Quality Assessment of Strips Produced from Soybean and Cassava Flour Blends

Onwuzuruike, U. A., Ndife, J., Abiamere, E. U. and Ike, C.

Abstract

This study evaluated the quality characteristics of strips produced from blends (%) of soybean and cassava flours (0:100, 100:0, 50:50, 40:60, 20:80, 60:40 and 80:20). The reference sample was produced from 100% wheat flour. Functional properties of the composite flours were evaluated, while the strips were evaluated for proximate, mineral, vitamin, antinutrient contents and sensory properties using standard methods. The results of the functional properties showed that bulk density, foam capacity, foam stability, oil absorption capacity, water absorption capacity and gelatinization temperature of the flour samples ranged from 0.53 to 0.77 g/mL, 3.76 to 12.88 %, 1.92 to 49.00 %, 108.00 to 204.00 g/mL, 81.00 to 140.50 g/mL and 61.07 to 87.00°C respectively. The results of proximate analysis ranged from 1.44 to 3.46 % for moisture, 1.63 to 3.91 % ash, 2.04 to 10.76 % fat, 0.18 to 1.37 % crude fibre, 4.07 to 24.16 % protein and 60.46 to 88.10 % carbohydrate. The phytate, tannin, trypsin inhibitor, saponin and hydrogen cyanide ranged from 0.22 to 5.59 mg/100g, 0.34 to 4.13 mg/100g, 0.04 to 1.69 mg/100g, 0.02 to 0.36 mg/100g and 0.00 to 2.11 mg/100g respectively. Sensory analysis revealed that SF80:CF20 possessed better organoleptic characteristics. Conclusively, the production of strips from soybean and cassava flour resulted into a product with improved nutrient composition, sensory properties and acceptable/safe antinutrient limit which can be optimized for value addition.

Keywords: Quality, Soybean, Cassava, Strips, Sensory Characteristics.

Department of Food Science and Technology, College of Applied Food Sciences and Tourism, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria.

Correspondence: onwuzuruike.uzochukwu@mouau.edu.ng,
Telephone: +234 8033981164

Introduction

Extrusion is one of the adopted processing techniques by food industries which employ mixing, forming, texturing and cooking to develop a novel food product (Gulati, 2016). The benefits of extrusion include but not limited to its low cost, variability of product shape and inactivation of anti-nutrient factors (Singh *et al*., 2016). The commonly used raw materials in the extrusion process are those that have substantial quantity of protein and starch (Pawar *et al.,* 2014). According to Steel *et al.* (2012), in choosing raw materials for extrusion, the type of raw material, its moisture content, physical state and chemical composition (quantity and type of starch, proteins, fats and sugars) should be put into consideration. Strips, being one of the products of extrusion are conventionally made from wheat flour. However, wheat cannot be economically produced in tropical countries like Nigeria due to unfavourable climatic conditions. This prompted research on the use of locally available crops such as cassava and soybean (Gernah and Anyam, 2014), in confectionaries production.

The wide use of soybean (*Glycine max*) in food production could be due to the fact that, it is a cheap source of protein that provides similar quality of protein as meat, milk and eggs (Kusuma, 2015). Soybean contains 37.69 % protein, 28.20 % fat and 16.31 % carbohydrate (Etiosa *et al*., 2018). It is also rich in isoflavones which have numerous health benefits such as lowering of blood cholesterol level, cancer prevention and reduction of risk of heart diseases (Kusuma, 2015). It can be processed into a wide variety of food products, including edible oil, milk, *tempeh*, infant formula and flour (O'Keefe *et al*., 2015). Flour from whole soybean seeds has huge potentials of being used to enrich foods in order to help individuals meet recommended daily intake of nutrients such as protein (Adelakun *et al*., 2013). Pele *et al*. (2016) reported that soybean flour has protein (23.98 to 28.44 %), carbohydrate (38.48 to 43.52 %), fat (20.51 to 26.20 %) and reduced anti-nutrient factors than the unprocessed seeds. Soybean flour can be used to fortify cassava flour in snack production.

Cassava (*Manihot esculenta,* Crantz) is a food security crop with the capacity of addressing some health-related problems such as ketosis (Onyenwoke and Simonyan, 2014). The starch content varies between 60.34 to 86.79 % of the mass of white-flesh cassava and 69.90 % of biofortified yellow-flesh cassava (Ayetigbo *et al*., 2018). Cassava root of 0.50 to 2.50 kg have 0.30 to 3.50 % protein, 0.03 to 0.50 % lipids, 0.10 to 3.70 % dietary fibre, 0.40 to 1.70 % ash, 0.03 to 0.28 mg/100g thiamin, 0.03 to 0.06 mg/100g riboflavin, 19.00 to 176.00 mg/100g calcium, 0.30 to 1.40 mg/100g iron and 6.00 to 152.00 mg/100g of phosphorus (USDA, 2013). It is versatile and its derivatives are applicable in many types of products such as confectionery, sweeteners and so on (Onyenwoke and Simonyan, 2014).

The increasing urbanization has profoundly contributed to the popularity and increased production and consumption of snacks. The possible exploration of non-wheat flours in snack production, could possibly increase the utilization of indigenous crops. Vitamin A deficiency which is responsible for visual impairment is a rising health concern in developing countries. Indigenous crops such as carotenoid rich cassava roots could contribute to its eradication. More so, protein energy malnutrition (PEM) which arises as a result of insufficient consumption of protein and energy is known to result in high rate of death particularly among children. Economically, the continuous production of snacks using imported wheat flour would continue to affect Nigeria's finances negatively. Production of strips from flour blends of cassava and soybean will reduce dependence on wheat imports and also increase livelihoods as well as generate more income for the local farmers and save the Nation's foreign exchange, create variety, contribute in combating protein energy malnutrition and vitamin A deficiency, make strips affordable and increase the demand of soybean and cassava for food development. This study which involves the production and evaluation of strips from Cassava and Soya beans blends is therefore aimed at finding alternative ways of exploiting the industrial potential and nutritional benefits of cassava and soybean.

Materials and Methods

Sources of raw materials

The cassava roots (*Manihot esculenta, Crantz*) (UMUCASS 38 (TMS 01/1371) variety) used for this study was procured from National Root Crops Research Institute Umudike. Soybean seeds (*Glycine max*) and other ingredients such as onion, salt, vegetable oil and water were procured from Ubani local market. All in Umuahia North Local Government Area, Abia State.

Sample preparation

Processing of cassava roots into flour

The method described by Alozie and Chinma (2015) was used in processing of cassava roots into flour. Cassava roots were sorted, cleaned, manually peeled and sliced prior to oven drying at 60°C for 9 h. The oven dried cassava roots were milled using attrition mill and sieved through 500 µm mesh size to obtain the cassava flour which was packaged in polyethylene bag prior to further use.

Processing of soybean seeds into soybean flour

The method of Adelekun *et al*. (2013) was used in processing of soybeans into flour with modification. Soybean seeds were sorted, cleaned and soaked in water for 6 h. The steeped seeds were then boiled in water for 30 min, cooled and manually dehulled. The dehulled soybean seeds were washed in water, drained, dried at 60 ºC for 6 h, milled, sieved through 500 µm mesh size and packaged for further use.

Formulation of soybean-cassava composite flour

The proportion of soybean flour (SF) and cassava flour (CF) used in the formulation of composite flour were as follows; 0:100

(SF100), 100:0 (CF100), 50:50 (SF50:CF50), 40:60 (SF40:CF60), 20:80 (SF20:CF80), 60:40 (SF60:CF40) and 80:20 (SF80:CF20). 100% wheat flour (WF100) was used as the reference sample.

Functional analysis

The method described by Onwuka (2018) was used in the determination of bulk density, gelatinization temperature, water absorption capacity, oil absorption capacity, foam capacity and stability and wettability of the flour samples.

Production of soybean-cassava strips

The recipe for the production of soybean-cassava strips comprised wheat flour (100 g), cassava flour (350 g), soybean flour (350 g), onion (360 g), salt (40 g), water (1200 mL) and vegetable oil (3000 mL). The method described by Dada *et al*. (2017) was used for the preparation of the strips.

Sample analyses

Proximate analysis

AOAC Official Method 2.210 (2010) was used in the determination of the moisture, ash, fat, crude fibre, crude protein and carbohydrate (by difference) contents.

Vitamin analysis

The spectrophotometric method described by Onwuka (2018) was employed in the determination of vitamin A, vitamin B_1, vitamin B_2, vitamin B_3 while the method described by Achikanu *et al*. (2013) was used in the determination of vitamin C.

Mineral analysis

Potassium and iron content of the soybean-cassava strips was determined using the method described by Achikanu *et al*. (2013). Zinc, calcium, magnesium, phosphorous contents were determined according to the method described by Onwuka (2018). Sodium content of the soybean-cassava strips was determined using the flame photometry method of AOAC (2010).

Antinutrient analysis

Trypsin inhibitor and tannin contents of the soybean-cassava strips was determined using the spectrophotometric method described by Nwosu (2011). The method of Onwuka (2018), was used for the determination of hydrogen cyanide. The saponin and phytate contents were respectively determined using the colorimetric and spectrophotometric methods of AOAC (2010).

Sensory analysis

The method described by Iwe (2014), was used for evaluating the sensory attributes of the soybean-cassava strips. The appearance, taste, aroma, texture, mouthfeel and general acceptability of the soybean-cassava strips were evaluated by 20 panelists randomly selected from students of Department of Food Science and Technology, Michael Okpara University of Agriculture, Umudike, Abia State. The panelists were semi-trained on how to evaluate the sensory attributes of the samples. The samples were presented in identical packaging materials labeled with appropriate codes. Portable water was served to the panelists for mouth rinsing after each tasting to avoid interference with the taste of the succeeding samples. Sensory attributes of the soybean-cassava strips were scored on a 9-point Hedonic scale. The degree of likeness was expressed as follows: like extremely (9), like very much (8), like moderately (7), like slightly (6), neither like nor dislike (5), dislike slightly (4), dislike moderately (3), dislike very much (2), dislike extremely (1).

Statistical Analysis

All experimental data were expressed as mean ± SD (standard deviation) of duplicate determinations. The data were subjected to one-way analysis of variance (ANOVA) while the Duncan Multiple

Range Test (DMRT) method was used to compare the means of experimental data at 95 % confidence interval (SPSS, 2018).

Results and Discussions

Functional properties of soybean-cassava flour blends

The functional properties of the soybean-cassava flour blends are presented in Table I. The bulk density (BD) of the samples ranged from 0.53 to 0.77 g/mL which was lower than the value (0.76 to 0.82 g/mL) reported by Suresh *et al*. (2015) for cassava-wheat composite flour which could be attributed to difference in raw materials used for flour processing. The highest BD (0.77 g/mL) was recorded in 100% cassava flour (CF100) while SF50:CF50 had the lowest BD (0.53 g/mL). BD is defined as the mass/volume of a substance. It could be used in determining the packaging requirement of flour as it relates to the load the packaging material could carry if the sample is allowed to rest directly on one another (Ezeocha and Onwuka, 2010). Suresh *et al*. (2015) reported that BD is dependent on the particle size, starch, and initial moisture content of flour. The BD obtained in this study is considerably low which might suggest their suitability in food formulation with an extra advantage in the formulation of complimentary foods (Akapata and Akubor, 1999) and may possibly encourage bulk packing of the flour samples using compact packaging material (Ezeocha and Onwuka, 2010).

The foam capacity (FC) of the flour blends ranged from 3.76 to 12.88 %. The reduction of soybean flour and increase in cassava flour resulted into decrease in the FC of the flour blends. The results implied that legumes have higher ability to form foam than root crops.

Table I: Functional properties of soybean-cassava flour blends.

Samples	BD(g/mL)	FC (%)	FS (%)	OAC (g/mL)	WAC (g/mL)	GT (°C)
WF100	$0.56^{cd}\pm0.01$	$7.15^{d}\pm0.21$	$49.00^{a}\pm2.80$	$204.00^{a}\pm1.01$	$140.50^{a}\pm0.01$	$61.07^{f}\pm0.01$
SF100	$0.63^{b}\pm0.01$	$12.88^{a}\pm0.21$	$24.00^{b}\pm1.41$	$108.00^{f}\pm1.04$	$81.00^{f}\pm1.01$	$87.00^{a}\pm1.01$
CF100	$0.77^{a}\pm0.01$	$3.76^{g}\pm0.31$	$1.92^{h}\pm0.03$	$145.00^{c}\pm1.04$	$140.50^{a}\pm0.01$	$79.75^{e}\pm0.31$
SF50:CF50	$0.53^{e}\pm0.01$	$7.09^{d}\pm0.01$	$15.50^{e}\pm0.40$	$121.00^{ed}\pm1.40$	$126.00^{d}\pm1.04$	$84.50^{c}\pm0.71$
SF40:CF60	$0.59^{c}\pm0.01$	$6.00^{e}\pm0.10$	$11.07^{f}\pm0.01$	$118.50^{e}\pm0.10$	$130.50^{c}\pm0.07$	$83.50^{cd}\pm0.71$
SF20:CF80	$0.57^{cd}\pm0.01$	$4.62^{f}\pm0.10$	$7.82^{g}\pm0.10$	$108.00^{f}\pm0.01$	$135.50^{b}\pm0.04$	$80.00^{d}\pm1.10$
SF60:CF40	$0.54^{ed}\pm0.01$	$8.41^{c}\pm0.08$	$18.33^{d}\pm0.20$	$123.50^{d}\pm0.07$	$124.00^{d}\pm1.01$	$85.50^{bc}\pm0.11$
SF80:CF20	$0.56^{d}\pm0.01$	$10.20^{b}\pm0.09$	$21.43^{c}\pm0.03$	$200.50^{b}\pm0.01$	$103.50^{e}\pm0.07$	$86.00^{ab}\pm1.41$

Values are means $\pm$ standard deviation of duplicate determination. Mean values in the same column with different superscripts are significantly different ($p<0.05$). WAC-Water absorption capacity, OAC-Oil absorption capacity, FS-Foam Stability, FC-Foaming capacity, BD-Bulk density, GT-Gelatinization temperature. WF-Wheat flour, SF-Soybean flour, CF-Cassava flour.

This is because, foam capacity (FC) is an index of foamability of protein dispersion. Legumes are rich is protein and may likely form foam than root crops. Foams improve texture and it is affected by processing methods, contamination and pest infestation (Onimawo and Akubor, 2005). The presence of legumes may cause a lowering in the surface tension at the water air interface, thus, forming a continuous cohesive film around the air bubbles in the foam (kaushal *et al.,* 2012) as a result of protein in dispersion. Consequently, higher legume-containing composite flours might have a better foam performance when used in formulating food materials that require foam formation.

Foam stability (FS) is known as aerating or whipping properties of food. It is the ability to incorporate air by it or a mixture with other ingredients and to hold the aerated structure long enough so that it can be set by heat or other means (Hung *et al.,* 2004). The FS of the flours ranged from 1.92 to 49.00 %, showing significant difference ($p<0.05$) among the flour samples. As the proportion of soybean flour decreased and cassava flour increased in the flour blends, the FS decreased concurrently. This observation could be attributed to the low surface tensions and high viscosity that exist at the surface of colloidal solutions, forming a tough amorphous solid surface film (Mwasaru *et al.,* 1999). Kinsella *et al.* (1985) attributed low FS in flours to inadequate electrostatic repulsions resulting from low protein availability as well as lesser solubility and to protein denaturation (Butt and Batool, 2010). Good FS are desirable attributes for flours intended for the production of a variety of baked products such as angel cakes, cookies, akara, etc and also act as functional agents in other food formulations (El-Adawy, 2001). The FS obtained in this study for the composite flours are quite high which implied that the flour blends may be useful as aerating agents in food productions (such as cakes and other baked products) that require the production of foam.

The oil absorption capacity (OAC) of the flour samples ranged from 108.00 to 204.00 g/mL, which was higher than 130.00

to 156.00 g/mL reported by Suresh *et al*. (2015) for cassava-wheat composite flour. The composite flours had lower OAC values than the reference sample. Increasing the proportion of soybean flour, increased the OAC of the flour samples which indicated that legumes might have better OAC. However, the OAC of the flour samples were generally high and differ significantly ($p<0.05$) from each other. OAC is the ability of the flour protein to physically bind fat by capillary attraction and it is of great importance, since fat acts as flavor retainer and also increases the mouth feel of foods (Onimawo and Akubor, 2005). It is affected by several factors such as the protein content, the liquidity of the oil and the method used. These factors could have led to the variations in the OAC of the composite flours (Ibeabuchi *et al*., 2017). The high OAC obtained for the flour blends might translate to good applicative potential in food formulations since high OAC increases the retention of flavor, and also increases the mouth feel of products. Although, the high OAC of the flour blends might be challenging with respect to shelf life particularly in bakery products (Adebowale and Lawal, 2004).

The water absorption capacity (WAC) ranged from 81.00 to 140.50 g/mL. There was no significant difference ($p \geq 0.05$) between WF100 (140.50 g/mL) and CF100 (140.50 g/mL), but differences existed among other samples which may be due to different protein concentration, their degree of interaction with water and their conformational characteristics (Butt and Batool, 2010). The WAC of the flour blends decreased with increasing proportions of soybean flour, which indicated that cassava flour might have better WAC than soybean flour. WAC is a critical property of protein in viscous foods and baked products. According to Butt and Batool (2010), protein has both hydrophilic and hydrophobic properties, and can interact with water in foods. Carbohydrates have also been reported to influence water absorption capacity of foods (Adejuyitan, 2009). The ability of protein to bind water is indicative of its water absorption capacity. The values of WAC for the composite flours were considerably high, which might be attributed to the presence of hydrophilic protein that has the capacity to bind water as well as high digestible starch. The values obtained in this study are desirable in flour and impliedly, legumes can be incorporated into food formulations involving other flours.

The gelatinization temperature (GT) of the flour blends ranged from 61.07 to 87.00°C. The lowest GT was recorded for 100% wheat flour (WF100) which implied that WF100 took the shortest time to gelatinize, while soybean (a legume with high protein content) and cassava flour required higher temperature to gelatinize and consequently longer time. More so, composite flours containing higher proportion of cassava flour gelatinized at a lower temperature. GT is the temperature at which food material form gel or become gelatinous. The primary function of gel in foods is to bind or solidify the free water (Onimawo and Egbekun, 1998). The GT results obtained in this study are generally high and suggested that the flours could be suitable for the stabilization of emulsion in soups and cakes and other food formulations.

Proximate composition

The proximate composition of soybean-cassava strips is presented in Table II. The moisture content of the soybean-cassava strips ranged from 1.44 to 3.46 %, which was generally low. The low moisture in the sample could be attributed to the frying process which has the capacity to extract almost all available free water. Since moisture content can be used as an index of stability of foods (Offor, 2015), it could be presumed that the strips might remain stable for a long period without spoilage at ambient temperature.

The ash content of the strips ranged from 1.63 to 3.91 %, with WF100 (100 % wheat flour strip) having the lowest value while SF80:CF20 (80 % soybean flour: 20 % cassava flour strip) had the highest value. Increase in the proportion of soybean flour resulted to increased ash content, suggesting the influence of legumes on the ash content of food formulation. Ash content is the fraction in biomass that is composed of incombustible mineral material. It represents total minerals content in foods and thus, serves as a viable tool for nutritional evaluation of mineral (Mamiro *et al.,* 2011). Soybean is a source of minerals such as potassium and adequate source of magnesium, iron, zinc, copper, calcium and phosphorus (Rooney and Waniska, 2000). The increased ash content of the strips containing soybean flour may suggest improved mineral content than in the strips containing 100% wheat or cassava flour.

The fat content of the soybean-cassava strips also increased significantly ($p<0.05$) with increased soybean substitution and ranged from 2.04 to 10.76 %. The fat content was highest in SF80:CF20 (80 % soybean flour: 20 % cassava flour strip) formulation. The increase in the fat content of the strips might be attributed to the effect of soybean (oil seed). Generally, the lipid content of the samples containing legumes is quite high which might result to decreased keeping quality as a result of increased susceptibility to rancidity (Ikujenlola *et al*., 2013). However, the strips containing legumes may have the capability of serving as a viable vehicle for fat soluble vitamins as well as improving mouth-feel and palatability (Coppin and Pike, 2011).

The fibre content of the soybean-cassava strips ranged from 0.18 to 1.37 %. The fibre content of the reference sample was lower than the composite samples, reflecting the beneficial importance of complementation. However, the fibre content of the composite samples were generally low and showed no significant differences ($p \geq 0.05$). Fibre has been reported to offer a variety of health benefits and is essential in reducing the risk of chronic diseases such as diabetes, obesity, cardiovascular diseases and diverticulitis (Ajani *et al.,* 2012). The low values obtained in this study may imply that, the strips produced from cassava and soybean flours might not contribute significantly to the dietary fibre needs of the human body.

The protein content of the soybean-cassava strips ranged from 4.07 to 24.16 %. The protein content of the strips increased significantly ($p<0.05$) as the proportion of soybean flour increased in the composite strips such that, SF80:CF20 (80 % soybean flour: 20 % cassava flour strip) had the highest value (20.07 %) among the composite strips as expected.

Table II: Proximate composition of the soybean-cassava strips.

Samples	Moisture (%)	Ash (%)	Fat (%)	Crude Fibre (%)	Protein (%)	Carbohydrate (%)
WF100	$2.61^{c}\pm0.02$	$1.63^{f}\pm0.01$	$4.51^{g}\pm0.01$	$0.18^{b}\pm0.01$	$9.71^{f}\pm0.02$	$81.36^{b}\pm0.04$
SF100	$1.44^{g}\pm0.01$	$2.91^{d}\pm0.01$	$9.66^{b}\pm0.01$	$1.37^{a}\pm0.01$	$24.16^{a}\pm0.01$	$60.46^{f}\pm0.00$
CF100	$2.16^{e}\pm0.01$	$2.51^{e}\pm0.01$	$2.04^{h}\pm0.01$	$1.12^{ab}\pm0.01$	$4.07^{g}\pm0.01$	$88.10^{a}\pm0.03$
SF50:CF50	$1.66^{f}\pm0.01$	$3.08^{c}\pm0.01$	$7.44^{d}\pm0.01$	$1.13^{ab}\pm0.01$	$12.23^{d}\pm0.01$	$74.46^{d}\pm0.00$
SF40:CF60	$2.32^{d}\pm0.01$	$2.84^{de}\pm0.01$	$6.88^{e}\pm0.01$	$1.12^{ab}\pm0.01$	$11.29^{e}\pm0.01$	$75.55^{c}\pm0.31$
SF20:CF80	$2.95^{b}\pm0.02$	$2.34^{ef}\pm0.01$	$5.59^{f}\pm0.01$	$1.17^{ab}\pm0.01$	$4.95^{g}\pm0.01$	$83.00^{b}\pm0.72$
SF60:CF40	$3.44^{a}\pm0.01$	$3.61^{b}\pm0.01$	$8.72^{c}\pm0.01$	$1.14^{ab}\pm0.01$	$19.24^{c}\pm0.01$	$63.85^{e}\pm0.15$
SF80:CF20	$3.46^{a}\pm0.01$	$3.91^{a}\pm0.01$	$10.76^{a}\pm0.01$	$1.14^{ab}\pm0.01$	$20.07^{b}\pm0.01$	$60.66^{f}\pm0.01$

Values are means $\pm$ standard deviation of duplicate determination. Mean values in the same column with different superscripts are significantly different ($p<0.05$). WF-Wheat flour, SF- Soybean flour, CF-Cassava flour.

Thus, the increased protein content of the strips could be attributed to the influence of the soybean flour. Ndife *et al.* (2011) reported an increase in protein content of bread as a result of partial substitution of wheat flour with soybean flour. Other studies also reported increase in protein content of snack (cookies) as a result the addition of soybean flour (Mashayekh *et al.*, 2008). The high protein content implied that the strips might be able to contribute significantly towards achieving the daily human protein requirements, usually about 23-56 g as recommended by FAO/WHO/UNU (1994).

The carbohydrate content of the soybean-cassava strips ranged from 60.46 to 88.10 % and was observed to decrease with increased soybean flour substitution. The carbohydrate values obtained in this study were higher than that (33.35 to 54.27 %) reported by Ndife *et al*. (2011) for wheat-soybean bread. The result agreed with the findings of Oguntona *et al.* (1987), who reported that food products from cassava are energy-rich foods. High content of carbohydrate and protein suggested good energy protein nutrition and has the ability to avert malnutrition resulting from insufficient proteins in the diets.

Vitamin composition

The result of the vitamin composition of the soybean-cassava strips are presented in Table III. The pro-vitamin A content of the strips ranged from 0.45 to 3.83 µg/100g with WF100 (100 % wheat flour strip) and SF80:CF20 (80 % soybean flour: 20 % cassava flour strip) having the lowest and highest pro-vitamin A value respectively. It was also observed that the vitamin value of the formulated samples decreased with increased cassava flour substitution. Vitamin A is important for improved vision and maintenance of epithelial cell functions (Akuyili *et al.*, 2013). The pro-vitamin A content obtained in this study are below the recommended daily intake of 700 – 1000 µg/day for men and 600 – 800 µg/day for women (FAO/WHO, 1998) which suggested that the formulated samples might not contribute beneficially to eye health.

The vitamin B_1 composition of the strips ranged between 0.03 to 0.06 mg/100g. The obtained values are generally low with no significant differences ($p \geq 0.05$) existing among the formulated samples (composite strips). However, these values are in agreement with the value (0.25 mg/100g) reported by Suresh *et al.* (2015) for cassava-wheat composite bread respectively but below the recommended daily nutrient intakes of vitamin B_1 for infants, children, and adults (0.2-0.9, 1.1-1.2, 1.1-1.5 mg/day) (FAO/WHO, 1998).

The results of vitamin B_2 (riboflavin) varied significantly ($p<0.05$) among the samples with values ranging from 0.16 to 0.63 mg/100g. SF20:CF80 had the highest value while SF80:CF20 had the lowest value. The cassava flour had more influence on the vitamin B_2 content than the soybean flour, the composite strips containing higher proportion of cassava flour had higher vitamin B_2 content. However, the values obtained in this study are generally low and were below the FAO/WHO recommended daily intake (RDI) for adolescents and adults (1.00 to 1.30 mg/day), pregnant women (1.40 mg/day) and lactating women (1.60 mg/day) but within the RDI for infants and children (0.30 to 0.90 mg/day).

The result of vitamin B_3 content of the strips ranged from 0.27 to 1.51 mg/100g with SF100 (100% soybean flour strip) and CF100 (100% cassava flour strip) having the highest vitamin B_3 value respectively. The formulation of composite strips had a positive influence on vitamin B_3 compared to the reference sample but the values were below the FAO/WHO recommended daily intake for infants and children (2.00 to 12.00 mg/day), adults (14.00 to 16.00 mg/day), pregnant women (18.00 mg/day) and lactating women (17.00 mg/day).

The vitamin C content of the strips ranged between 1.33 to 2.71 mg/100g. The reference sample had lower values than the composite strips which implied that the blending of soybean and cassava flours had beneficial impact on the vitamin C level of the strips. Increasing soybean flour proportion resulted to an increase in the vitamin C content of the samples.

Table III: Vitamin composition of soybean-cassava strips.

Sample	pro-Vitamin A (µg/100g)	Vitamin B_1 (mg/100g)	Vitamin B_2 (mg/100g)	Vitamin B_3 (mg/100g)	Vitamin C (mg/100g)
WF100	$0.45^{g}\pm0.01$	$0.06^{a}\pm0.00$	$0.53^{b}\pm0.01$	$0.34^{e}\pm0.01$	$1.33^{de}\pm0.01$
SF100	$3.17^{b}\pm0.01$	$0.03^{d}\pm0.00$	$0.47^{c}\pm0.01$	$0.27^{f}\pm0.01$	$2.56^{ab}\pm0.01$
CF100	$2.50^{d}\pm0.01$	$0.05^{b}\pm0.00$	$0.52^{b}\pm0.01$	$1.51^{a}\pm0.00$	$1.51^{d}\pm0.01$
SF50:CF50	$2.51^{d}\pm0.01$	$0.04^{cd}\pm0.00$	$0.43^{c}\pm0.01$	$0.93^{b}\pm0.00$	$1.86^{c}\pm0.01$
SF40:CF60	$2.40^{e}\pm0.01$	$0.04^{cd}\pm0.00$	$0.55^{b}\pm0.01$	$0.74^{c}\pm0.01$	$1.71^{cd}\pm0.01$
SF20:CF80	$1.94^{f}\pm0.01$	$0.03^{d}\pm0.00$	$0.63^{a}\pm0.01$	$0.68^{d}\pm0.01$	$1.64^{cd}\pm0.01$
SF60:CF40	$3.21^{c}\pm0.01$	$0.03^{d}\pm0.00$	$0.25^{d}\pm0.01$	$0.68^{d}\pm0.01$	$2.37^{b}\pm0.01$
SF80:CF20	$3.83^{a}\pm0.01$	$0.04^{cd}\pm0.00$	$0.16^{e}\pm0.01$	$0.72^{c}\pm0.01$	$2.71b^{a}\pm0.01$

Values are means + standard deviation of duplicate determination. Mean values in the same column with different superscripts are significantly different ($p<0.05$). WF-Wheat flour, SF- Soybean flour, CF-Cassava flour.

The result obtained in this study was below the value (3.67 mg/100g) reported by Jitngarmkusol *et al*. (2008) for cassava strips. Also, the vitamin C values obtained in this study were below the FAO/WHO recommended daily intake for infants and children (25.00 to 35.00 mg/day), adults (40.00 to 45.00 mg/day), pregnant women (55.00 mg/day) and lactating women (70.00 mg/day) (FAO/WHO, 1998).

Mineral composition

The result of the mineral analysis of soybean-cassava strips are shown in Table IV. The calcium content of the strips ranged from 1.01 to 5.83 mg/100g. The calcium content increased with increased proportion of soybean flour. The values obtained suggested that the consumption of every 100 g of the strips would result to calcium intake that is below the FAO/WHO recommended daily intake for calcium of different target consumer such as Infants and children of 0 to 9years (300 to 700 mg/day), Adolescents of 10 to 18 years (1300 mg/day), adults of 19+ years (1000 to 1300 mg/day), pregnant women (1200 mg/day) and lactating women (1000 mg/day) (FAO/WHO, 1998). Calcium is also an important mineral required for bone formation, blood clotting and muscle contraction. Although, the composite strips had improved calcium contents which are below the FAO/WHO recommended daily intake and might possibly not provide the needed calcium for body needs.

The magnesium content of the strips ranged from 1.35 to 42.60 mg/100g. Increasing the proportion of soybean flour resulted to an increase in the magnesium content of the composite strips. However, the values obtained are below the recommended nutrient intake for infants and children (26 to 100 mg/day), adolescents (230 mg/day for females and 220 mg/day for males) and adults (220 mg/day for females and 260 mg/day for males) respectively (FAO/WHO, 1998). The magnesium content of the strips may not be adequate to satisfy the daily functions in the human body due to their inability to reach the recommended daily allowance.

The phosphorus content of the strips ranged from 1.16 to 27.40 mg/100g. SF100 (100% soybean flour strip) had the highest phosphorus value (27. 40 mg/100g) while CF100 (100% cassava flour strip) had the lowest value. The phosphorous content of the composite strips was higher than the reference sample (3.13 mg/100g) which suggested an improvement after blending except for SF40:CF60 (40% soybean flour: 60% cassava flour) with a value 1.16 mg/100g. The phosphorus content of the strips increased with increased soybean flour substitution. Phosphorus is an important constituent of adenosine triphosphate (ATP) and nucleic acid and is also essential for acid-base balance, bone and tooth formation (Soetan *et al.,* 2010). The increased phosphorous content implied that the mineral content of snacks might be improved by developing composite products.

The sodium content of the strips ranged from 0.25 to 6.53 mg/100g. The composite strips had lower sodium content than the reference sample, thus, the production of strips from soybean and cassava flours resulted into product with lower sodium content. The low sodium content of the strips might be beneficial since low sodium diet has been reported to be beneficial in the prevention of high blood pressure (Onwuka, 2018).

Potassium is a very important mineral for the proper functioning of all cells, tissues, and organs in the human body. It plays a key role in skeletal and smooth muscle contraction, making it important for normal digestive and muscular function (Gerlin *et al.*, 2007). The potassium content of the strips ranged from 0.22 to 2.64 mg/100g which was lower than the value obtained for the reference sample (100% wheat flour strip) (2.64 mg/100g). The values suggested that the potassium content of the studied samples are quite low and might not be good sources of potassium.

The iron content of the strips ranged from 0.13 to 3.02 mg/100g. The reference sample (100% wheat flour strip) had the highest iron value (3.02 mg/100g) which implied that the development of composite strips from soybean and cassava flours did not improve the iron content of the final product.

Table IV: Mineral composition of soybean-cassava strips (mg/100g).

Samples	Calcium	Magnesium	Phosphorus	Sodium	potassium	Iron	Zinc
WF100	$5.83^{a}\pm0.01$	$7.14^{e}\pm0.01$	$3.13^{f}\pm0.14$	$6.53^{a}\pm0.14$	$2.64^{a}\pm0.14$	$3.02^{a}\pm0.14$	$0.24^{f}\pm0.01$
SF100	$4.62^{b}\pm0.01$	$42.60^{a}\pm0.01$	$27.40^{a}\pm0.14$	$2.14^{b}\pm0.14$	$0.17^{e}\pm0.14$	$0.13^{e}\pm0.14$	$2.54^{a}\pm0.01$
CF100	$1.01^{h}\pm0.01$	$1.35^{f}\pm0.01$	$1.20^{g}\pm0.01$	$0.25^{f}\pm0.14$	$0.35c^{d}\pm0.14$	$0.16^{e}\pm0.14$	$0.03^{g}\pm0.01$
SF50:CF50	$3.11^{e}\pm0.14$	$20.40^{c}\pm0.01$	$15.40^{c}\pm0.01$	$1.16^{c}\pm0.14$	$0.27^{ed}\pm0.14$	$1.53^{b}\pm0.2$	$1.27^{b}\pm0.01$
SF40:CF60	$2.16^{g}\pm0.14$	$15.05^{d}\pm0.01$	$1.16^{g}\pm0.01$	$0.26^{f}\pm0.14$	$1.43^{b}\pm0.01$	$1.26^{d}\pm0.01$	$1.06^{e}\pm0.01$
SF20:CF80	$2.27^{f}\pm0.14$	$14.55^{d}\pm0.01$	$11.95^{e}\pm0.14$	$0.89^{e}\pm0.01$	$0.22^{ed}\pm0.71$	$1.41^{c}\pm0.01$	$1.21^{d}\pm0.01$
SF60:CF40	$3.35^{d}\pm0.01$	$15.10^{d}\pm0.01$	$13.15^{d}\pm0.14$	$1.04^{d}\pm0.14$	$0.24^{ed}\pm0.01$	$1.42^{c}\pm0.01$	$1.24^{c}\pm0.01$
SF80:CF20	$3.71^{c}\pm0.01$	$22.35^{b}\pm0.01$	$18.35^{b}\pm0.01$	$1.13^{c}\pm0.14$	$0.42^{c}\pm0.14$	$1.51^{b}\pm0.01$	$1.29^{b}\pm0.01$

Values are means $\pm$ standard deviation of duplicate determination. Mean values in the same column with different superscripts are significantly different ($p<0.05$).

Iron deficiency anemia is a serious problem for certain at-risk groups (Food and Nutrition Board, Institute of Medicine, 2002) and continued research is ongoing for the development of snack with appreciable iron content. However, the iron content obtained in this study was below the recommended daily intake for a dietary iron bioavailability of 15% with respect to infants and children (5.90 to 6.20 mg/day), adolescents (9.30 to 20.70 mg/day for females and 9.70 to 12.5 mg/day for males) and adults (19.60 mg/day for females and 9.10 mg/day for males) respectively (FAO/WHO, 1998).

The zinc values of the strips ranged between 0.03 to 2.54 mg/100g. The addition of the soybean flour increased the zinc value of the samples. Zinc is an important mineral for growth and development, and also appears to improve immune function in elderly people who are often deficient in several micronutrients (Chandra, 2002). Minerals such as iron and zinc are low in cereal and tuber-based diets, but the addition of legumes can slightly improve the iron and zinc content of these diets as observed in the present study. However, the zinc content of the formulated strips was below the recommended daily intake with respect to infants and children (6.60 to 11.20 mg/day), adolescents (14.40 mg/day for females and 17.10 mg/day for males) and adults (9.80 mg/day for females and 14.00 mg/day for males) respectively (FAO/WHO, 1998).

Anti-nutrient composition

The results of the antinutrient composition of the soybean-cassava strips are shown in Table V. The phytate content of the strips ranged from 0.22 to 5.59 mg/100g which was lower than 25 mg/100g, the amount considered lethal to health (Nagel, 2010). The formulated strips had higher phytate content than the reference sample (100% wheat flour strip). Increasing proportion of cassava flour resulted to increased phytate content in the strips. Phytate is often considered as an antinutrient because it binds minerals (Zn^{2+}, $Fe^{2+/3+}$, Ca^{2+}, Mg^{2+}, Mn^{2+}, and Cu^{2+}) in the digestive tract, making them unavailable (Dick *et al.*, 2018). It reduces mineral absorption thereby reducing bioavailability (Gupta *et al.*, 2013).

Table V: Antinutrient composition of soybean-cassava strips (mg/100g).

Samples	Phytate	Tannin	Trypsin Inhibitor	Saponin	Hydrogen Cyanide
WF100	$0.22^{g}\pm0.01$	$0.34^{f}\pm0.01$	$0.04^{g}\pm0.01$	$0.36^{a}\pm0.01$	$0.06^{d}\pm0.01$
SF100	$1.31^{e}\pm0.01$	$4.13^{a}\pm0.02$	$1.69^{a}\pm0.01$	$0.02^{d}\pm0.01$	$0.00^{c}\pm0.01$
CF100	$5.31^{b}\pm0.01$	$0.12^{g}\pm0.01$	$0.54^{d}\pm0.01$	$0.02^{d}\pm0.01$	$2.11^{a}\pm0.01$
SF50:CF50	$5.33^{a}\pm0.02$	$3.11^{b}\pm0.01$	$0.67^{c}\pm0.02$	$0.06^{c}\pm0.01$	$0.87^{b}\pm0.01$
SF40:CF60	$3.59^{c}\pm0.02$	$1.63^{d}\pm0.02$	$0.25^{e}\pm0.01$	$0.04^{d}\pm0.01$	$0.97^{b}\pm0.01$
SF20:CF80	$5.59^{f}\pm0.01$	$0.54^{e}\pm0.01$	$0.16^{f}\pm0.01$	$0.07^{c}\pm0.01$	$1.14^{b}\pm0.01$
SF60:CF40	$2.15^{d}\pm0.01$	$2.04^{c}\pm0.01$	$0.91^{b}\pm0.01$	$0.02^{b}\pm0.01$	$0.57^{c}\pm0.01$
SF80:CF20	$2.15^{d}\pm0.0$	$2.04^{c}\pm0.01$	$0.89^{b}\pm0.01$	$0.03^{b}\pm0.01$	$0.14^{b}\pm0.08$

Values are means $\pm$ standard deviation of duplicate determination.
Mean values in the same column with different superscripts are significantly different ($p<0.05$).

The tannin content ranged from 0.34 to 4.13 mg/100g. The reference sample had lower tannin content than the formulated strips. Increasing proportion of soybean flour resulted into increased tannin content in the strips. However, the tannin in the strips were generally below the reported lethal dose of 90 mg/100g (Ifie and Emeruwa, 2011). Therefore, the tannin level in the strips might not influence digestion negatively since high tannin concentration impairs microbial enzyme activities including cellulose and intestinal digestion may be depressed (Ferrell and thorington, 2006).

The trypsin inhibitor for the reference sample was lower than the formulated sample with values ranging from 0.04 to 1.69 mg/100g. Trypsin inhibitor reduce the biological activity of trypsin by controlling the activation and catalytic reactions of proteins. They compete with proteins to bind to trypsin and therefore render it unavailable to bind with proteins for the digestion process (Aviles-Gaxiola *et al.*, 2018). However, the values obtained in this study are quite low and might not influence protein digestion negatively.

The saponin content of the reference sample was higher than the values obtained for the formulated samples with values ranging from 0.02 to 0.36 mg/100g. Saponin can form complexes with zinc and iron, thus, limiting their bioavailability (Sun *et al.*, 2009). It has been reported that, consumption of 5 – 10 mg/kg of saponin produces local effect of corrosion and paralytic ileus (Joint FAO/WHO Expert Committee on Food Additives, 2005). From this study, the soybean-cassava strips contained low amount of saponin, and may possibly cause no health adverse effect.

The results of hydrogen cyanide ranged from 0.00 to 2.11 mg/100g. The results showed that hydrogen cyanide obtained in the formulated samples was solely contributed by the cassava flour since the hydrogen cyanide in SF100 (100% soybean flour strip) was absent. Increasing proportion of cassava flour resulted into increased hydrogen cyanide content in the formulated strips. However, the hydrogen cyanide content of the strips was below the lethal those of >10 mg/kg as stipulated by Codex Alimentarius Commission (2013).

Sensory evaluation

The result of sensory evaluation of soybean-cassava strips are presented in Table VI. The appearance score of the sample ranged from 5.45 to 8.45. SF20:CF80 (20% soybean flour: 80% cassava flour) was rated higher by the panelist than other strips. This could be due to the fact that the increasing addition of soybean caused the strips to turn darker than strips containing higher proportion of cassava flour. The browning could also be as a result of caramelization and mallard reactions, as the proteins contributed by soybean flour must have reacted with sugar during frying (Manzocco *et al.*, 2011), thus, SF20:CF80 (20% soybean flour: 80% cassava flour strip) was liked very much by the panelist. SF50:CF50 (50% soybean flour: 50% cassava flour strip) and SF40:CF60 (40 % soybean flour: 60 % cassava flour strip) was liked moderately by the panelists, SF80:CF20 (20 % soybean flour: 80% cassava flour strip) was neither liked nor disliked. The crispiness ranged from 1.45 to 8.40. The crispiness decreased with increased soybean flour supplementation. Among the formulated samples, SF20:CF80 (20 % soybean flour: 80 % cassava flour strip) was liked very much by the panelist. It might be implied that the presence of soybean flour affected the crispiness of the strips. The result of mouth feel ranged from 4.15 to 7.30. SF100 (100 % soybean flour strip), SF80:CF20 (80 % soybean flour: 20 % cassava flour strip) and SF60:CF40 (60 % soybean flour: 40 % cassava flour strip) with values of 7.30, 7.20 and 7.05 respectively was liked moderately by the panelist. The results showed that, increasing proportion of soybean flour resulted to improved mouthfeel. The result of texture of the strips ranged from 3.20 to 7.30 with SF20:CF80 (20 % soybean flour: 80 % cassava flour strip) exhibiting better texture than other samples as rated by the panelist and was liked moderately. The improved texture associated with strips with higher proportion of cassava flour might be attributed to the cohesiveness of starch matrix present in cassava flour. The result for taste ranged from 5.60 to 7.15.

Table VI: Sensory properties of soybean-cassava strips.

Samples	Appearance	Crispiness	Mouthfeel	Texture	Taste	Flavour	General acceptability
WF100	$6.85^{cb}\pm1.71$	$6.45^{e}\pm1.71$	$6.40^{ab}\pm1.51$	$4.10^{cd}\pm1.51$	$6.30^{ab}\pm1.51$	$6.25^{abc}\pm0.51$	$6.45^{dcb}\pm0.51$
SF100	$5.65^{ab}\pm1.61$	$4.55^{a}\pm0.51$	$7.30^{a}\pm0.71$	$5.25^{cb}\pm1.61$	$6.90^{a}\pm1.71$	$7.25^{a}\pm1.61$	$7.55^{ab}\pm1.61$
CF100	$7.95^{d}\pm0.51$	$7.60^{c}\pm1.51$	$6.20^{ab}\pm1.71$	$5.55^{b}\pm1.71$	$6.25^{ab}\pm1.61$	$4.65^{ab}\pm2.51$	$6.40^{dcb}\pm0.71$
SF50:CF50	$7.45^{cd}\pm1.71$	$4.80^{c}\pm1.61$	$5.65^{b}\pm1.51$	$4.80^{cb}\pm1.81$	$6.15^{ab}\pm1.81$	$6.85^{cb}\pm1.81$	$5.40^{d}\pm2.51$
SF40:CF60	$7.80^{ab}\pm1.71$	$5.75^{c}\pm1.71$	$6.30^{ab}\pm2.51$	$5.25^{cb}\pm1.61$	$6.65^{ab}\pm1.61$	$5.95^{ab}\pm1.61$	$7.10^{ab}\pm1.81$
SF20:CF80	$8.45^{a}\pm1.71$	$8.40^{a}\pm0.31$	$4.15^{a}\pm1.71$	$7.30^{a}\pm2.51$	$7.15^{a}\pm1.91$	$5.35^{a}\pm1.51$	$7.70^{a}\pm1.61$
SF60:CF40	$6.00^{ab}\pm2.71$	$5.35^{b}\pm0.51$	$7.05^{a}\pm0.51$	$5.75^{b}\pm1.61$	$6.55^{ab}\pm1.41$	$6.85^{ab}\pm1.71$	$6.80^{abc}\pm1.91$
SF80:CF20	$5.45^{cd}\pm1.71$	$2.80^{d}\pm0.51$	$7.20^{b}\pm0.51$	$3.20^{d}\pm1.71$	$5.60^{b}\pm1.91$	$7.25^{c}\pm1.81$	$5.67^{cd}\pm0.51$

Values are means $\pm$ standard deviation of duplicate determination. Mean values in the same column with different superscripts are significantly different ($p<0.05$).

The result showed that all the samples were liked slightly by the panelist except SF20:CF80 (20 % soybean flour: 80 % cassava flour strip) that was liked moderately and SF80:CF20 (80 % soybean flour: 20 % cassava flour strip) that was neither liked nor disliked by the panelist. The result for flavour showed that SF80:CF20 (80 % soybean flour: 20 % cassava flour strip) with a rating of 7.25 was rated higher by the panelist and it was not significantly different from SF100 (100 % soybean flour). The improved flavour in strips containing higher proportion of soybean flour could be attributed to the higher lipid and protein content of the flour. The results of general acceptability showed that SF80:CF20 (80% soybean flour: 20 % cassava flour strip) was best generally accepted among the soybean-cassava strips with a rating of 7.70.

Conclusion

The findings of this study showed that the applicability of soybean and cassava flours in the production of strips. The functional analysis revealed that 100 % wheat flour had better functional properties, however, increasing the proportion of soybean flour in the composites resulted to increased foam capacity, foam stability and oil absorption capacity but decreased water absorption capacity and gelatinization temperature. Strips produced from SF80:CF20 (80 % soybean flour: 20 % cassava flour blends) had better proximate composition and sensory characteristics. The vitamin content was improved in the composite strips but the values were below the FAO/WHO recommended daily intakes. The mineral analysis showed that the reference sample had better mineral composition However, the mineral contents of the samples were below the FAO/WHO recommended daily intakes. The antinutrient contents of the formulated samples exceeded those of the reference samples but were within the safe limit for consumption. It is therefore recommended that strips produced from soybean and cassava flours could be improved and optimized for the benefit of individuals with diabetes, celiac diseases, as well as protein energy malnutrition.

References

Achikanu, C. E., Eze-Steven, P. E., Ude, C. M. and Ugwuokolie, O. C. (2013). Determination of the vitamin and mineral composition of common leafy vegetables in south eastern Nigeria. *International Journal of Current Microbiology and Applied Sciences* 2(11):347-353.

Adebowale, K.O. and Lawal, O. S. (2004). Comparative Study of the functional properties of Bambara groundnut (*Voandzeia subterranean*), Jack bean *(Cana vliaensiformis)* and Mucuna bean *(Mucuna pruriens)* flour. *Food Resource International* 37:355-365.

Adelakun, O. E., Duodu, K. G., Buys, E. and Olanipekun, B. F. (2013). Potential Use of Soybean Flour in Food Fortification. *Intech*, 513-520.

Adejuyitan, J.A., Otunola, E. T., Akande, E. A., Bolarinwa, I. F. and Oladokun, F. (2009). Some physicochemical properties of flour obtained from fermentation of Tigernut (*Cyperus esculentus*). *Food Science*, 3(2): 51- 055

Ajani, A. O., Oshundahunsi, O. F., Akinoso, R., Arowora, K. A., Abiodun, A. A. and Pessu, P. O. (2012). Proximate Composition and Sensory Qualities of Snacks Produced from Breadfruit Flour. *Global Journal of Science Frontier Research Biological Sciences*, 12(7): 56-65. Online ISSN: 2249-4626.

Akapata, M. I. and Akubor P. I. (1999). Chemical composition and selected functional properties of sweet orange (*Citrus sinensis*) seed flour. *Journal of Plant Food Human Nutrition*, 54:353-362.

Akuyili, D.O., Igwe, S.A. and Ogbogu, C.E. (2013). Effects of garden egg on some visual functions of visually active Igbos of Nigeria. Journal of Ethnopharmacology 4: 25-40.

Alozie, Y. E. and Chinma, C. E. (2015). Proximate composition, physical and sensory properties of cake prepared from wheat and cocoyam flour. Journal of Food Research 4(5): 181-188.

Aviles-Gaxiola, S., Chuck-Hernandez, C., and Serna Saldivar, S.O (2018). Inactivation methods of trypsin inhibitor in legumes: a review. Journal of Food Science 83 (1): 17–29. doi:10.1111/1750-3841.13985

Association of Official and Analytical Chemists (AOAC) (2010). Official Methods of Analysis. 18th Edition., Association of Official Analytical Chemists, Official Method 2.210, Washington DC, USA.

Ayetigbo, O., Latif, S., Abass, A. and Muller, J. (2018). Comparing characteristics of root, flour and starch of biofortified yellow-flesh and white-flesh cassava variants, and sustainability considerations: A Review. Sustainability 10: 3089.

Butt, M. S. and Batool, R. (2010). Nutritional and functional properties of some promising legumes proteins isolates. Pakistan Journal of Nutrition 9(4):373–379. doi: 10.3923/pjn.2010.373.379.

Chandra, R. K. (2002). Nutrition and the immune system from birth to old age. European Journal of Clinical Nutrition. 56:73–76. PubMed.

Codex Alimentarius Commission (2013). Joint FAO/WHO Food Standards Programme, Codex Committee on Contaminants in Foods: Proposed Draft Maximum levels for Hydrogen Cyanide in cassava and cassava products; seventh session, Moscow, Russian Federation,1-34.

Coppin, E. A. and Pike, O. A. (2001). Oil stability index correlated with sensory determination of oxidative stability in light-exposed soybean oil. Journal of American Oil Chemists Society 78(11): 13-18.

Dada, T. A., Barber, L. I., Ngoma, L. and Mwanza, M. (2017). Formulation, sensory evaluation, proximate composition and storage stability of cassava strips produced from composite flour of cassava and cowpea. Food Science and Technology 6: 395-399.

Dick, R. A., Zadrozny, K. K., Xu, C., Schur, F. K., Lyddon, T. D., Ricana, C. L., Wagner, J. M., Perilla, J. R., Ganser-Pornillos, B. K., Johnson, M. C., Pornillos, O. and Vogt, V. M. (2018). Inositol phosphates are assembly co-factors for HIV-1. Nature 560 (19): 509-512.

El-Adawy T.A. (2001). Characteristics and Composition of watermelon, pumpkin and paprika seed oils and flours. Journal of Agriculture Food Chemistry 49:1253-1259.

Etiosa, O. R., Nnadozie, B. C. and Anuge, B. (2018). Mineral and proximate composition on of soybean. Asian Journal of Physical and Chemical Sciences 4(3): 1-6.

Ezeocha, V.C. and Onwuka, G. I. (2010). Effect of processing methods on the Physico-chemical and nutritional quality of maize and soybean based complimentary blends. Nigerian Food Journal 28 (2): 210-216.

FAO/WHO (1998). Vitamin and mineral requirements in human nutrition: report of a FAO/WHO expert consultation Bangkok, Thailand. 2nd Edition. 1-362. ISBN 92 4 154612 3.

FAO/WHO/UNU (1994). Energy and Protein Requirements. WHO Technical Report Series 724.ISSN: 0512-3034. Expert consultation, FAO Publications. http://www.fao.org/clorep/003/aa04oe/AA040E01. Accessed on 23rd June, 2020.

Ferrao, J.E.M, Ferro, A.M.B.C and Antures, A.M.G. (1987). Bambara groundnut (*Vigna- subterranean)* Aspect of its nutritive value. Gracia deorta seriede Estudos Agronomics. 14:35-35.

Ferrell, K. E. and Thorington, R. W. (2006). Squirrels: the animal answer guide. Baltimore: Johns Hopkins University Press. 91. ISBN 978-0-8018-8402-3.

Food and Nutrition Board, Institute of Medicine, (2002). Dietary reference intakes for vitamin A, vitamin K, arsenic, boron, chromium, copper, iodine, iron, manganese, molybdenum, nickel, silicon, vanadium, and zinc. Washington, DC: National Academy Press.

Gernah, D. I. and Anyam, K. (2014). Production and quality assessment of protein-rich biscuits from blends of wheat and defatted sesame flours. International Journal of Food Processing Technology 1(1): 27-31.

Gerlin, J.R., Forster, S., Grafton, K.F., McClean, P.E. and Rojas-Cifuentes, G.A. (2007). Analysis of seed zinc and other minerals in a recombinant inbred population of navy bean (*Phaseolus vulgaris* L.). Crop Science 47:1361–1366.

Gulati, P. (2016). Effects of feed moisture and extruder screw speed and temperature on physical characteristics and antioxidant activity of extruded proso millet flour. International Journal of Food Science and Technology 50: 114-122.

Gupta, R. K., Gangoliya, S. S. and Singh, N. K. (2013). Reduction of phytic acid and enhancement of bioavailable micronutrients in food grains. Journal of Food Science and Technology 52 (2): 676–684. doi:10.1007/s13197-013-0978-y

Hung, H. C., Joshipura, K. J. and Jiang, R. (2004). Fruit and vegetable intake and risk of major chronic disease. Journal of National Cancer Institute 96:1577.

Ibeabuchi, J. C., Okafor, D. C., Peter, I. A., Agunwa, I. M., Eluchie, C. N. and Ofoedu, C. E. (2017). Cooperative study on the proximate composition, functional and sensory properties of the three varieties of Beans *"Phaseolus tunatus*", *Phaseolus vulgaris"* and "*Vigna umbellatu*". *I*nternational Journal of Advancement of Engineering Technology Management and Applied Science 5(1):1-23.

Ifie, I. and Emeruwa, C. (2011). Nutritional and anti-nutritional characteristics of the larva of Oryctes monoceros. Agriculture and Biology Journal of North America, (1992): 42–46. http://doi.org/10.5251/abjna.2011.2.1.42.46

Ikujenola, A.V., Oguntuase, S.O. and Omosuli, S.V. (2013). Physico-chemical Properties of complementary foods from malted quality protein maize and defatted fluted pumpkin flour. Food and Public Health 3(6): 323-328.

Ishiwu, C. N. and Tope, V. A. (2015). Effect of period of fermentation on nutrients of Castor oil seed (*Ricinus communis*). Direct Research Journal of Agriculture and Food Science 3(10):178-183

Iwe, M. O. (2014). Current trends in sensory evaluation of foods. Revised Edition. Rojoint Communication Services Ltd. Uwani Enugu, Nigeria. Pp. 144-145.

Jitngarmkusol, S., Hongsuwankul, J. and Tananuwong, K. (2008). Chemical composition, functional Properties and microstructure of cassava strips. Journal of Food Chemistry 110:23-30, doi:10.1016.

Joint FAO/WHO Expert Committee on Food Additives (2005). Sixty-fifth meeting Geneva, 7 -16. Summary and Conclusions. http://www.who.int/ipcs/food/jecfa/summaries/summary65.pdf, accessed 14/1/2021.

Kaushal, P., Kumar, V. and Sharma, H. K. (2012). Comparative study of physico-chemical, functional, anti-nutritional and pasting properties of taro (*Colocasia esculenta*), rice (*Oryza sativa*), pegion pea (*Cajanus cajan*) flour and their blends. LWT-Food Science Technology 48:59-68.

Kusuma, N. B. (2015). Soybean consumption and health benefits. International Journal of Scientific and Technology Research 4(7): 50-53.

Kinsella, J. E., Damodaran, S. and German, B. (1985). Physicochemical and Functional Properties of Oil Seed Proteins with emphasis on Soy Proteins. In: new Protein Foods Alschul, A. M and H. L. Wilke (Eds) volume 5. New York, Academic Press 107-179.

Kuntz, I. D. (1971). Hydration of macromolecules III. Hydration of polypeptides. Journal of American Chemical Society 93: 514-515

Mamiro, P. S., Mbwaga, A. M., Mamiro D. P., Mwanri A. W. and Kinabo, J. L. (2011). Nutritional quality and utilization of local and improved cowpea varieties in some regions in

Tanzania. African Journal of Food Agriculture and Nutrition Development 11(5):4490-4506.

Manzocco, L., Calligaris, S., Mastrocola, D., Nicoli, M. and Lerici, C. (2011). Review of nonenzymatic browning and antioxidant capacity in processed food. *Trends Food Science and Technology*, 11, 340-346.

Mashayekh, M., Mahmoodi, M. R., and Enterazzi, M. H. (2008). Effect of fortification of defatted soy flour on sensory and rheological properties of wheat bread. International Journal of Food Science Technology 43: 1693-1698.

Mwasaru, M. A., Muhammad, K., Bakar, J., Yaakob, B. and Man, C. (1999). Effects of isolation technique and conditions on the extractability, physicochemical and functional properties of pigeon pea (*Cajanus cajan*) and cowpea (*Vigna unguiculata*) protein isolates. Physicochemical properties. Food Chemistry 67:435-444

Nagel, R. (2010). Living with Phytic Acid. Wise Traditions in Food, Farming and the Healing Arts, the quarterly journal of the Weston. 8-13

Ndife, J., Abdulraheem, L. O and Zakari, U. M. (2011). Evaluation of the nutritional and sensory quality of functional breads produced from whole wheat and soya bean flour blends. African Journal of Food Science 5(8), Pp. 466-472.

Nwosu, J. N. (2011). The effects of processing on the antinutritional properties of moin-moin made from cowpea (*Vigna unguiculata*) and asparagus bean seed (*Vigna sequipedalis*). World Rural Observations 3(3): 1-5.

Offor, C.E. (2015). Determination of vitamin composition of *Dissotis rotundifolia* leaves. International Journal of Current Microbiology and Applied Sciences 4(1): 211.

Oguntona, T., Bernstein, C. R., and Williams, L. (1987). Dietary (Nutrient) intake of Nigerian peasants living in a semi-arid zones. Ethiopian Journal of Health and Development 2(1), 27-36.

O'Keefe, S., Bianchi, L. and Sharman, J. (2015). Soybean nutrition. SM Journal of Nutrition and Metabolism 1(1): 1-9.

Onimawo, A.I. and Akubor, P.I. (2005). Functional properties of food. In: Food Chemistry. Integrated approach with Biochemical Background. Ambik Press Limited, Benin City, Nigeria, 208-221.

Onimawo, A.I. and Egbekun, K.M. (1998). Comprehensive Food Science and Nutrition. (2nd ed.). ADMIK Press Ltd Benin. Pp. 193-201

Onwuka, G. I. (2018). Food Analysis and Instrumentation. Theory and practices. Naphtali Prints Lagos, Nigeria.

Onyenwoke, C. A. and Simonyan, K. J. (2014). Cassava post-harvest processing and storage in Nigeria: A review. African Journal of Agricultural Research 2(1): 3854-3863.

Pawar, S. G., Pardeshi, I. L., Borkar, P. A. and Rajput, M. R. (2014). Optimization of process parameters of microwave puffed sorghum based ready to-eat (RTE) food. Journal of Ready to Eat Foods 1(2): 59-68.

Pele, G. I., Ogunsua, A. O., Adepeju, A. B., Esan, Y. O. and Oladiti, E. O. (2016). Effect of processing methods on the nutritional and anti-nutritional properties of soybeans. African Journal of Food Science and Technology 7(1): 9-12.

Rooney, L. W. and Waniska, R. D. (2000). Sorghum food and industrial utilization. 'Sorghum: Origin, History, Technology, and Production', John Wiley and Sons, New York.

Singh, J. P., Kaur, A., Shevkani, K., Singh, N. and Singh, A. (2016). Physiochemical characterization of corn extrudates prepared with varying levels of beetroot at different extrusion temperatures. International Journal of Food Science and Technology, 51(4): 911-919.

Soetan, K. O., Olaiya, C. O., and Oyewole, O. E. (2010). The importance of mineral elements for humans, domestic animals and plants: A review. African Journal of Food Science 4(5): 200-222.

SPSS (2018). Statistical package for the social sciences. Guild for personal computers, version 22.0 Edition, Chicago.

Steel, C. J., Leoro, M. G. Y., Schmiele, M., Ferreira, R. E. and Chang, Y. K. (2012). *Thermoplastic extrusion in food processing.* In: Thermoplastic elastomers, Prof. A. Z. El-Sonbati (Ed.). Intech 265-290.

Sun, H., Xie, Yong. and Ye, Y. (2009). Advances in saponin-based adjuvants. Vaccine 27 (12): 1787–1796. doi:10.1016/j.vaccine.2009.01.091

Suresh, C., Samsher S., and Durvesh, K. (2015). Evaluation of the functional properties of composite flours and sensorial attributed of composite flour biscuits. Journal of Food Science technology 52(6): 3681-3688.