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Micronutrients, antinutrients composition and sensory properties of extruded snacks made from sorghum and charamenya flour blends

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The effect of process variables (feed composition, feed moisture, and exit barrel temperature) on the vitamins, antinutrients, and sensory profile of extruded snacks produced from sorghum and charamenya flour blends using response surface methodology were investigated in this study. Feed composition (FC, 10-30%), feed moisture content (FMC, 25-30%) and exit barrel temperature (EBT, 110-130°C) were the independent process variables considered while vitamins, anti-nutrients and sensory evaluation were the response variables. Flour produced from sorghum (SF) and charamenya (CF) seeds were blended in the ratio of 3.2:96.8, 10:90, 20:80, 30:70 and 36.8:63.2%. The blends were conditioned to desired moisture content and allowed to equilibrate overnight in a refrigerator (4°C). Feeding temperature, cooking temperature, screw speed, and pressure of the extruder were set at 90 and 100°C, 250 rpm, and >300 psi, respectively. Extruded snacks from each run were collected when steady state extrusion conditions were attained and dried overnight at 40°C in a cabinet dryer. The vitamins (A, B_1, B_2, B_6, B_{12}, C, and D) and antinutrients (phytate, oxalate and tannin) content reduced post extrusion when compared with the flour blends prior to extrusion. They were significantly (p<0.05) affected by FC, FMC, and EBT. There were also observed significant (p<0.05) differences in the sensory scores of all the attributes tested except flavor (p>0.05), indicating the extrusion process's ability to reduce the beany flavor associated with legumes.

Key words: Extrusion, snacks, micronutrient, antinutrients, sensory, cereal-legume.

INTRODUCTION

Currently, snack consumption has increased in its popularity in Nigeria, shown by their conspicuous presence in the market. Cereal based snacks are the most widely consumed snack food items, many of which are low in nutrient density but high in calories and/or fat content (Hess et al., 2016). There has been huge concern from nutritionists over the years on snack consumption pattern of children, especially pre-schoolers; they frequently consume in-between meal snacks; thus, their diets are often nutritionally poor (Hess et al., 2016).

Processing methods reduced the level of anti-nutritional factors and minimize micronutrients losses are of great interest, both to manufacturers and consumers. Mechanical, thermal, or biological processes had the

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potential to improve the nutrient availability in foods (Hotz and Gibson, 2007). Extrusion cooking technology, a high-temperature-short-time process has been advocated for the production of half- or completely- cooked safe and acceptable foods (Guy, 2001). Raw materials of interest included flour and starch granules from cereal, tubers, and legumes. Extruded foods such as breakfast cereals, snacks, flakes, quick cooking pasta and texturised vegetable protein and breakfast gruel are important products from this process (Iwe, 2001; Nwabueze and and Iwe 2010; Leszek, 2011). Like other processes for heat treatment of food, extrusion cooking may have both beneficial and undesirable effects on nutritional value. Beneficial effects included the destruction of anti-nutritional factors and gelatinization of starch. However, heat-labile vitamins may be lost to varying extents. Thus, retention of vitamins and anti-nutrients post extrusion cooking is of great importance to food technologists and consumers, to assess the effects of food processing on these chemical components (Baskar and Aiswarya, 2016).

More still, consumers have higher interest in snacks that taste good, smell good, feel good, look good, and in addition, are nutritionally superior and healthy. These desirable product qualities are mostly influenced by conditions employed during processing; conditions of processing such as the type of extruder, quantity of moisture in the feed material, temperature of different sections of the barrel, screw speed and feed rate into the extruder (Thymi et al., 2005). The importance of bioactive compounds in human health and nutrition cannot be overemphasized. The bioactive compounds in extruded foods are mostly influenced by extrusion process variables such as shear, temperature, resonance time, and moisture content of the feed material (Brennan et al., 2011). The nutrient composition of sorghum indicated that it is a good source of energy, proteins, carbohydrates, vitamins, and minerals, including the trace elements, particularly iron and zinc, except calcium (Dicko et al., 2006).

Sorghum seeds are considered to be one of the most important sources of carbohydrates, vitamins, mineral elements, and dietary fiber (Stefoska-Needham et al., 2015). Legumes contained high levels of protein and important amino acids – lysine, and tryptophan; as such, their combination with cereals will make well-balanced food. Legumes such as cowpea, soybean, and groundnuts with diverse varieties are nutritionally important, containing about 17 to 25% protein, and good sources of phosphorus and iron; they are considered one of the underutilized crops that have great potentials for becoming industrial raw materials (FAO, 2004).

The cowpea variety (*Vigna unguiculata* Fabaceae*)* used for this study is a local species, small-sized, white in color with a black ringed eye called c*haramenya* in Nsukka, Nigeria. The seeds are traditionally consumed as *otipi* maize or yam based meals; they contained about 24 to 26% crude protein (Akinwale and Obiesan, 2012) and have great potential for industrial use to generate assorted snack products when suitable processing method is used.

The aim of this study was to validate extrusion cooking and conditions' ability to retaining more of the heat labile micronutrients (vitamins), reducing antinutrients and beany flavour which restricted legumes' use in snack making and establish or predict how much consumers are willing to accept products from a novel base ingredient.

MATERIALS AND METHODS

Sorghum grains and cowpea seeds used for this study were purchased from the Orba market in Nsukka L.G.A, Enugu State of Nigeria. Sorghum seeds (5 kg) were cleaned and dehulled after mild wetting, using a grain dehuller. The dehulled grains were washed, and the remaining hulls floated off, then dried for 6 h to a moisture content of 10%. The dried seeds were milled to flour in a locally fabricated attrition mill thrice in order to obtain fine flour. The flour was passed through a 150 µm pore sized sieve and stored in an airtight plastic container at room temperature until further use. Cowpea (*Charamenya*) seeds, on the other hand, were thoroughly cleaned and soaked in tap water at ambient temperature (30 ± 2°C) for 3 h to loosen the seed coats. The seeds were dried at a temperature of 30 ± 2°C for 8 h to approximately 12% moisture content. The seeds were dehulled with an attrition mill set to the right tolerances. The dehulled mass was manually winnowed and then milled to flour in a locally fabricated attrition mill. The flour was passed through a 150 µm pore sized sieve and stored in an airtight plastic container at room temperature until further use.

Experimental design

Independent variables considered were Feed composition, X_1 (10-30%), Feed moisture content, X_2 (25-35%) and Barrel exit temperature, X_3 (110-130°C). A three-factor (variable) central composite rotatable design (CCRD) (Box and Hunter, 1957) at five levels, shown in Table 1, was adopted for the study.

Composite flour formulation and moisture adjustment

Sorghum and cowpea flours were mixed at defined weight ratios (3.2:96.8, 10:90, 20:80, 30:70, and 36.8:63.2%) to obtain five composite flour blends. The initial moisture content of the blends was measured, M_1, prior to conditioning to the desired moisture content (M_2). This was done by spraying with a calculated amount of water and mixing continuously at medium speed in a small scale food mixer. The samples were kept in an airtight container and left in the refrigerator overnight for moisture equilibration. The amount of water to be added was calculated using the equation below:

$$W_w = W_d \times \frac{(M_2 - M_1)}{(1 - M_1)\,(1 - M_2)}$$

Where: W_w= weight of water to be added, W_d= weight of the raw flour, M_1 = initial moisture content, and M_2 = desired moisture content.

The outlines of the 15 experimental runs in their coded and natural values are presented in Table 2.

Table 1. Independent variable levels used for central composite design.

Variable	Coded variable				
	-α	**Low**	**Medium**	**High**	**+α**
	-1.68	**-1**	**0**	**1**	**1.68**
Feed composition (X_1)	3.2	10	20	30	36.8
Feed moisture content (X_2)	21.6	25	30	35	38.4
Barrel exit temperature (X_3)	103.2	110	120	130	136.8

Table 2. Experimental design for extrusion cooking exercise in their coded forms and natural units.

Run	Coded form			Natural form		
	X_1	**X_2**	**X_3**	**X_1(%)**	**X_2(%)**	**X_3(^oC)**
1	-1	-1	-1	10	25	110
2	+1	-1	-1	30	25	110
3	-1	+1	-1	10	35	110
4	+1	+1	-1	30	35	110
5	-1	-1	+1	10	25	130
6	+1	-1	+1	30	25	130
7	-1	+1	+1	10	35	130
8	+1	+1	+1	30	35	130
9	-1.68	0	0	3.2	30	120
10	+1.68	0	0	36.8	30	120
11	0	-1.68	0	20	21.6	120
12	0	+1.68	0	20	38.4	120
13	0	0	-1.68	20	30	103.2
14	0	0	+1.68	20	30	136.8
15	0	0	0	20	30	120

-1 = Lowest value, 1=Highest value, 0=Medium value, -1= -α, 1 = +α. feed composition (X_1), feed moisture content (X_2) and barrel exit temperature (X_3) Each design point will be run in triplicates and the average recorded. The experimental runs were randomized.

Production of extruded snacks using a single screw extruder

A small scale laboratory single screw extruder (Cosmic Controls, India), equipped with three heating zones (entry, mid and exit), 20 flighted screw feeder, 4 mm diameter die nozzle, and 30 cm barrel length was used to extrude the different runs. The extruder was fed gradually but continuously through a conical-shaped hopper mounted vertically above the end of the extruder. Experimental samples were collected when a steady state has been achieved. The extrudates were further dried in a cabinet dryer (GENLAB DC 500, Germany) overnight at 60°C. The resulting dried extrudates were packaged in zip lock polyethylene bags and coded according to the corresponding runs. Extrudates were subjected to sensory and laboratory analysis.

Analytical methods

Determination of Beta carotene, Vitamins B_1, B_2, B_6, B_{12}, C, and D

The pro-vitamin A and Vitamins B_1, B_2, B_6, B_{12}, C, and D contents of the extruded snacks were determined according to AOAC (2010).

Determination of phytate, tannin and oxalate contents

Phytate content was determined by the method described by Latta and Eskin (1980), tannin content was determined by the Folin-Denis colorimetric method described by Kirk and Sawyer (1998) while oxalate content of the extruded snacks was determined by the method described by Onwuka (2005).

Sensory evaluation of the extruded snacks samples

Extruded snacks from sorghum-cowpea blends were coded, placed in identical containers, and presented randomly. Twenty semi-trained panel members were used to assess the sensory attributes. The attributes tested were appearance, color, flavor, taste, mouthfeel, and overall acceptability using a 9-point hedonic scale (with 9 = extremely like and 1 = extremely dislike) as described by Ihekoroonye and Ngoddy (1985).

Data analysis

All data generated were subjected to statistical analysis of variance

Table 3. Vitamin contents of the extruded snacks produced from sorghum and charamnya flour blends.

Run	Pro-vitamin A (µg/100 g)	Vitamin B_1 (mg/100 g)	Vitamin B_2 (mg/100 g)	Vitamin B_6 (mg/100 g)	Vitamin B_{12} (mg/100 g)	Vitamin C (mg/100 g)	Vitamin. D (IU)
1 (10:25:110)	$24.67^{d} \pm 0.11$	$0.94^{bcd} \pm 0.04$	$0.56^{abc} \pm 0.01$	$0.74^{cd} \pm 0.01$	$1.94^{d} \pm 0.03$	$0.28^{b} \pm 0.03$	$0.65^{g} \pm 0.03$
2 (30:25:110)	$13.98^{k} \pm 0.07$	$0.62^{f} \pm 0.04$	$0.44^{d} \pm 0.05$	$0.52^{f} \pm 0.03$	$1.02^{h} \pm 0.01$	$0.34^{ab} \pm 0.01$	$1.08^{c} \pm 0.02$
3 (10:35:110)	$19.18^{h} \pm 0.08$	$0.93^{cd} \pm 0.05$	$0.56^{abc} \pm 0.05$	$0.73^{cd} \pm 0.03$	$1.49^{g} \pm 0.03$	$0.31^{ab} \pm 0.04$	$0.87^{ef} \pm 0.01$
4 (30:35:110)	$24.42^{de} \pm 0.06$	$0.78^{e} \pm 0.03$	$0.50^{cd} \pm 0.06$	$0.63^{e} \pm 0.01$	$1.92^{d} \pm 0.03$	$0.34^{ab} \pm 0.02$	$1.07^{c} \pm 0.03$
5 (10:25:130)	$13.48^{l} \pm 0.36$	$0.64^{f} \pm 0.02$	$0.44^{d} \pm 0.01$	$0.62^{e} \pm 0.06$	$1.06^{h} \pm 0.04$	$0.28^{b} \pm 0.02$	$0.66^{g} \pm 0.04$
6 (30:25:130)	$18.57^{j} \pm 0.01$	$0.76^{e} \pm 0.04$	$0.50^{cd} \pm 0.03$	$0.53^{f} \pm 0.03$	$1.44^{g} \pm 0.01$	$0.31^{ab} \pm 0.02$	$0.84^{f} \pm 0.01$
7 (10:35:130)	$18.94^{hi} \pm 0.11$	$0.93^{cd} \pm 0.04$	$0.50^{cd} \pm 0.06$	$0.63^{e} \pm 0.04$	$1.47^{g} \pm 0.03$	$0.31^{ab} \pm 0.04$	$0.86^{ef} \pm 0.05$
8 (30:35:130)	$24.35^{e} \pm 0.04$	$0.78^{e} \pm 0.05$	$0.56^{abc} \pm 0.02$	$0.73^{cd} \pm 0.01$	$1.92^{d} \pm 0.04$	$0.31^{ab} \pm 0.04$	$1.07^{c} \pm 0.01$
9 (3.2:30:120)	$20.45^{g} \pm 0.18$	$1.10^{a} \pm 0.09$	$0.62^{a} \pm 0.04$	$0.85^{a} \pm 0.01$	$2.42^{a} \pm 0.02$	$0.32^{ab} \pm 0.04$	$0.68^{g} \pm 0.01$
10 (36.8:30:120)	$30.41^{a} \pm 0.21$	$0.82^{e} \pm 0.02$	$0.51^{bcd} \pm 0.03$	$0.66^{e} \pm 0.01$	$1.60^{f} \pm 0.01$	$0.37^{a} \pm 0.04$	$1.31^{a} \pm 0.02$
11 (20:21.6:120)	$28.65^{b} \pm 0.03$	$1.05^{ab} \pm 0.02$	$0.60^{ab} \pm 0.07$	$0.81^{ab} \pm 0.03$	$2.27^{b} \pm 0.04$	$0.36^{a} \pm 0.04$	$1.24^{b} \pm 0.02$
12 (20:38.4:120)	$18.72^{ij} \pm 0.04$	$0.77^{e} \pm 0.04$	$0.49^{cd} \pm 0.04$	$0.62^{e} \pm 0.04$	$1.45^{g} \pm 0.03$	$0.31^{ab} \pm 0.01$	$0.85^{f} \pm 0.01$
13 (20:30:103.2)	$28.65^{b} \pm 0.03$	$1.05^{ab} \pm 0.05$	$0.60^{ab} \pm 0.03$	$0.81^{ab} \pm 0.01$	$2.27^{b} \pm 0.03$	$0.36^{a} \pm 0.03$	$1.24^{b} \pm 0.04$
14 (20:30:136.8)	$21.49^{f} \pm 0.04$	$0.85^{de} \pm 0.06$	$0.52^{abcd} \pm 0.04$	$0.68^{de} \pm 0.02$	$1.68^{e} \pm 0.01$	$0.34^{ab} \pm 0.01$	$0.96^{d} \pm 0.01$
15 (20:30:120)	$25.98^{c} \pm 0.15$	$0.97^{bc} \pm 0.07$	$0.57^{abc} \pm 0.01$	$0.76^{bc} \pm 0.03$	$2.05^{c} \pm 0.04$	$0.35^{a} \pm 0.01$	$1.13^{c} \pm 0.04$

Values are means ± standard deviation of triplicate determinations. Means with different superscripts in the same column are significantly ($p<0.05$) different. Sample /Run ratio = Feed composition (%): Feed moisture content (%): Exit barrel temperature (Celsius).

(ANOVA) using the Statistical Package for Service Solution (SPSS) version 20.0 (SPSS Inc., USA). Means were separated using Duncan's new multiple range test. Significance was accepted at $p<0.05$, according to Steel and Torrie (1980).

RESULTS AND DISCUSSION

Vitamins contents of the extruded snacks

The vitamin contents of the extruded snack samples are presented in Table 3. Extrusion cooking conditions significantly ($p<0.05$) affected all the vitamins. This is expected as vitamins differed in composition and stability during thermal processing.

Provitamin A content of the extruded samples ranged from 13.48 to 30.41 µg/100 g. Sample No. 10 had the highest pro-vitamin A retention, while sample No.5 had the least vitamin A retention. The reason could be due to the unstable nature of vitamins during heat processing (FAO/WHO, 2001). However, pro-vitamin A content significantly ($p<0.05$) increased as levels of cowpea flour and feed moisture content increased, and as exit barrel temperature decreased. Samples Nos. 4 and 8 appeared similar; this could be attributed to similar feed composition effects. Vitamin A has been indicated for the development of good eyesight in children and also to improve color blindness.

Vitamin B_1 content of the extruded snacks ranged from 0.62 to 1.10 mg/100 g. Significant ($p<0.05$) differences exist in the Vitamin B_1 retention of extruded snacks post extrusion cooking. Samples with lower feed composition (10%) had higher vitamin B_1, which reduced as feed composition levels increased. This is not surprising as cereals have been implicated as rich sources of B vitamins. Lower exit barrel temperature (110°C) also favored more retention of thiamine when compared at an exit barrel temperature of 130°C. However, Thiamine content appeared to be highest and stable at 120°C EBT. Thiamine help the body maximize the use of carbohydrates, its major source of energy. It is also important for the proper functioning of the heart, nervous system, and muscle coordination (ICMR, 2002). Thiamine values obtained for this study were higher than the RDI value (0.5 mg/100 g) for feeding infants below three years (Nestle, 2000).

Vitamin B_2 content of the extruded snack samples ranged from 0.44 to 0.62 mg/100 g, as shown in Table 3. Samples Nos. 2 and 5 had the least, while sample No. 9 had the highest riboflavin (B_2) content. Significant ($p<0.05$) differences exist in the vit.B_2 contents of the products, although some samples appeared similar. Samples Nos. 1, 3, and 8 were similar despite higher variations in feed moisture content. This showed that feed moisture content had no significance ($p>0.05$) on the extruded products. Extruded snack samples with lower feed composition levels had higher riboflavin content; this is shown in sample No.9, which had the least feed composition value (3.2%). At higher exit barrel temperature (130°C), riboflavin content reduced. However, it appeared to stabilize at 120°C. Vit. B_2 is important for human nutrition and health (ICMR, 2002).

Extruded samples met the RDA (0.5 mg/day) for 1 to 3 years, as recommended by the report of a joint FAO/WHO (2001).

Table 4. Antinutrient composition of the extruded snacks produced from sorghum and charamnya flour blends.

Run	Phytate (%)	Oxalate (%)	Tannin (%)
1 (10:25:110)	$0.039^{cd} \pm 0.002$	$0.013^{gh} \pm 0.001$	$0.087^{a} \pm 0.007$
2 (30:25:110)	$0.037^{de} \pm 0.004$	$0.040^{ef} \pm 0.028$	$0.031^{de} \pm 0.030$
3 (10:35:110)	$0.047^{b} \pm 0.002$	$0.036^{efg} \pm 0.003$	$0.083^{a} \pm 0.003$
4 (30:35:110)	$0.046^{b} \pm 0.004$	$0.033^{efgh} \pm 0.004$	$0.087^{a} \pm 0.003$
5 (10:25:130)	$0.023^{gh} \pm 0.005$	$0.028^{efgh} \pm 0.003$	$0.042^{d} \pm 0.008$
6 (30:25:130)	$0.022^{h} \pm 0.004$	$0.068^{cd} \pm 0.003$	$0.074^{b} \pm 0.002$
7 (10:35:130)	$0.028^{fg} \pm 0.003$	$0.008^{h} \pm 0.002$	$0.057^{c} \pm 0.067$
8 (30:35:130)	$0.022^{h} \pm 0.003$	$0.016^{fgh} \pm 0.001$	$0.001^{g} \pm 0.008$
9 (3.2:30:120)	$0.033^{ef} \pm 0.004$	$0.155^{a} \pm 0.002$	$0.087^{a} \pm 0.002$
10 (36.8:30:120)	$0.071^{a} \pm 0.003$	$0.046^{de} \pm 0.003$	$0.001^{g} \pm 0.002$
11 (20:21.6:120)	$0.043^{bc} \pm 0.006$	$0.021^{efgh} \pm 0.002$	$0.067^{b} \pm 0.002$
12 (20:38.4:120)	$0.043^{bc} \pm 0.002$	$0.021^{efgh} \pm 0.006$	$0.021^{ef} \pm 0.030$
13 (20:30:103.2)	$0.067^{a} \pm 0.004$	$0.088^{bc} \pm 0.002$	$0.069^{b} \pm 0.007$
14 (20:30:136.8)	$0.029^{fg} \pm 0.003$	$0.038^{efg} \pm 0.003$	$0.007^{g} \pm 0.003$
15 (20:30:120)	$0.031^{ef} \pm 0.003$	$0.100^{b} \pm 0.002$	$0.003^{g} \pm 0.001$

Values are means ± standard deviation of duplicate determinations. Means with different superscripts in the same column are significantly different ($p<0.05$). Sample /Run ratio = Feed composition (%): Feed moisture content (%): Exit barrel temperature (Celsius)

Pyridoxine (B_6) content of the extruded snack samples ranged from 0.52 to 0.85 mg/100 g. Sample No.2 had the least, while sample No.9 had the highest pyridoxine content. There were significant ($p<0.05$) differences in the vit. B_6 contents of the extruded snack products, although some samples appeared similar. Vit. B_6 contents followed a similar trend as vitamins $B_{1,}$ and $B_{2,}$ that is, samples containing more sorghum flour had higher pyridoxine values. Feed moisture content and exit barrel temperature had no significant ($p>0.05$) effect on the products as samples extruded at various conditions were similar.

Vitamin B_{12} content of the extruded snack samples ranged from 1.02 to 2.42 mg/100 g. Cobalamin (B_{12}) values were higher than other B vitamins in all extruded snack samples. At higher feed moisture content, a significant ($p < 0.05$) increase was observed in the vitamin, which could be attributed to cobalamin is a water-soluble vitamin.

Vitamin C contents of the extruded snack samples ranged from 0.28 to 0.37 mg/100 g. Sample No.1, as shown in Table 3, had the least vitamin C content, while sample No.10 had the highest. There were no significant ($p>0.05$) differences in the vitamin C contents of the extrudates, as most of the extrudates appeared similar. The vitamin D contents of the extrudates ranged from 0.65 to 1.31%. The result followed the same trend as vitamin C. However, samples that had a higher level of the legume flour and extruded at lower exit barrel temperatures appeared to have better retention of vitamins C and D.

Antinutrients composition of the extruded products

Phytate content of the extruded snack samples ranged from 0.022 to 0.067%, as shown in Table 4. Sample No. 13 had the highest phytate retention, while samples Nos. 5, 6, and 8 had the least retention for phytate. These values were very much lower than 0.26% reported by Anuonye et al. (2012), for extruded pigeon pea and unripe plantain. It was observed that increasing feed composition caused significant ($p<0.05$) reduction in phytate values. Also, higher exit barrel temperature was found to have reduced phytate significantly ($p<0.05$), while higher feed moisture content caused slight increases. It would be expected that lowering this compound should be enhanced the bioavailability minerals like zinc and iron in the extrudates. This is expected as phytic acid has been implicated in making certain minerals unavailable, as reported by Anuonye et al. (2012). Oxalate content of the extrudates which ranged from 0.008 to 0.155% was higher when compared with 0.04% reported by Anuonye et al. (2012), for extruded pigeon pea and unripe plantain. Although, there were significant ($p<0.05$) differences in the retention of oxalates among the extruded snack samples, most of the extruded samples were similar. From the result, a significant ($p<0.05$) increase was observed as cowpea flour increased in the blend.

The tannin composition of the extruded snack samples ranged from 0.001 to 0.087%. Low levels of tannin observed could be attributed to sorghum variety (white) used and proper dehulling given to the seeds during

Table 5. Sensory scores of the extruded snack produced from sorghum and charamnya flour blends.

Run/sample	Appearance	Color	Flavor	Taste	Mouth feel	Overall acceptability
1 (10:25:110)	$5.73^{bcd} \pm 1.62$	$5.93^{bcd} \pm 1.62$	$5.07^{a} \pm 1.43$	$4.33^{a} \pm 2.06$	$5.27^{ab} \pm 2.06$	$5.47^{abc} \pm 1.88$
2 (30:25:110)	$6.07^{bcde} \pm 1.49$	$5.93^{bcd} \pm 1.44$	$5.47^{a} \pm 2.17$	$4.93^{ab} \pm 2.40$	$5.27^{ab} \pm 2.58$	$5.47^{abc} \pm 4.46$
3 (10:35:110)	$6.53^{cde} \pm 1.60$	$6.93^{cd} \pm 1.49$	$6.20^{a} \pm 1.42$	$6.13^{ab} \pm 2.23$	$5.80^{ab} \pm 2.88$	$6.73^{bc} \pm 1.71$
4 (30:35:110)	$7.40^{c} \pm 1.55$	$7.20^{d} \pm 1.70$	$5.80^{a} \pm 2.08$	$6.47^{b} \pm 2.39$	$6.33^{ab} \pm 2.38$	$7.07^{c} \pm 1.71$
5 (10:25:130)	$5.80^{bcde} \pm 2.43$	$5.80^{bc\backslash d} \pm 2.51$	$5.40^{a} \pm 1.96$	$5.07^{ab} \pm 2.63$	$5.73^{ab} \pm 2.74$	$5.67^{abc} \pm 2.26$
6 (30:25:130)	$5.27^{abc} \pm 2.31$	$5.20^{ab} \pm 2.31$	$6.13^{a} \pm 1.85$	$5.80^{ab} \pm 2.39$	$5.20^{ab} \pm 2.45$	$5.73^{abc} \pm 2.28$
7 (10:35:130)	$4.73^{ab} \pm 1.98$	$5.40^{ab} \pm 2.10$	$5.53^{a} \pm 1.77$	$5.20^{ab} \pm 2.78$	$6.13^{ab} \pm 2.42$	$5.53^{abc} \pm 2.10$
8 (30:35:130)	$6.07^{bcde} \pm 2.15$	$6.00^{bcd} \pm 2.07$	$5.67^{a} \pm 1.95$	$5.67^{ab} \pm 2.66$	$6.60^{b} \pm 2.20$	$5.93^{abc} \pm 1.75$
9 (3.2:30:120)	$5.00^{abc} \pm 1.65$	$5.13^{ab} \pm 1.88$	$4.87^{a} \pm 1.60$	$5.33^{ab} \pm 2.06$	$5.00^{ab} \pm 1.96$	$5.00^{ab} \pm 1.89$
10 (36.8:30:120)	$5.07^{abc} \pm 1.83$	$5.27^{ab} \pm 1.62$	$5.67^{a} \pm 1.84$	$5.80^{ab} \pm 1.66$	$5.47^{ab} \pm 2.42$	$4.80^{a} \pm 2.04$
11 (20:21.6:120)	$3.93^{a} \pm 2.37$	$4.00^{a} \pm 2.42$	$5.93^{a} \pm 1.79$	$5.20^{ab} \pm 2.31$	$4.40^{a} \pm 2.67$	$4.33^{a} \pm 2.29$
12 (20:38.4:120)	$5.87^{bcde} \pm 2.03$	$6.00^{bcd} \pm 2.10$	$5.53^{a} \pm 1.88$	$5.27^{ab} \pm 1.75$	$6.00^{ab} \pm 1.89$	$5.20^{ab} \pm 2.14$
13 (20:30:103.2)	$5.40^{abc} \pm 1.80$	$5.13^{ab} \pm 1.77$	$4.87^{a} \pm 1.81$	$5.33^{ab} \pm 2.41$	$5.60^{ab} \pm 1.72$	$5.47^{abc} \pm 2.03$
14 (20:30:136.8)	$7.33^{de} \pm 1.40$	$7.07^{d} \pm 1.67$	$5.47^{a} \pm 2.64$	$5.93^{ab} \pm 2.71$	$5.80^{ab} \pm 2.40$	$5.80^{abc} \pm 2.78$
15 (20:30:120)	$3.87^{a} \pm 2.36$	$4.00^{a} \pm 2.07$	$5.07^{a} \pm 2.63$	$4.73^{ab} \pm 2.31$	$5.87^{ab} \pm 2.47$	$4.93^{ab} \pm 2.89$

Values are means ± standard deviation of 15 determinations. Means with different superscripts in the same column are significantly different ($p<0.05$). Sample /Run ratio = Feed composition (%): Feed moisture content (%): Exit barrel temperature (Celsius).

processing into flour. Higher feed moisture content caused a slight significant ($p<0.05$) increase in tannin contents of the products. According to Obadoni and Ochuko (2001), tannins are polyphenols, and all polyphenolic compounds are water-soluble in nature. Tannins form insoluble complexes with proteins, thereby decreasing the digestibility of proteins (Uzeochina, 2007). They have also been found to decrease palatability, caused damage to the intestinal tract, and enhanced carcinogenesis (Kumari and Jain, 2012).

Sensory evaluation of the extruded snack samples

The mean sensory scores of the extruded snack samples for appearance, crust color, flavor, taste, mouth feel, and overall acceptability are presented in Table 5. The mean score for appearance ranged from 3.87 to 7.40. There were significant ($p<0.05$) differences in the appearance of the extruded snack samples. Sample No. 4 had the highest value, while sample 15 had the least appearance mean score. The appearance however, improved with increased inclusion of the cowpea flour. There was observed reduction in appearance score as exit barrel temperature increased. This could be attributed to the darkening / browning effect (Leonel et al., 2010). The color score of extruded snacks ranged from 4.00 to 7.20. There were significant ($p<0.05$) differences in the color rating of extruded snack samples by the panelist. Mean scores for color were within the range of values (6.13 to 7.40) reported by Sawant et al. (2013) for ready-to-eat finger millet based composites. Samples Nos. 11 and 15 had the least, while sample No.14 had the highest mean score for color. Color is an important quality factor directly related to the acceptability of food products and is an important physical property to report for extruded products (Mesquita et al., 2013). The mean score for flavor ranged from 4.87 to 6.20. Sample No.3 had the highest flavor rating, while samples Nos.9 and 13 had the least score. There was no significant ($p>0.05$) difference in the flavor score of the extrudates. This could justify that beany flavor associated with legumes, which limit its use in industrial application, was significantly ($p<0.05$) reduced by extrusion cooking. Taste mean scores ranged from 4.37 to 6.47, with sample 1 having the least, while sample 4 had the highest value. Sample No. 1 differed significantly ($p<0.05$) than sample No.4, while the rest of the samples were similar in their taste rating. Mean scores for taste were, however, lower than the range of values (7.13 to 8.47) reported by Sawant et al. (2013), for ready-to-eat finger millet based composites. The low taste mean scores observed could be attributed to the non-use of basic snack ingredients such as sugar, butter, etc. From the results, taste perception by the panelist increased as the level of cowpea flour increased, while there were decreases in the taste scores as temperature decreased. This could be attributed to the fact that cowpea is enjoyed by many especially, in combination with cereal, for example, rice; at lower temperatures, the beany flavor maybe more intense, which may leave sour taste in the mouth, respectively. Mouthfeel means score ranged from 4.40 to 6.60 with sample No.11 having the least while sample No.8 had the highest mean score, while the rest of the samples were similar. The overall acceptability score ranged from 4.33 to 7.07 with sample No.11 having the least, while sample No. 4 had the highest overall acceptability score. The result implied that cowpea flour could be incorporated in extruded snacks production with up to 30% substitution without fear of product rejection by consumers.

Conclusion

Vitamin retention stabilized at the exit barrel temperature of 120°C and 20% feed composition. High retention in vitamins post extrusion showed that extrusion conditions were adequate. The extrusion process considerably reduced most of the antinutrients. Extrudates are good sources of antioxidants, which will help in scavenging the activities of free radicals in the body asides nutrients supply. In this regard, low level of phytic acid in the extruded snack samples is desirable. The overall acceptability by panelists showed that extrudates have good potentials as a cheap source of ready-to-eat diet, safe in antinutrients, and could be utilized to improve food security against malnutrition.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Akinwale RO, Obisesan IO (2012). Collection and characterization of some underutilized cowpea *(Vigna unguiculata* L.*)* cultivars of southwestern Nigeria. Journal of Sustainable Development and Environmental Protection 2(2):2-9.

Anuonye JC, Jigam AA, Ndaako GM (2012). Effects of extrusion cooking on the nutrients and antinutrients composition of pigeon pea and unripe plantain blends. Journal of Applied Pharmaceutical Science 2(5):58-162.

Association of Official Analytical Chemists (AOAC) (2010). Official methods of analysis. Association of Official Analytical Chemists.18th edition. (Horwitz, W. and Latimer, G. eds.). Gaithersburg, Maryland USA.

Baskar G, Aiswarya R (2016). Role of extrusion Technology in food processing and its effect on nutritional values. International Journal of Modern Science and Technology 1(1):1-4.

Box GEP, Hunter JS (1957). Multifactor experimental design for exploring response surfaces. The Annals of Mathematical Statistics 28(1):195–242.

Brennan CS, Brennan M, Derbyshire E, Kumar TB (2011). Effects of extrusion on the polyphenols, vitamins and antioxidant activity of foods. Trend in Food Science and Technolog 22(10):570-575

Dicko MH, Gruppen H, Zouzou OC, Traore AS, Vanberkhel WJH, Voragen AGJ (2006). Effects of germination on the amylases and phenolics related enzymes in fifty sorghum varieties grouped according to food-end use properties. Journal of Science, Food and Agriculture 86(6):953-963.

Food and Agriculture Organisation (FAO) (2004). Cowpea: Post-harvest Operation. INPho – Post-harvest Operations. Food and Agriculture Organisation of the United Nations, Rome.

Food and Agriculture Organisation (FAO) (2001). Human Vitamin and Mineral Requirements. Report of a joint FAO/WHO expert consultation Bangkok, Thailand. Food and Nutrition Division, Food and Agriculture Organisation of the United Nations, Rome.

Guy R (2001). Raw materials for extrusion cooking. In: Extrusion Cooking Technology and Applications. CRS Press, Woodhead Publishing Limited, Cambridge England P 217.

Hess JM, Jonnalagadda SS, Slavin JL (2016). What Is a Snack, Why Do We Snack, and How Can We Choose Better Snacks? A Review of the Definitions of Snacking, Motivations to Snack, Contributions to Dietary Intake, and Recommendations for Improvement. Advances in Nutrition 7(3):466-475.

Hotz C, Gibson RS (2007). Traditional food-processing and preparation practices to enhance bioavailability of micronutrient in plant-based diets. Journal of Nutrition 137(4):1097-1100.

Ihekoroonye AI, Ngoddy PO (Eds.) (1985). Integrated Food Science and Technology of the Tropics. Macmillan publishers, London. pp. 265.

Indian Council of Medical Research (ICMR) (2002). Nutrient requirements and recommended dietary allowances for Indians P 83.

Iwe MO (2001). Organoleptic assessment of extruded blends of soy and sweet potato flour by response surface analysis. Plants Foods for Human Nutrition 60:1-14.

Kirk RS, Sawyer R (1998). Pearsons' composition and analysis of foods.9th Edition. Addison Wesley Longman Ltd, England pp. 609-655.

Kumari M, Jain S (2012). Tannins: an antinutrient with positive effect to manage diabetes. Journal of Recent Sciences 1(12):1–8.

Latta M, Eskin M (1980). A simple and rapid colorimetric method for phytate determination. Journal of Agricultural and Food Chemistry 28:1213-1215.

Leonel M, Martins JC, Mischan MM (2010). Production of functional snacks made from sour flour and soy flour. Rura Science 1(40):1418-1423.

Leszek M (2011). Extrusion Cooking Techniques Applications, Theory and Sustainability. Wiley - VCH Verlag & Co. Weinheim, Germany.

Mesquita CD, Leonel M, Mischan MM (2013). Effects of processing on physical properties of extruded snacks with blends of sour cassava starch and flaxseed flour. Food Science and Technology 33(3):1678-1687.

Nestle (2000). Food politics. University of California Press, Berkeley. pp. 45-46.

Nwabueze TU, Iwe MO (2010). Residence time distribution (RTD) in a single screw extrusion of African breadfruit mixtures. Food Bioprocess Technology 3:135-145.

Obadoni BO, Ochuko PO (2001). Phytochemical studies and comparative efficacy of the crude extract of some homeostatic plants in Edo and Delta states of Nigeria. Global Journal of Pure and Applied Science 8:203-208.

Onwuka GI (2005). Food analysis and instrumentation theory and practice. Naphthdi prints Lagos Nigeria P 160.

Sawant AA, Thakor NJ, Swami SB, Divate AD, Balasaheb SK, Krishi V (2013). Physical and sensory characteristics of ready-to-eat food prepared from finger millet based composite mixer by extrusion. Journal of Agricultural Engineering International 15:11-13.

Steel RCD, Torrie JH (1980). Principles and procedures of statistics. McGraw Hill Book Co., New York pp. 336-337.

Stefoska-Needham A, Beck EJ, Johnson SK, Tapsell LC (2015). Sorghum: an underutilized cereal whole grain with the potential to assist in the prevention of chronic disease. Food Reviews International 31(4):401-437.

Thymi S, Krokida MK, Pappa A, Marourlis ZB (2005). Structural properties of extruded corn starch. Journal of Food Engineering 68(4):519-526.

Uzeochina OB (2007). Evaluation of the effect of processing techniques on the nutrient and antinutrients contents of pigeon pea (*Cajanus cajan*) seed flours. Journal of Food Science 28:76-77.