.42^{c}±0.01	2.49 ^{a} ±0.01	1.38 ^{c} ±0.01	0.52 ^{a} ±0.01	42.66 ^{a} ±0.01
S	30.85 ^{c}±0.01	0.45 ^{c} ±0.01	69.29^{a}±0.18	0.61 ^{c} ±0.01	2.07 ^{b}±0.01	0.16 ^{c} ±0.04	27.43 ^{c} ±0.13

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, Q = 100% YRC, R = 100% Plantain, S = 100% OFSP being that sample Q presented highest in moisture content which was the fresh of yellow root cassava (TMS/07/0593) lower than (10.78 – 12.23%) on high quality cassava reported by Maziya et al. [43] while the least was seen in sample S which was the fresh of orange-fleshed sweet potato. Sample S (0.45%) presented very low as compared to (69.80%) for moisture content of fresh sweet potato variety reported by Adepoju and Adejumo, [59]. The dry matter of the fresh sample ranged from sample S (30.85%) to R (48.58%) were sample S was the least and R presented the highest content of dry matter. Wasiu et al. [39] reported dry matter content of (30.54%) which was in agreement with the dry matter content of (30.85%) for sample S which is the fresh of orange-fleshed sweet potato.

Crude fiber present that portion of food not used up by the body but mainly made up of cellulose together with a little lignin and is known to increase bulk stool [60]. Crude fiber consists largely of cellulose and lignin 97% (plus some mineral matter). Values obtained in the sample analyzed in Table 5 showed significant difference in raw samples (P<0.05) which ranged between (51.42 – 69.29%) were sample S had the highest and sample R, the recorded the least of crude fiber. The crude fiber from this research on the fresh samples were higher than (2.26 – 2.38%) reported by Emetole, [61] on the vine of orange-fleshed sweet potato. The protein content ranged from sample O (3.52%) to P (5.92%) with sample P having the highest value which significantly differ (P<0.05) in protein and O the least.

The protein content of the fresh of plantain (sample R) had the highest of (0.52%). Though, no significant difference (P>0.05) occurred among the samples. They have the protein content less than 1% which agreed with the claim from Eleazu and Eleazu [62] that sweet potato; cassava and plantain contain less protein content less than 1%.

Ash is a reflection of the inorganic mineral elements present in the samples. Some of the samples investigated contained significant quantities of ash than the other which ranged from (0.61 – 2.49%). The ash and fat content of (2.18%) and (2.28%) in sample Q which is the yellow root cassava was higher than the fresh cassava reported by Eleazu and Eleazu [62], who reported (1.54%) and (1.15%) for TMS/ 0473.

Fat are vital to the structure and biological functions of cells and are used as alternative energy source. Sample Q (2.28%) had the significantly highest fat content (P<0.05) than the other samples investigated. Carbohydrate content was highest in sample R (42.66%), followed by sample Q (31.04%) and S (27.43%). Fresh plantain contained a lot of carbohydrate than bio fortified cassava and yellow-fleshed sweet potato.

4. CONCLUSION

All the composite flours displayed stronger affinity for water than oil. In general, water absorption index among the composite flours did not differ significantly and has implications for viscosity. A significant difference exists among the samples which increases in swelling index as the proportion of cassava increases which. To some extent, the protein content of root crops is influenced by variety, cultivation practice, climate growing season and location [57].

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/54971