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PRODUCTION AND QUALITY EVALUATION OF READY TO EAT EXTRUDED SNACKS FROM FLOUR BLENDS OF ACHA-COWPEA AND SWEET POTATO STARCH

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ABSTRACT

Acha is a potential food security crop that contributes significantly to people's diet, especially in developing countries such as Nigeria. The suitability of acha-cowpea composite flour and sweet potato starch in the production of extruded snacks was investigated. Acha flour (ACF), cowpea flour (CPF)and sweet potato starch (SPS),were mixed in various proportions of percentage weights (ACF:CPF:SPS)and were used to produce extruded snacks totaling 7 samples: 100:0:0, 90:5:5, 85:5:10, 75:5:20, 70:5:25:, 65:5:30 and50:0:50.The flour blends and starch mixes were analyzed for functional properties while the extruded snacks were evaluated for proximate, physicochemical and sensory properties. There was significant differences ($p<0.05$) in the functional properties of the flour and starch blends. Oil and water absorption capacity reduced as the proportion of SPS increased while the wettability followed the same trend. Foam capacity and foam stability were higher in all the blends containing cowpea flour. Gelatinization temperature was highest in blends with equal proportions of acha and sweet potato starch.The proximate composition of the extruded snacks were significantly difference ($p<0.05$) amongst the samples. The result showed that all the samples with cowpea flour had higher protein and ash contents than the control. Samples with 90% AF, 5% SPS and 5% CF performed best in sensory scores particularly in terms of appearance, taste, texture and general acceptability. However, all the samples were generally accepted. It was concluded that nutritious extruded snacks with acceptable sensory qualities can be produced from blends of *acha*-cowpea flour and sweet potato starch.

Keywords: Acha, cowpea, extruded snacks, quality assessment, sweet potato

INTRODUCTION

Acha(*Digitaria exilis*) an underutilized food security crop, is considered as one of the cereal crops of health benefit. Acha flour contains 3.4 % fat, 6.7 % crude protein, 7.4% crude fibre and 67.60% carbohydrate (Majekodunmi and Olapade, 2018).Ayo *et al*. (2018) opined that Acha contributes significantly to wellness, economic status improvement and food security in developing economy of a nation like Nigeria. Cowpea (*Vigina unguiculata*) seed contributes to a large extent the protein intake of several rural and urban families; hence is said to be the poor man's major source of protein (Agbogidi, 2010). Previous researchers reported that cowpea is an important source of essential macronutrients and micronutrients (Luthria *et al*., 2014)such as iron, calcium, phosphorus, potassium, magnesium, sodium, magnesium, sodium, (Okereke and Hans-Anukam, 2015), zinc, manganese, copper, selenium, vitamin A, vitamin C, vitamin B_6, thiamin, riboflavin, niacin, pantothenic and folate (Agugo*et al*., 2013).The seeds are considerably cheaper than most crops (Ayenlere *et al*., 2012) and is said to bea good food security crop as it blends well with other recipes (Muoneke *et al*., 2012).

Sweet potato (*Ipomoea batata*), is an extremely versatile and nutritious crop (Parle and Monika, 2015) that serves as a very good vehicle for addressing some health related problems. It is a source of macro and micronutrients such as carbohydrates, carotenes, thiamine, riboflavin, niacin, potassium, zinc, calcium, iron, and vitamin C (Oke and Workneh, 2013). Sweet potato can be consumed in different forms such as boiled, fried or cooked with other staple foods like beans. Despite the potentials of sweet potato, it is highly underutilized (Sanoussi *et al*., 2016). FAO (2018) recorded that, Nigeria is the leading producer of sweet potato with an annual production of 3.46 million metric tonnes per year, in Africa.

Starch is a naturally occurring biodegradable, inexpensive and abundantly available polysaccharide molecule (Abbas *et al*., 2010) that can be obtained mainly from cereals and tubers (Tagliapietra *et al*., 2021).Its food application in the industries dates back to ancient times (Falade and Okafor, 2013). Starch is relatively cheap, available in large quantities and pure (Daudt *et al*., 2014), thus justifies its widespread use.

Extrusion is a process by which a set of mixed ingredients are forced through an orifice in a perforated die with a design specific to the food (Bordoloi and Ganguly, 2014). Charles *et al*. (2016), in his study revealed that extrusion process has a potential to generate quality snack products while Khanna *et al*.(2019), stated that using extruder will give room for production of different shapes, textures, and colours of snacks. This prompted the use of blends of acha-cowpea flours and sweet potato starch, in the production of extruded snack. Although composite flours have been used in various forms to produce convenient extruded foods like pasta and breakfast cereals, not much has been done to assess the quality of extruded snacks produced from non-wheat composite flour of acha, cowpea and sweet potato starch.

The objective of this study therefore, was to produce extruded snack from blends of acha-cowpea flour and sweet potato starch. Other specific objectives were to determine: (1) the functional properties of blends of acha-cowpea flours and sweet potato starch (2) proximate composition, physicochemical and sensory properties of the extruded snacks.

MATERIALS AND METHODS

Source of raw materials

Acha(*Digitaria exilis*) grains(plate 1), Cowpea (*Vignaun guiculata*) seeds(plate 2), and sweet potato (*Ipomoea batata* L.) tubers(plate 3)were purchased from Aba Main Market, Abia State, Nigeria.

Sample preparation

Preparation of acha, cowpea flours and sweet potato starch

The standard method described by Olapade *et al*. (2010) was used in the production of acha flour (Plate 4). Acha grains were sorted, washed (in clean tap water) and drained using a plastic perforated container. Thereafter, the grains were oven dried at 50ºC for 4 h (Gallenkemp, 300 Plus, England), milled using hammer mill (model ED-5 Thomas Wiley, England) and sieved (0.2 mm mesh size) to obtain acha flour. The resultant flour was packaged in a transparent airtight polyethylene bag stored under room temperature (23ºC) for further use.

The standard method described by Dada *et al*. (2018) was used in the production of cowpea flour (Plate 5). Cowpea seeds were sorted, washed (in clean water), soaked (in water for 30 min), dehulled(manually) and oven dried at 60ºC for 6 h (Gallenkemp, 300 Plus, England). This was followed by milling using hammer mill (model ED-5 Thomas Wiley, England) and sieving (0.2 mm mesh size) to obtain cowpea flour. The cowpea flour was packaged in a transparent airtight polyethylene bag stored under room temperature (23ºC) for further use.

Sweet potato starch (Plate 6) was processed using the standard method described by Ojimelukwe *et al.* (2017). Sweet potato tubers were sorted, washed (using clean tap water), peeled with stainless kitchen knife and re-washed in clean water. Thereafter, they were wet-milled (using hammer mill, model ED-5 Thomas Wiley, England), mixed with water, filtered (with 80 µm mesh size), centrifuged (for 30 min) to obtain sweet potato starch. The resulting starch was dried in an oven at 40°C for 10 h (Gallenkemp, 300 Plus, England) and packaged in a transparent airtight polyethylene bag, stored under room temperature (23ºC) for further use.

Formulation of flour blends of acha-cowpea and sweet potato starch: The flours obtained from acha-cowpea and sweet potato starch were formulated into different ratios of six proportions:

90:5:5 (acha:cowpea:sweetpotato)
85:5:10 (acha:cowpea:sweet potato)
75:5:20 (acha:cowpea:sweet potato)
70:5:25 (acha:cowpea:sweet potato)
65:5:30 (acha:cowpea:sweet potato)
50:0:50 (acha:cowpea:sweet potato)
A 100% acha served as the control.

Production of extruded snacks

The standard method used by Dada *et al.* (2018) was adopted in the production of extruded snacks. The *acha*-cowpea flours and sweet potato starch were blended according to the formulated proportions. A 200g of the composite blends of flour and starch were thoroughly mixed with salt (10 g), wet ground onion (90 g), and water(150 ml) to form soft dough. Afterward, the soft dough was loaded into manual co-rotating twin screw extruder and rotated(extruded) into a frying pan containing hot vegetable oil (750 ml)on an electric cooking gas flame. The extruded dough was allowed in the oil for about 10 min, until the colour changes to golden brown. The resultant hot extruded snacks were drained off oil using a stainless metallic perforated bowl and cooled to obtain ready to eat extruded snacks. The extruded snacks were then packaged in transparent airtight polythene bags.

Analysis

Functional properties of flours and starch blends

Oil absorption capacity (OAC), water absorption capacity (WAC), wettability, foam capacity, foam stability and gelatinization temperature were determined according to the methods described by Onwuka (2018).

Proximate composition and energy value of ready to eat extruded snacks

Moisture content, crude protein, fat content, crude fibre content, ash content, carbohydrate content and energy value were determined according to the methods described by Onwuka (2018)

Physicochemical properties of ready to eat extruded snacks

Moisture retention, mass flow rate, true and tap density, were determined according to the method described by Deshpande and Poshadri (2011). Expansion rate was determined according to the method described by Shruthi *et al.* (2019).

Sensory properties of extruded snacks

Sensory properties were carried out according to the method described by Iwe (2014). A 25-member (semi-trained) panel and 9-point hedonic scale were used; where 1 = Dislike extremely and 9 = Like extremely. Sensory parameters tested include appearance, taste, texture, aroma, and general acceptability.

Statistical analysis

The experimental data was expressed as mean ± SD (standard deviation) of duplicate determinations. The data was 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. All statistical analyses were done using the Statistical Product of Service Solution version 22.0 software.

RESULTS AND DISCUSSION

Functional properties of acha-cowpea composite flour and sweet potato starch blends

The functional properties of acha-cowpea flours and sweet potato starch blends are presented in Table 1.There was significant difference ($p<0.05$) in the functional properties of the composite blends. Oil absorption capacity (OAC) increased from 1.02% (control sample-100% *acha*) to 1.85 g/ml (90% acha flour:5% cowpea flour:5% sweet potato starch).It was observed that all the samples that have cowpea flour had higher value for oil absorption than the control (100% *acha* flour). The highest oil absorption capacity (1.51g/ml) recorded for 90% acha flour:5% cowpea flour:5% sweet potato starch blends could be attributed to lipid binding capacity of the hydrophobic proteins present in the flour. The values obtained were however lower than the range (1.61-1.79g/g) reported by Orisa and Udofia (2020). This could be attributed to differences in the method employed and also the proportion of the raw materials used. Oil absorption capacity has been attributed to the physical entrapment of oil. Samples with high oil content are an indication of high level of energy and calories. Previous researchers have shown that frequency of some diseases associated with high fat-diets including diabetes and obesity is on the increase (Honerlaw *et al*., 2019) Water absorption capacity significantly ($p<0.05$) increased from 2.31-2.65 g/ml for composite blends with 50% acha flour:50% sweet potato starch) and control sample(100%*acha*flour) respectively. High water absorption capacity could be attributed to the alteration in starch polymer structure while low value indicates compactness of the structure. The values obtained in this study were higher than the values (0.87-1.11g/ml) reported by Orisa and Udofia (2020) for blends of wheat, acha, cowpea and *Moringa oleifera* powder but agrees with the values(1.64-2.52g/ml) reported by Moutaleb *et al.* (2017). The ability of flour to absorb water improves dough making potentials(Adeola *et al*., 2019).Wettability of the composite blends was highest (0.58 min) in sample 90:5:5(90% acha flour:5% cowpea flour:5%weet potato starch) but lowest(0.30 min) in sample 50:0:50(50% acha flour: 50% sweet potato starch).This is an indication that samples with high value of wettability would have slow rate of dispersion in water than that of composite flours with lower wettability values. The variations in wettability values could be attributed to the polarity of the flour molecules, their contact surfaces and their porosity (Mohebby *et al*., 2011).

Foam capacity of the composite sample blends progressively increased in samples with inclusion of cowpea. The highest value (20.41%) was recorded for 65:5:30(65% *acha* flour:5% cowpea:30% sweet potato starch) while the lowest value (4.83) was recorded for the control sample(100% *acha* flour). Foam capacity is the ability of the flour to foam when water and heat are applied, and is dependent on soluble proteins (Samaila *et al*., 2017).The significant variation in foam capacity of the composite blends could be attributed to differences in the samples solubilized protein and polar and non-polar lipids. High foam capacity in extruded snack is not desirable; however, preparation at reduced pressure minimizes its formation (Samaila *et al*., 2017).The values obtained for foam capacity in this study was higher than 6.67 to 10.33 % reported for wheat and cocoyam flour blends (Anon *et al*., 2021), and 8.20 - 11.28 % reported for finger millet, wheat, soybean and peanut flour blends (Okache *et al*., 2020). These variations could be attributed to differences in the composite flour blends.

Foam stability ranged from 76.18-80.32% for control sample 100:0:0(100% acha flour) and90:5:5(90% acha flour:5% cowpea flour:5% sweet potato starch) respectively. Foam stability is an important functional property of proteins essential in many food formulations (Ganesan, 2021). Acuña *et al*. (2012)opined that flours with high foam stability has more protein-protein interactions at the air-water interface which promotes the formation of a multilayer film which results in viscoelastic resistance. The high foam stability observed in sample90:5:5(90% acha flour:5% cowpea flour:5% sweet potato starch) could be attributed to the inclusion of cowpea flour and high proportion of acha flour in the sample. It was observed that the value reduced as the proportion of acha reduced despite the 5% inclusion of cowpea. This indicates that acha also contributed part of the protein content of the samples as revealed in this present study (Table 2).The significantly lower foam stability values obtained for the composite blends containing higher proportion of sweet potato is an indication that sweet potato is not a source of protein. According to Iwe *et al*. (2016) the foam stability of flours increases with increased protein content.

Gelatinization temperature was significantly different ($p < 0.05$) among the composite sample blends. The highest gelatinization temperature (78.00ºC) was recorded for sample50:0:50(50%acha flour:0% cowpea flour:50% sweet potato starch) while sample70:5:25(70% acha flour:5% cowpea flour:25% sweet potato starch) had the least (73.00ºC). It was observed that gelatinization temperature increased with increased proportion of sweet potato starch. The gelatinization temperature of the composite blends are higher than the values (56.50 to 75.00°C) recorded by Ubbor *et al*. (2022) on composite blends of wheat:acha:orange sweet potato flours. This could be attributed to the high percentage of carbohydrate in the sample (Table 1). Gelatinization temperature is the temperature at which the gelatinization of starch takes place. The highest gelatinization temperature (78.00°C) recorded in this study for sample 50:0:50(50%acha flour:0% cowpea flour:50% sweet potato starch)could be attributed to the sample's high carbohydrate content (Table 2). It could also be said that its starch granules were more damaged thus facilitating swelling (Awuchi *et al*., 2019).

Table 1: Functional properties of acha-cowpea composite flour and sweet potato starch blends

ACF:CPF:SPS (%)	Oil absorption capacity (g/ml)	Water absorption capacity (g/ml)	Wettability (min.sec)	Foam capacity (%)	Foam stability (%)	Gelatinization temperature (ºC)
100:0:0	$1.12^{e}\pm0.03$	$2.65^{a}\pm0.03$	$0.47^{b}\pm0.03$	$5.83^{f}\pm0.04$	$76.18^{f}\pm0.03$	$77.00^{ab}\pm0.00$
90:5:5	$1.51^{a}\pm0.01$	$2.62^{a}\pm0.03$	$0.58^{a}\pm0.01$	$14.52^{a}\pm0.02$	$80.32^{a}\pm0.01$	$76.00^{bc}\pm1.41$
85:5:10	$1.29^{b}\pm0.01$	$2.52^{a}\pm0.02$	$0.38^{c}\pm0.01$	$14.02^{b}\pm0.01$	$79.60^{d}\pm0.02$	$77.50^{a}\pm0.71$
75:5:20	$1.22^{c}\pm0.02$	$2.42^{b}\pm0.01$	$0.38^{c}\pm0.01$	$13.41^{c}\pm0.02$	$79.33^{c}\pm0.01$	$74.00^{de}\pm0.00$
70:5:25	$1.21^{c}\pm0.01$	$2.38^{c}\pm0.02$	$0.35^{d}\pm0.01$	$13.28^{d}\pm0.03$	$79.29^{c}\pm0.03$	$73.00^{e}\pm0.00$
65:5:30	$1.17^{d}\pm0.01$	$2.31^{d}\pm0.13$	$0.34^{d}\pm0.01$	$13.08^{e}\pm0.01$	$77.54^{d}\pm0.01$	$75.00^{cd}\pm0.00$
50:0:50	$1.02^{f}\pm0.01$	$2.28^{e}\pm0.01$	$0.30^{e}\pm0.01$	$5.41^{g}\pm0.02$	$76.83^{e}\pm0.03$	$78.00^{a}\pm0.00$

$^{a-g:}$ Values are means $\pm$ standard deviation of duplicate determinations. Mean values in the same column with different superscripts are significantly different ($P < 0.05$). ACF = acha flour, CPF = cowpea flour, SPS = sweet potato starch.

Key;
100:0:0=100% acha flour(control)
90:5:5(90% acha flour:5% cowpea flour:5% sweet potato starch)
85:5:10(85% acha flour:5% cowpea flour:20% sweet potato starch)
75:5:20(75% acha flour:5% cowpea flour:20% sweet potato starch)
70:5:25(70% acha flour:5% cowpea flour:25% sweet potato starch)
65:5:30(65% acha flour:5% cowpea flour:30% sweet potato starch)
50:0:50(50% acha flour:0% cowpea flour:50% sweet potato starch)

Proximate composition of extruded snacks from acha-cowpea composite flour and sweet potato starch blends

Table 2 shows the proximate composition of the extruded snacks samples. Significant differences ($p<0.05$) existed in the proximate composition of the extruded snacks. Moisture content ranged from 3.34-3.96% for samples 65:5:30(65%acha flour:5% cowpea flour:30% sweet potato starch) and 85:5:10(85%acha flour:5% cowpea flour:10% sweet potato starch) respectively. The values obtained in this study were lower than the range (4.74-6.72%) reported by Honi*et al.* (2018) for orange-fleshed sweet potato and bambara groundnut-based snacks. Low moisture content is an indication that the extruded snacks will have long shelf life stability.

The crude protein content progressively increased from 9.29-13.17% for extruded snacks produced from 50% acha flour: 50% sweet potato starch and 90% acha: 5% cowpea:5% sweet potato starch respectively. It was observed that all extruded snacks with 5% proportion of cowpea and increased level of acha flour had higher protein content than samples with increased proportion of sweet potato starch. This could be attributed to the fact that cowpea is a good source of protein and acha also has significant protein compared to sweet potato. The results are a bit lower than the range (10.3 -18.2%) reported by Olapade *et al.* (2011) for biscuits made from acha and cowpea flour blends. This could be attributed to differences in the proportion of cowpea and sweet potato starch in their formulation. Cowpea is responsible for much of the protein in acha-cowpea composite flour, contributing more than 3 times the amount of protein in *acha* (Olapade *et al.,* 2011).

Crude fat content ranged from 8.72-12.54% for samples 50:0:50(50% acha:50% sweet potato) and 100% acha(control). It was observed that the fat content reduced as the proportion of sweet potato starch increased. This indicates that sweet potato contains low level of fat than cowpea and acha. Olapade *et al*. (2011) reported crude fat content ranging from 1.12 to 1.48% in snacks (biscuit) produced from blends of acha and cowpea flours. Fat/lipids represent a major component of food and are important structural and functional constituents of cells in biological systems; they impart many desirable qualities to foods, including attributes of texture, structure, mouth feel, flavour, and colour (Montesano *et al.*, 2018).

Crude fibre of the extruded snacks significantly increased ($p<0.05$) from 0.92 – 2.22% for the control sample(100% acha) and sample 50:0:55(90% acha flour:0% cowpea flour:50% sweet potato starch) respectively. It was observed that the crude fibre content of the extruded snacks increased as the proportion of sweet potato starch increased. This result shows that sweet potato is a good source of dietary fiber. Crude fibre is important for the removal of waste from the body thereby preventing constipation and many health disorders (Fakolujo and Adelugba, 2021).

Ash content ranged from 1.96 – 2.43%. It was observed that the ash content of the extruded snacks were higher in all the samples containing cowpea flour and sweet potato starch. However, increased in the proportion of sweet potato starch also resulted to increased ash content. This is an indication that both cowpea and sweet potato starch have higher ash content than acha and would serve as good sources of minerals. Foods with high percentage of ash content are expected to have high concentrations of various mineral elements, which help to speed up metabolic processes and improve growth and development (Bello *et al*., 2008).

Table 2: Proximate composition (%) and energy value (Kcal) of extruded snacks from blends of acha-cowpea flour and sweet potato starch

ACF:CPF:SPS (%)	Moisture	Crude protein	Crude Fat	Crude fibre	Ash	Carbohydrate	Energy value
100:0:0	$3.59^{cd}\pm0.05$	$9.77^{f}\pm0.01$	$12.54^{a}\pm0.01$	$0.92^{g}\pm0.03$	$1.96^{f}\pm0.02$	$71.22^{c}\pm0.06$	$436.82^{a}\pm0.40$
90:5:5	$3.45^{e}\pm0.06$	$13.17^{a}\pm0.02$	$11.52^{b}\pm0.03$	$1.36^{f}\pm0.03$	$2.03^{e}\pm0.01$	$68.47^{f}\pm0.05$	$430.24^{b}\pm0.03$
85:5:10	$3.96^{a}\pm0.05$	$13.07^{b}\pm0.01$	$11.11^{c}\pm0.01$	$1.55^{e}\pm0.03$	$2.07^{de}\pm0.02$	$68.24^{g}\pm0.00$	$425.23^{c}\pm0.07$
75:5:20	$3.63^{c}\pm0.04$	$12.97^{c}\pm0.01$	$10.89^{d}\pm0.02$	$1.74^{d}\pm0.02$	$2.23^{c}\pm0.02$	$68.54^{e}\pm0.05$	$424.05^{d}\pm0.06$
70:5:25	$3.48^{d}\pm0.03$	$12.54^{d}\pm0.02$	$10.75^{e}\pm0.02$	$1.88^{c}\pm0.01$	$2.36^{b}\pm0.03$	$68.99^{d}\pm0.01$	$422.87^{e}\pm0.05$
65:5:30	$3.34^{f}\pm0.04$	$10.20^{e}\pm0.03$	$10.66^{f}\pm0.01$	$1.92^{b}\pm0.03$	$2.43^{a}\pm0.02$	$71.45^{b}\pm0.02$	$422.54^{e}\pm0.07$
50:0:50	$3.76^{b}\pm0.05$	$9.29^{g}\pm0.02$	$8.72^{g}\pm0.02$	$2.22^{a}\pm0.02$	$2.09^{d}\pm0.01$	$73.92^{a}\pm0.04$	$411.32^{f}\pm0.06$

$^{a-g:}$ Values are means $\pm$ standard deviation of duplicate determination. Mean values in the same column with different superscripts are significantly different ($P < 0.05$). ACF = acha flour, CPF = cowpea flour, SPS = sweet potato starch.

Key;
100:0:0=100% acha flour(control)
90:5:5(90% acha flour:5% cowpea flour:5% sweet potato starch)
85:5:10(85% acha flour:5% cowpea flour:20% sweet potato starch)
75:5:20(75% acha flour:5% cowpea \lour:20% sweet potato starch)
70:5:25(70% acha flour:5% cowpea flour:25% sweet potato starch)
65:5:30(65% acha flour:5% cowpea flour:30% sweet potato starch)
50:0:50(50% acha flour:0% cowpea flour:50% sweet potato starch)

Carbohydrate ranged from 68.24-73.492% for samples 85:5:10(85% acha flour:5%:cowpea flour:10%) and 50:0:50(50% acha flour:0% cowpea flour:50% sweet potato starch) respectively. The carbohydrate content of the extruded snacks increased with increased proportion of acha flour and sweet potato starch blends. Results are within the range (68.70-83.60%) reported by Olapade *et al.* (2011) for biscuits produced from acha and cowpea flour blends. Carbohydrates are good sources of energy, and a high concentration of it is desirable in breakfast meals and weaning formulas. The carbohydrate contents of the extruded snacks are an indication that the products are good sources of energy.

Energy value ranged from 411.34-4376.82 Kcal. The control sample (100% acha flour) had the highest energy value while the sample with 50% acha flour and 50% sweet potato starch had the least energy value. Abiodun and Ogugua (2012) also observed that extruded snacks from acha flour had higher energy value than extruded snacks produced from cowpea flour blends.

Physicochemical properties of extruded snacks from blends of acha-cowpea flour and sweet potato starch

The physicochemical properties of the extruded snacks samples are presented in Table 3.There were significant differences ($p<0.05$) in the physicochemical properties of the extruded snacks. Moisture retention ranged from 3.33 – 3.97% for 75:5:20 (75% acha flour:5% cowpea flour: 20% sweet potato starch) and control sample(100% acha flour) respectively. Moisture retention content of the extruded snacks increased with the addition of the blends. Moisture retention plays an important role in influencing the texture of the final product. Hardness is proportional to the amount of moisture in a food sample. The texture of the extrudate is very essential for evaluation of physical properties for ready-to-eat snacks, and it largely depends on the composition and nature of the raw material of the mix used for extrusion (Sharmila and Athmaselvi, 2017).

Mass flow rate ranged from 7.549 – 8.25 g/s for samples 70:5:25(70% acha flour:5% cowpea:25% sweet potato starch) and control sample(100% acha flour) respectively. The results of the mass flow rate are higher than the values reported by Shruthi *et al.* (2017) for corn-based extrudates (3.31 – 4.50 g/s). This could be as a result of differences in feed moisture, temperature and viscosity of the dough. Mass flow rate in a single-screw extruder is dependent on the drag flow developed by the rotation of the screw and the pressure developed because of the restriction of the die (Oke *et al*., 2012). Higher screw speed means higher mass flow rate, and there is greater ability for the material to move along the extruder barrel (Poonam *et al*., 2017).

Expansion rate ranged from 0.46(90:5:5-90% acha flour:5% cowpea flour:5% sweet potato starch) – 0.57(control sample-100% acha flour). This is less than the range reported by Oke *et al.* (2013) for extruded water yam (*Dioscorea alata*) starches: 1.05-1.93.Lower expansion rate obtained in this study could be attributed to the presence of protein-rich composite flours which affected starch-crude fibre balance. Expansion ratio describes the degree of puffing a food sample undergoes as it exits the extruder. Expansion of extrudate is mainly due to sudden change in state of high pressure to atmospheric pressure (Sharmila and Athmaselvi, 2017). Expansion is a function of viscosity and elasticity of dough governed by ratio of starch, protein and fibre (Sharmila and Athmaselvi, 2017).

True density ranged from 0.35 – 0.47 g/cm^{3}for samples 85:5:10(85% acha flour:5% cowpea flour:10% sweet potato flour) and 65:5:30(65% acha flour: 5% cowpea flour:30% sweet potato flour) respectively. Gasparre *et al.* (2020) reported true density ranging from 1.35-1.54 g/cm^3 in rice-based gluten-free extruded snacks blended with tiger nut flour. Lower true density (0.35 – 0.47 g/cm^3) obtained in this study could be attributed to feed moisture and feed blends. True density is the constant value for matter and also the mass of a food particle divided by its volume, excluding open and closed pores (Shefali and Florian, 2017).

Table 3: Physicochemical properties of extruded snacks from blends of acha-cowpea flour and sweet potato starch

ACF:CPF:SPS (%)	Moisture retention (%)	Mass flow rate (g/s)	Expansion rate	True density (g/cm^3)	Tap density (g/cm^3)
100:0:0	$3.33^{f}\pm0.03$	$8.25^{a}\pm0.01$	$0.57^{a}\pm0.03$	$0.42^{abc}\pm0.03$	$0.63^{ab}\pm0.01$
90:5:5	$3.54^{e}\pm0.03$	$8.24^{a}\pm0.02$	$0.46^{d}\pm0.03$	$0.37^{bcd}\pm0.03$	$0.60^{bc}\pm0.01$
85:5:10	$3.75^{c}\pm0.04$	$7.88^{b}\pm0.01$	$0.52^{bc}\pm0.02$	$0.35^{d}\pm0.01$	$0.68^{a}\pm0.01$
75:5:20	$3.97^{a}\pm0.04$	$7.75^{c}\pm0.01$	$0.52^{bc}\pm0.01$	$0.36^{cd}\pm0.03$	$0.65^{ab}\pm0.03$
70:5:25	$3.77^{c}\pm0.03$	$7.49^{f}\pm0.02$	$0.55^{ab}\pm0.01$	$0.43^{ab}\pm0.03$	$0.63^{ab}\pm0.04$
65:5:30	$3.65^{d}\pm0.03$	$7.68^{d}\pm0.03$	$0.48^{cd}\pm0.01$	$0.47^{a}\pm0.03$	$0.57^{d}\pm0.02$
50:0:50	$3.82^{b}\pm0.03$	$7.57^{e}\pm0.02$	$0.51^{bc}\pm0.01$	$0.45^{a}\pm0.01$	$0.63^{ab}\pm0.01$

$^{a-f:}$ Values are means $\pm$ standard deviation of duplicate determination. Mean values in the same column with different superscript are significantly different ($P<0.05$).

ACF = acha flour, CPF = cowpea flour, SPS = sweet potato starch.

Key;

100:0:0=100% acha flour(control)
90:5:5(90% acha flour:5% cowpea flour:5% sweet potato starch)
85:5:10(85% acha flour:5% cowpea flour:20% sweet potato starch)
75:5:20(75% acha flour:5% cowpea flour:20% sweet potato starch)
70:5:25(70% acha flour:5% cowpea flour:25% sweet potato starch)
65:5:30(65% acha flour:5% cowpea flour:30% sweet potato starch)
50:0:50(50% acha flour:0% cowpea flour:50% sweet potato starch)

Tap density ranged from 0.57 – 0.68 g/cm^3 for extruded samples 65:5:30(65% acha flour:5% cowpea flour:30% sweet potato starch) and 85:5:10(85% acha flour:5% cowpea flour:10% sweet potato flour).Shefali and Florian (2017) reported that tap density is the apparent powder density obtained under standard conditions of tapping.

Sensory properties of extruded snacks from blends of acha-cowpea flour and sweet potato starch

The sensory scores of the extruded snacks samples are presented in Table 4.The appearance scores significantly ($p<0.05$) increased from 5.88 (control sample-100% acha flour) – 7.04 (90% acha flour:5%cowpea flour:5% sweet potato starch). The result showed that inclusion of cowpea and sweet potato starch enhanced the appearance. No significant difference (p>0.05) existed amongst the extruded snacks in terms of taste. The scores for taste ranged from 6.08 – 6.76 for samples 70% acha flour:5% cowpea flour:25% sweet potato starch and 90% acha flour:5% cowpea flour: 5% sweet potato starch respectively. Sample 90% acha flour:5% cowpea flour: 5% sweet potato starch was the most preferred in terms of taste of the extruded snacks while extruded snacks from sample70% acha flour:5% cowpea flour:25% sweet potato starch was least preferred.

Table 4: Sensory properties of extruded snacks from acha-cowpea flours and sweet potato starch blends

ACF:CPF:SPS (%)	Appearance	Taste	Texture	Aroma	General acceptability
100:0:0	$5.88^{c}\pm1.42$	$6.48^{a}\pm0.77$	$6.52^{ab}\pm1.29$	$5.76^{bc}\pm1.27$	$6.52^{a}\pm1.08$
90:5:5	$7.04^{a}\pm1.06$	$6.76^{a}\pm1.45$	$7.28^{a}\pm1.02$	$6.64^{ab}\pm1.70$	$7.12^{a}\pm1.17$
85:5:10	$6.00^{bc}\pm1.68$	$6.32^{a}\pm1.63$	$6.12^{b}\pm1.54$	$6.24^{abc}\pm1.33$	$6.44^{a}\pm1.33$
75:5:20	$6.48^{abc}\pm1.19$	$6.68^{a}\pm1.31$	$6.56^{ab}\pm1.45$	$6.20^{abc}\pm1.35$	$6.60^{a}\pm1.26$
70:5:25	$6.80^{ab}\pm1.35$	$6.08^{a}\pm1.82$	$6.28^{b}\pm1.70$	$5.72^{c}\pm1.46$	$6.24^{a}\pm1.61$
65:5:30	$6.60^{abc}\pm1.00$	$6.48^{a}\pm1.39$	$6.84^{ab}\pm1.46$	$6.16^{abc}\pm1.11$	$6.44^{a}\pm1.53$
50:0:50	$7.04^{a}\pm1.49$	$6.40^{a}\pm1.71$	$6.72^{ab}\pm1.54$	$6.68^{a}\pm1.63$	$7.00^{a}\pm1.58$

[a – c:] Values are means $\pm$ standard deviation of duplicate determination. Mean values in the same column with different superscripts are significantly different ($P<0.05$).
ACF = acha flour, CPF = cowpea flour, SPS = sweet potato starch.

Key;
100:0:0=100% acha flour(control)
90:5:5(90% acha flour:5% cowpea flour:5% sweet potato starch)
85:5:10(85% acha flour:5% cowpea flour:20% sweet potato starch)
75:5:20(75% acha flour:5% cowpea flour:20% sweet potato starch)
70:5:25(70% acha flour:5% cowpea flour:25% sweet potato starch)
65:5:30(65% acha flour:5% cowpea flour:30% sweet potato starch)
50:0:50(50% acha flour:0% cowpea flour:50% sweet potato starch

The texture of the extruded snacks ranged from 6.12(85% acha flour:5% cowpea flou:10% sweet potato starch) - 7.28 (90% acha flour:5% cowpea flour:5% sweet potato starch) The panelists mostly preferred the texture of sample 90% acha flour:5% cowpea flour:5% sweet potato starch while sample 85% acha flour:5% cowpea flour:10% sweet potato starch was least preferred. Scores for aroma ranged from 5.72(70% acha flour:5% cowpea flour:25% sweet potato starch) – 6.68(50% acha flour:0% cowpea flour:50% sweet potato starch). The extruded snacks made from 50% acha flour and 50% sweet potato starch was best preferred in terms of aroma. It could be attributed that the beany flavour must have affected the aroma of the extruded snacks. Ubbor *et al*.(2022) opined that aroma is an attribute that influences the acceptance of products even before they are tasted. There was no significant difference (p>0.05) in the overall acceptability of the extruded snacks. The general acceptability ranged from 6.24 – 7.12 for extruded snacks made from70% acha flour:5% cowpea flour:25% sweet potato starch and 90% acha flour:5% cowpea flour:5% sweet potato starch, respectively. Extruded snacks made from90% acha flour:5% cowpea flour:5% sweet potato starch performed best in the overall acceptability. The result revealed that extruded snacks made from 90% acha flour:5% cowpea flour:5% sweet potato starch was the best in all the sensory attributes except aroma. However, the result of this study has shown that all the extruded snacks were accepted by the panelists.

CONCLUSION

This study has shown that extruded snacks with acceptable sensory characteristics can be produced from blends of acha-cowpea composite flour and sweet potato starch. It was observed that inclusion of cowpea flour enhanced the functional properties such as foam capacity and stability, although this advantage may be end product-dependent. The resulting extruded snacks had good proximate composition especially moisture (as low as 3.34 – 3.96%) and crude protein (as high as 9.29 – 13.17%), implying good shelf-life and significant, though not sufficient, source of protein for complementary feeding. Inclusion of starch however reduced protein content. Cowpea is responsible for much of the protein in acha-cowpea composite flour, contributing more than 3 times the amount of protein in acha. The findings of this research are useful in developing not only extruded snacks but also other convenient food products from local staples like acha, sweet potato and cowpea, and hence ensure food and nutritional security. Further research is however needed to optimize production.

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Plates 1-3: Raw materials used for the study (*acha* grain, cowpea seed and sweet potato tuber).


Plate 1:*Acha* grains

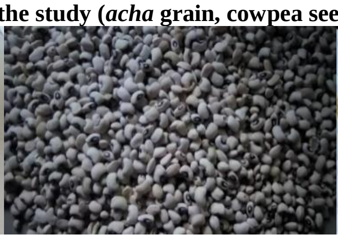
Plate 2:Cowpea seeds

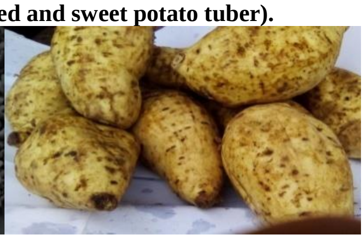
Plate 3: Sweet potato tubers

Plates 4-6: Flour samples (*acha* grain, cowpea seed and sweet potato tuber).

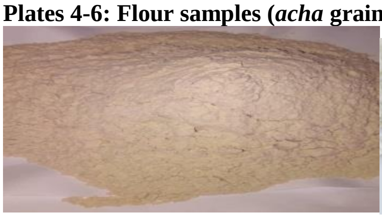

Plate 4: *Acha* flour (ACF)

Plate 5:Cowpea flour (CPF)

Plate 6: Sweet potato starch (SPS)

Plates 7-14: Extruded products from flour blends of acha-cowpea and sweet potato starch

Plate 7: 100:0:0(ACF:CPF:SPS)

Plate 8: 95:5:5(ACF:CPF:SPS)

Plate 9: 85:5:10(ACF:CPF:SPS)

Plate 10: 75:5:20(ACF:CPF:SPS)

Plate 11: 70:5:25(ACF:CPF:SPS)

Plate 12: 65:5:30(ACF:CPF:SPS)

Plate 13: 50:0:50(ACF:CPF:SPS)