

Production and evaluation of cold extruded and baked ready-to-eat snacks from blends of breadfruit (*Treculia africana*), cashewnut (*Anacardium occidentale*) and coconut (*Cocos nucifera*)

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Abstract
Five samples of ready-to-eat (RTE) snacks were produced by cold extrusion, baking (150°C for 30 minutes) and drying (50°C for 15 minutes) from blends of breadfruit, cashew nut, whole and defatted coconut along with other ingredients. The snacks were subjected to physical, chemical and sensory analyses. The results revealed the following ranges: physical properties (bulk density 0.32 to 0.51g/cm^3, apparent density 0.37 to 0.49g/cm^3, porosity -6.08 to 0.28g/cm^3 and lateral expansion 16% to 22%); proximate parameters (moisture 1.33 to 3.08%, ash 1.97 to 2.05%, crude fibre 0.32 to 1.47%, crude protein 13.45 to 15.90%, crude fat 13.37 to 21.50% and carbohydrate 62.27 to 66.49%) and micronutrients (vitamin B 0.202 to 0.501mg/100g, vitamin B_1 0.130 to 0.423mg/100g, vitamin B_2 0.014 to 0.114mg/100g, vitamin B_3 0.157 to 0.477mg/100g and iron 2.61 to 5.86mg/100g). Sensory evaluation revealed that highly acceptable nutrient dense snacks were produced from blends of breadfruit, cashewnut, and defatted coconut.
Keywords: Physical properties, Proximate composition, Micronutrients, Sensory properties.

1. Introduction

Ready-to-eat (RTE) snacks are savoury products that are capable of being held at ambient temperature for a reasonable length of time (Okaka, 1997). In recent times, RTE snack products are increasingly gaining global acceptance, due to job demands, convenience driven lifestyles and dietary habits. Snack foods add variety to diet, which partially explain their popularity (Lasekan *et. al.* 1996). RTE snacks are produced to meet various needs, using a combination of cereals and other ingredients. According to Bressani & Elias (1974), high protein snacks could be produced by combining cereals with animal food sources or, better with cheaper and more available plant protein sources, such as legumes and oil seeds. Some traditional snacks have been produced from such combinations, but they are not shelf stable, especially if stored at ambient temperature. Industrial production of RTE snacks using extrusion, baking and drying technologies will yield shelf stable, hygienically processed and acceptable products. Extrusion technology with its numerous advantages over traditional and conventional methods (Balley, *et. al.* 1991; Rizvi *et. al.* 1995), is one of the most versatile and energy efficient processes currently contributing solutions to world hunger and nutritional problems (Hauck, 1981). It has become one of the major processes of creating new food products and improving existing ones (Faubion & Hoseney, 1982; Lawton, *et. al.* 1985). Chigumira (1992) investigated production of extruded maize, sorghum and soybean based snacks, and reported the development of a nutritious RTE high protein snack food products, which showed marked improvement on children's health upon consumption in Zimbabwe. Extrusion process could be handled in either cold or hot mode. Cold extrusion technology has been used to shape products (Boyaci, *et. al.* 2012) by mixing flour and other ingredients with water to obtain a uniform dough that is extruded through variety of dies, depending on the desired shape of the product. Cold extrusion technology is however, different from extrusion cooking, which uses high temperature short time processing technology to manufacture RTE snack foods (Linko *et. al.* 1981). This implies that a heat treatment process such as baking ought to be applied on the cold extrudates to transform them into RTE snacks. Application of extrusion technology in Nigeria has been reported for soybean flour and its blends with cereals, roots, tubers and other low protein legumes (Dashiell *et. al.* 1990; Lasekan & Akintola, 2002; Iwe & Ngoddy, 2000; Nwabueze, 2007; Nwabueze & Anoruoh, 2009). Though, this technique has gained ground in fabrication of human foods worldwide, it has not been applied to the processing of composite flour of three seasonal agricultural produce such as African breadfruit, cashew nut and coconut that are consumed as traditional snacks.

African breadfruit (*Treculia africana*) is produced in the Eastern and Southern parts of Nigeria between March and July, when cultivated plant food sources are limited –yet to be harvested. It is also available in other tropical countries like Ghana, Gambia, Republic of Congo, East Indices, Angola, Cameroon, Tanzania, Sierra Leone, Malawi, Benin, Togo, Senegal and many other countries (Mbuya *et. al.* 1994). The seed of African breadfruit is obtained after macerating the fruit in water. The seeds are traditionally cooked in water with or without other ingredients (Jellof breadfruit), roasted or fried. The seeds are also dried and milled into flour known as breadfruit flour, which can be used to produce variety of baked foods (Bijtterbier, 1986). African breadfruit seeds are used to supplement the bulk of diets in the rural communities in south-eastern Nigeria, whose diets comprises essentially of cereal grains, starchy root and tuber crops (Ariahu *et. al.* 1999). The cashew nut (*Anacardium occidentale*) is a highly nutritious and concentrated form of food (Nandi, 1998), which contributes fat in the diet. It is widely used in a variety of ways (Russel, 1979), in different countries. The chemical composition of the kernel, which is considered to be of high nutritive value, is as follows; protein 21%, fat 46% and carbohydrates 25% (Nandi, 1998). The cashew nut kernel has a pleasant taste and flavor, and can be eaten raw, fried and sometimes salted or sweetened with sugar (Manay & Shadakshara, 1987). The coconut (*Cocos nucifera)* which is a common feature in most markets within the tropics, has been an important component of local diets. Coconut presscake is the bye product of coconut milk extraction, which has been dried, milled and used as an ingredient in weight control foods (Thampman, 1993), curry and chutney formulations, (Arumughan *et. al.* 1993), breakfast cereals (Okafor & Usman, 2013). It is envisaged that careful combination of these important food sources followed by extrusion and baking, would yield acceptable RTE snacks for both children and adults. The obtained nutrient dense RTE snack products can be reconstituted by stirring in hot milk or could be taken with soft drinks.

2. Materials and Methods

2.1 Procurement of raw materials

Undehulled breadfruit seeds, cashew nut and dehusked coconuts together with sugar, flavor, salt and flour were purchased from Ogige market in Nsukka, Enugu State, Nigeria.

2.2 Preparation of breadfruit flour

Undehulled African breadfruit seeds (6kg) were sorted to remove spoilt seeds, washed in a basin of tap water to free them from slimy materials, dust and other foreign bodies (Fig. 1).

Undehulled African Breadfruit Seed (*Treculia africana*)
↓
Cleaning/washing
↓
Hot water blanching
↓
Draining/cooling
↓
Dehulling/winnowing
↓
Drying (60^{o}C for 7 hours)
↓
Cooling
↓
Milling
↓
Sieving
↓
Storage

Figure 1. Production of breadfruit flour

The cleaned seeds were blanched in hot water at 100^{o}C for 15 mins, poured in a plastic basket to drain and cooled for 15 mins. The seeds were cracked in a commercial attrition mill and the hulls were removed manually. The dehulled seeds were dried in an oven (Shellab model VWR ≡ 1370G) at 60^{o}C for 7 hours to moisture content of 6%, cooled to room temperature prior to milling in a Brabender Roller Mill (Germany) to pass through a 75µm screen openings, stored in an air-tight container at room temperature until used.

2.3 Preparation of cashew nut flour

Undehulled cashew seeds (5kg) were washed to remove dirts and other contaminants, sun dried for 90mins at ambient temperature of 30±2ºC prior to roasting. The dried nuts weighing 2kg were roasted using a 60cm diameter open pan made of mild steel that was placed on an ignited gas cooker. The cashew nuts were stirred constantly, till cashew nut shell liquid (CNSL) started to exude and ignite. After two minutes, the pan was doused and the charred, swollen and brittle nuts were poured out of the pan. The moisture evaporated quickly leaving the nuts ready for shelling. The nuts were manually shelled and dehulled to produce clean, crack free whole kernels. The shelled nuts were weighed using a Top loading digital balance (JT302N England), prior to milling in a Brabender roller mill (Germany) to pass through a 75µm screen opening. The flour was stored in an air-tight plastic container at room temperature until used.

2.4 Preparation of partially defatted coconut flour

The coconuts were manually cracked and detached from the pericarp using a knife. The endocarp (6kg) was manually scraped with a sharp knife, grated and made into smooth paste with a Moulinex blender. The liquid component of the endocarp was extracted with an extractor (Bellini model GT 006/01/32 China). The obtained residue was dried in an oven (Shellab model VWR≡1370G) at 60^{o}C for 10 hours, to a moisture content of 7%. The dried coconut residue lumps were milled in a Brabender Roller Mill (Germany) to pass through a 75µm screen opening. The resulting flour was stored in an air-tight plastic container at room temperature until used.

2.5 Preparation of blends

The breadfruit flour, cashew nut and coconut (whole and defatted) were weighed using a digital balance (JT302N, England) and blended together in the ratio of 8:5:2 respectively, to obtain their composite flour. Other ingredients such as sugar, water, salt, flavor and wheat flour were also added in their right proportions as shown in Table 1.

Table 1. Composition of the extruded snack feed blends

Ingredients	2Q	2R	2S	2T	2U
Breadfruit	26.7	33.3	33.3	26.7	26.7
Cashew nut	10	-	-	-	10
Roasted cashew nut	-	-	20	10	-
Defatted Coconut	25	20	-		25
Whole coconut	-	-	-	25	-
Flour	13.3	16.7	16.7	13.3	13.2
Salt	0.3	0.3	0.3	0.3	0.3
Sugar	3.3	3.3	33	3.3	3.3
Flavour	1.4	1.4	1.4	1.4	1.25
Water	20	25	25	20	20
Vitamin premix	-	-	-	-	0.25
Total	100	100	100	100	100

2.6 Extrusion and baking

The flowchart for production of the ready –to- eat snacks is shown in Fig. 2.

Raw Materials

↓

Weighing

↓

Preconditioning

↓

Extrusion

↓

Baking (150^{o}C for 30 minutes)

↓

Oven drying (50^{o}C for 15 minutes)

↓

Cooling

↓

Packaging/Storage

Figure 2. Production of cold extruded, baked and dried ready-to-eat snacks from blends of African breadfruit, cashew nut and coconut.

The composite flour, sugar, water, salt, flavor and wheat flour in their different proportions were manually mixed and then fed into a hand pressed extruder cylinder and cold extruded through a selected die shape (Fig. 3).

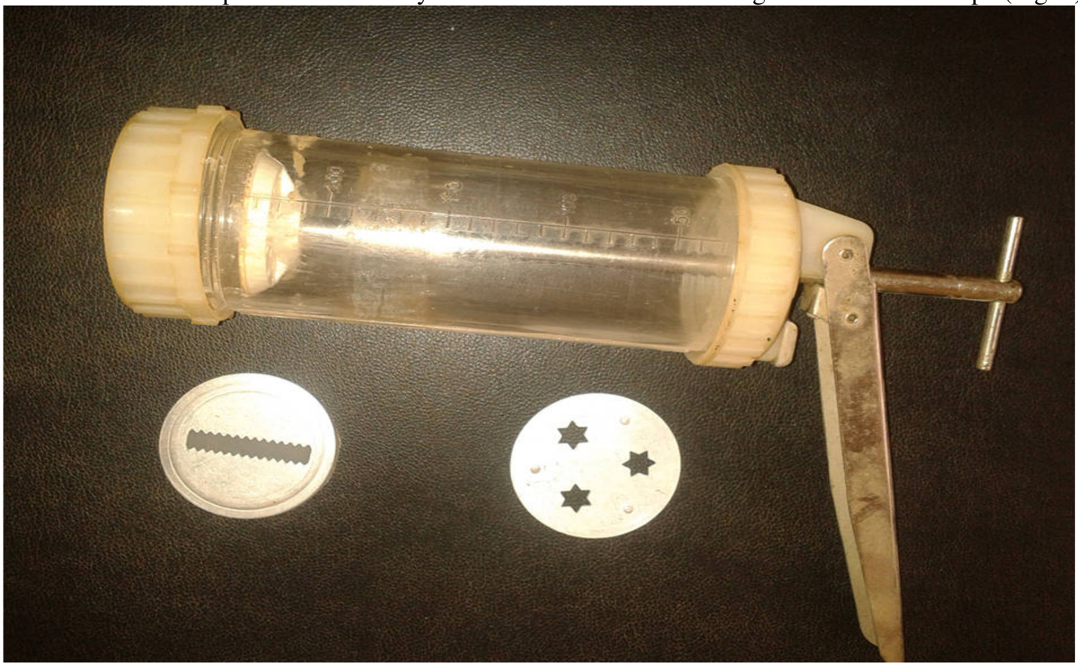

Figure 3. Manual cold extruder with two dies

The extrudates were arranged on a tray and subsequently baked in an oven (Novosibirisk-2, Cibelectroterm, Russia) at the temperature of 150°C for 30 minutes prior to drying in the same oven at 50°C for 15 minutes. The samples (Fig. 4) were allowed to cool before packaging in a flexible material and kept till further use.

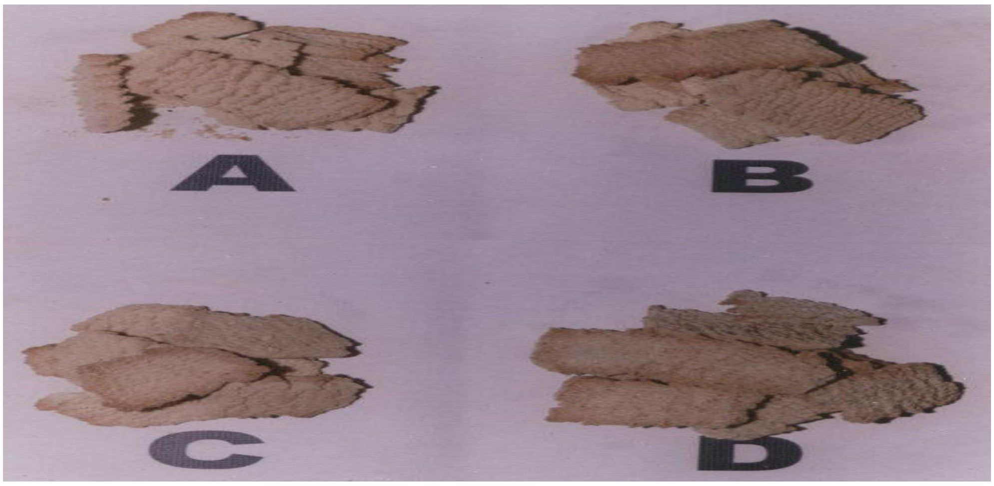

Figure 4. Cold extruded, baked and dried snacks samples. (A) 2Q = Breadfruit, cashew nut, defatted coconut and other ingredients. (B) 2R= Breadfruit, defatted coconut and other ingredients. (C) 2S = Breadfruit, roasted cashew nut and other ingredients. (D) 2T = Breadfruit, roasted cashew nut, whole coconut and other ingredients

2.7 Chemical analysis of the products

The samples were subjected to proximate (moisture, protein, fibre, ash, fat and carbohydrate) analysis using AOAC (1995) methods, while micronutrients such as vitamins A, B_1, B_2, B_3 and Fe were determined by the methods described by Pearson (1976).

2.8 Sensory evaluation

Sensory evaluation of the extruded snacks was carried out using a Panel made up of 10 members, drawn from Staff and students of the Department of Food Science and Technology, University of Nigeria, Nsukka. Snack attributes such as taste, after taste, flavor, texture, mouthfeel, crumb color, crust color, appearance and overall acceptability were evaluated (Ihekoronye & Ngoddy, 1985) using a 9-point hedonic scale questionnaire, where 9 = extremely like, 5 = neither like nor dislike and 1 = extremely dislike. Each snack sample was assigned a three digit code and presented in a white ceramic plate under a white light. The assessors were carefully positioned to avoid bias. Samples were served in a randomized order on a tray, with portable water and spit cup for rinsing mouth in between tasting of samples to minimize rating errors, due to carry over of perceived attributes of previous sample.

2.9 Determination of some physical properties of the extrudates

2.9.1 Bulk density

The bulk density was determined by measuring the actual dimension of the extrudates (Thymi *et. al.* 2005). The diameter of the extrudates were measured using a digital vernier caliper (JT 302N, England), while the length was measured with the aid of a metric ruler. The weights per unit length of the extrudates were determined by weighing measured lengths. The bulk density (Pb) was then calculated using the following formula.

$$Pb = \frac{4}{\pi d^2 L} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (1)$$

Where: Pb = Bulk density (g/cm^3)
d = Diameter of the extrudate (mm)
L = Length per gram of the extrudate (mm/g)

2.9.2 Apparent density

Apparent density was determined according to the method of Onyango *et. al.* (2004). The extrudates were manually ground using a ceramic pestle and mortar. A 5ml gradated cylinder was tarred using a digital balance (JT 302N, England) and gently filled with the milled extrudate. The bottom of the cylinder was repeatedly tapped gently until there was no further reduction of sample volume and was weighed. The apparent density (Ps) of the extruded sample was calculated as mass per unit volume (g/cm^3);

$$\text{Ps} = \frac{Mass}{Volume}(g/cm^3) \quad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (2)$$

2.9.3 Porosity

The porosity of the extrudates was determined from the bulk and apparent volumes (Onyango et al. 2004). Porosity was calculated using the equation;

$$\text{Porosity} = \frac{Bulk\ volume - Apparent\ volume}{Bulk\ volume} \quad \ldots\ldots\ldots \qquad (3)$$

Where: Bulk volume = 1/Pb; Apparent volume = 1/Ps

2.9.4 Lateral expansion

The ratio of the diameter of the extrudates and that of the die was used to express the expansion of the extrudate (Alvarez-Martinez *et. al.* 1988; Fan *et. al.* 1996). The size and length of the extrudates (approximately 120mm) were selected at random. The diameter of the extrudates was measured at 10 different positions along the length of each of the six samples using a digital vernier caliper. Lateral expansion (LE) was calculated using the mean of the measured diameters as follows:

$$\text{LE} = \frac{Diameter\ of\ product - Diameter\ of\ die\ hole}{Diameter\ of\ die\ hole} \times 100\ \% \ldots\ldots\ldots\ldots \qquad (4)$$

2.9.5 Data analysis

The experiment followed a completely randomized design (CRD). All the data obtained were statistically analyzed using a one-way analysis of variance (ANOVA) and means were separated by Duncan's New Multiple Range Test (DNMRT) using the Statistical Package for Social Sciences (SPSS) version 17. Significance was accepted at 0.05 probability level.

3. Results and Discussion

3.1 Proximate composition

The proximate composition of the cold extruded, baked and dried snack samples is shown in Table 2.

Table 2. Proximate composition of the RTE snacks

Samples	Moisture %	Ash %	Fibre %	Protein %	Fat %	*CHO %
2Q	1.33±0.03[a]	1.99±0.05[a]	1.47±0.03[d]	13.88±0.20[a]	14.53±0.25[b]	62.27±4.07[a]
2R	2.67±0.02[c]	1.97±0.10[a]	0.77±0.08[b]	13.45±0.48[a]	14.64±0.14[b]	66.49±0.59[a]
2S	1.96±0.02[b]	2.05±0.09[a]	0.52±0.03[a]	15.90±0.92[b]	13.37±0.51[ab]	66.14±1.24[a]
2T	3.08±2.26[d]	2.02±0.03[a]	1.00±0.01[c]	15.20±0.68[b]	21.50±0.66[c]	64.17±0.53[a]

Values represent mean ± S.D (n=3). Values bearing the same superscript within the same column are not significantly ($p>0.05$) different from each other. 2Q = Breadfruit, cashew nut, defatted coconut and other ingredients; 2R = Breadfruit, defatted coconut and other ingredients; 2S = Breadfruit, roasted cashew nut and other ingredients; 2T = Breadfruit, roasted cashew nut, whole coconut and other ingredients. *CHO= Carbohydrate

3.1.1 Moisture content

The moisture content of the snacks which ranged from 1.33 to 3.08% were significantly ($p<0.05$) different from each other, due to ingredient variation. Sample 2T had the highest moisture content, while that of sample 2Q was lowest. The high moisture content of 2T may be probably due to the use of whole coconut in its formulation, while the low moisture content of 2Q could be due to addition of defatted coconut, as well as the baking and drying processes employed in producing the samples. Akanmu & Omobuwajo (2009) reported a moisture content of 2.17 - 2.49 %, for bouillon cubes from calabash nutmeg seeds, while Sonido *et. al.* (2007) established 1.1 -2.2% as the roasted peanut's safe moisture range for storage, which will readily absorb moisture from the atmosphere if unprotected by proper packaging. The low moisture content of the snacks is important because, it will help in extending the shelf life if adequately protected, by inhibiting the development of contaminating microorganisms, whose growth and activities are favored by presence of moisture.

3.1.2 Ash content

The ash content which is the residue remaining after destroying the samples organic matter, ranged from 1.97 to 2.05%. The ash content of the samples were not significantly ($p>0.05$) different from each other, however samples with roasted cashew nut had the highest values. This could be due to roasting process that concentrated the organic materials of cashew nut in the formulations. The samples contained sufficient amount of ash implying that they are rich in mineral elements. The values were however, close to the range (1.34-2.58%) reported by Eke *et. al.* (2007) for banana-wheat composite cake.

3.1.3 Crude fibre

The crude fibre content of the snacks, which ranged from 0.52 to 1.47%, differed significantly ($p<0.05$) from each other, probably due to varying ingredient proportions. The samples with coconut had the highest values, implying that addition of coconut to the snacks increased their fibre contents. The fibre content of the snacks also increased with increase in the quantity of defatted coconut in the formulation. Trinidad *et. al.* (2006) reported that coconut flour contains 60.9% total dietary fiber consisting of 56.8% insoluble and 3.8% soluble, which are fermentable and produced short chain fatty acids with butyrate >acetate >propionate. Fibre is important for the removal of waste from the body thereby preventing constipation and many health disorders. Consumption of vegetable fibre has been shown to reduce serum cholesterol level, risk of coronary heart disease, colon and breast cancer and hypertension; enhance glucose tolerance and increase insulin sensitivity (Hassan & Umar, 2004). The viscose and fibrous structure of dietary fibre controls the release of glucose with time in the blood, which helps in proper control and management of diabetes mellitus and obesity (Gurr & Asp, 1994; Aleixandre & Miguel, 2008). As a result, Codex (2009) associated dietary fibre with properties such as decrease intestinal transit time and increase in stools bulk, fermentable by colonic microflora, reduce blood total and/or LDL cholesterol levels, and reduce post-prandial blood glucose and /or insulin levels. The snacks have a great potential for application as diabetic food, because of the fibre source in their formulation that could be modified to generate a near perfect recipe for production of diabetic snacks.

3.1.4 Crude protein

The crude protein content of the snacks ranged from 13.45 to 15.90%, implying that the snacks are good sources of protein that could be attributed to added breadfruit and cashew nut in their formulations. The values obtained were in agreement with the values reported by Edet *et. al.* (1985) for African breadfruit, which ranged from 14 to 23%. The variations in the crude protein content may be due to the ingredients used in their formulations. The samples containing defatted coconut (2Q and 2R) had significantly ($p<0.05$) lower protein content than samples 2S and 2T with high levels of roasted cashew nut and whole coconut, respectively. The samples with cashew nut also had higher protein values, implying that addition of cashew nut to the formulations increased the protein content of the snacks. However, the samples had higher protein content than RTE extrudates (12.36 ± 0.25) made by incorporating egg albumin powder at 20% level into corn and rice flour (Kocherla *et. al.* 2012). Hence, consumption of theses snacks will help to furnish adequate amount of most essential amino acids to the body (Ariahu *et. al.* 1999).

3.1.5 Crude fat

The crude fat which increased with addition of whole coconut to the snacks ranged from 13.37 to 21.50%, suggesting that they are good sources of fat needed by the body for optimum health and energy. However, there were significant ($p<0.05$) differences in the fat content of the samples, which depended on the quantity and type of added coconut (whole or defatted), with sample 2T containing whole coconut being significantly ($p<0.05$) higher than the samples (2Q and 2R) with defatted coconut. Trinidad *et al.* (2006) reported 10.9% fat content of coconut flour per 100 g sample, which contributed to the significantly ($p<0.05$) higher fat content of the samples with coconut. Dietary fats that provides essential fatty acids (EFA) have been shown to enhance the taste and acceptability of foods, slow gastric emptying and intestinal motility, thereby prolonging satiety and facilitate the absorption of lipid-soluble vitamins (FAO, 2010). The lipid components also help to determine the texture, flavor and aroma of foods. The Expert Consultation considered that the acceptable macronutrient distribution range (AMDR) for total fat intake ranges between 20% and 35% of energy (E) (Elmadfa & Kornsteiner, 2009). Consumption of these samples would contribute to meeting the recommended fat intake.

3.1.6 Carbohydrate content

The carbohydrate content of the snacks were not significantly ($p>0.05$) different from each other, and ranged from 62.27 to 66.49%. This implies that the snacks are good sources of energy needed for normal body metabolism. The carbohydrate contents of the samples with defatted coconut (2Q and 2R) were highest, while the formulation with whole coconut was significantly ($p<0.05$) lower than other samples. This could be attributed to the significantly ($p<0.05$) high levels of moisture, protein and fat in the sample. The range of carbohydrate detected, was lower than 73.26% reported by Osabor *et. al.* (2009) for that of breadfruit seeds. This suggests that addition of ingredients other than breadfruit helped to reduce the carbohydrate content of the snacks.

3.2 Energy value

The energy values of the samples shown in Fig. 5 ranged 435.7 to 510.98 Kcal, with the sample containing defatted coconut being the least, while the sample containing whole coconut having the highest value.

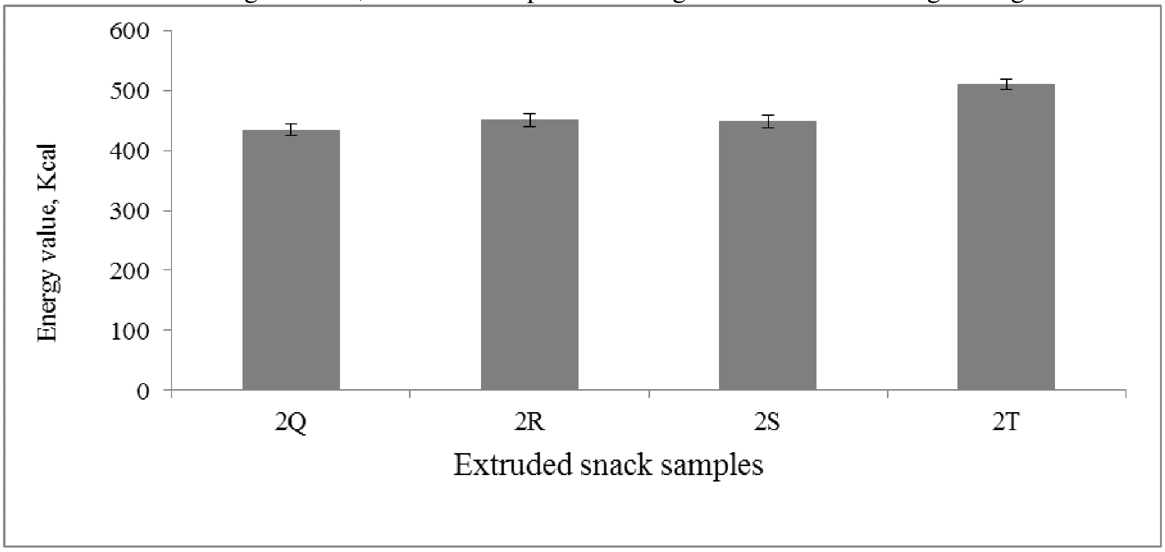

Figure 5. Energy value of extruded snack samples.

2Q = Breadfruit, cashew nut, defatted coconut and other ingredients, 2R = Breadfruit, defatted coconut and other ingredients, 2S = Breadfruit, roasted cashew nut and other ingredients and 2T = Breadfruit, roasted cashew nut, whole coconut and other ingredients.

The values were higher than those reported by Kent, (1983) and Mbaeyi, (2005) for breakfast cereals made from treated and untreated sorghum and pigeon pea (316.46–420 kcal). Accurate evaluation of the energy value of foods is essential for dealing with challenges of normal nutrition, under nutrition and obesity (Merrill & Watt, 1973). The snacks will help to reduce protein energy malnutrition which is very prevalent in the developing countries if commercialized. Sample 2T containing breadfruit, roasted cashew nut, whole coconut and other ingredients will be ideal for underweight children.

3.3 Physical properties of the RTE snacks

The physical properties such as length, thickness, weight per unit length, bulk density, apparent density, lateral expansion and porosity of the snacks are presented in Table 3.

3.3.1 Length, thickness and weight per unit length of the extrudates

The snack formulations influenced the length, thickness and weight per unit length of the extrudates. Sample 2Q with the highest level of defatted coconut was least in all the parameters while that of sample 2T with whole coconut was highest, probably due to their fat contents. According to Mattil *et. al.,* (1964) fat entraps and hold considerable air during mixing, which expands under the influence of heat in the oven, hence contributing to leavening of the samples. Their thicknesses were however, not significantly ($p>0.05$) different from each other, while significant ($p<0.05$) differences existed between their lengths and weights.

3.3.2 Bulk density

The bulk density of the snack samples ranged from 0.32-0.51 g/cm^3 with sample 2Q being the maximum, while sample 2T was the least. Addition of defatted coconut flour increased the bulk density of the extruded snack samples. Bulk density has been linked with the expansion ratio in describing the degree of puffing in the extrudates (Saalia, 1995; Asare *et. al.* 2004). Therefore, it is expected that, under similar conditions, as expansion index increases the bulk density would automatically decrease. High bulk density is important with regards to packaging. High bulk density is associated with low expansion index because more compact material is obtained after milling a less expanded product (Onyango *et al.* 2004).

3.3.3 Lateral expansion

Lateral expansion of the extrudates ranged from 16-22%. Normally lateral expansion increases as screw speed is increased, but it was less pronounced especially at high coconut level of addition. Since starch is the main component responsible for dough development inside the extruder barrel, as well as consequent expansion at the die exit (Merrier & Feille, 1975). It was observed that the amount of starch in the formulation decreased as more defatted coconuts were added except for SD whose coconut was whole (undefatted).

3.3.4 Porosity

The porosity of the extruded snacks which ranged from -0.24 to 0.28 increased with increase in breadfruit and cashew nut addition, but decreased with increase in coconut addition. Porosity indicates the volume fraction of void space or air space inside a material (Barbosa-Cánovas *et. al.* 2006). Giannini *et. al.* (2011) observed that porosity decreases with extrusion temperature, while fiber particles usually decrease the product's expansion by rupturing the cell walls, before the gas bubbles could expand to their full potential. Decrease in porosity may be due to dilution of starch available for expansion with addition of coconut flour. However, porosity created during extrusion has been used to describe the expansion properties of extruded products (Thymi *et. al.* 2005; Yanniotis *et. al*. 2007). It helps in modeling, design of heat and mass transfer processes, and serves as an important parameter in predicting diffusional properties of cellular foods (Sahin & Sumnu, 2006).

3.3.5 Apparent density

The apparent density of the snacks ranged from 0.37 to 0.49 g/cm^3. According to Sahin and Sumnu (2006) apparent density reflects the snack's density, including all the pores within them. The apparent density was found to with increasing addition of cashew nut in the formulations. The samples containing roasted cashew nut equally had higher levels of apparent density, probably due to concentration effect of moisture loss during roasting that increased their density.

Table 3. Physical properties of the cold extruded, baked and dried snacks

Samples	Length (mm)	Thickness (mm)	Weight /length (g)	Bulk density (g/cm^3)	Apparent density (g/cm^3)	Porosity	Lateral expansion %
2Q	42.30 ± 0.10^d	7.59 ± 0.06^a	5.86 ± 0.6^c	0.51 ± 0.12^a	0.40 ± 0.02^c	-0.24 ± 0.28^a	19.00 ± 0.1^b
2R	48.49 ± 0.06^b	7.80 ± 0.03^a	7.48 ± 0.1^b	0.46 ± 0.03^a	0.37 ± 0.02^c	-0.24 ± 0.15^a	16.00 ± 0.04^c
2S	43.56 ± 0.50^c	8.01 ± 0.01^a	7.28 ± 0.3^b	0.45 ± 0.02^a	0.49 ± 0.05^a	0.28 ± 0.09^b	21.67 ± 0.02^a
2T	61.89 ± 1.02^a	8.04 ± 0.05^a	9.10 ± 0.4^a	0.32 ± 0.05^b	0.45 ± 0.03^b	0.28 ± 0.14^b	22.33 ± 0.10^a

Values represent mean $\pm$ S.D (n=3). Values bearing the same superscript within the same column are not significantly ($p>0.05$) different from each other. 2Q = Breadfruit, cashew nut, defatted coconut and other ingredients; 2R = Breadfruit, defatted coconut and other ingredients; 2S = Breadfruit, roasted cashew nut and other ingredients; 2T = Breadfruit, roasted cashew nut, whole coconut and other ingredients.

3.4 Micronutrient content of the extruded snacks

The micronutrient content of the snacks is shown in Table 4. The pro-vitamin A content of the snacks that ranged from 2.42 to 6.02mg, were significantly ($p<0.05$) different from each other. Addition of cashew nut and vitamin premix significantly ($p<0.05$) increased the micronutrients especially those of samples 2Q and 2U, while roasting of cashew nut led to significant ($p<0.05$) reduction in samples 2S and 2T. The values were however, below the recommended daily intake of pro vitamin A (6.0-12.0mg) (Belitz *et. al.* 2009). It appears that there was little effect of heat on the pro-vitamin A content of the snacks during baking and drying processes. Samples 2R and 2T had similar values, which differed significantly ($p<0.05$) from other samples. Vitamin A is essential for growth, healthy eyes as well as structuring and functioning of the cells of the skin (Ihekoronye & Ngoddy, 1985).

Vitamin B_1 content of the snacks ranged from 0.130mg/100g to 0.423mg/100g, while the recommended daily intake for <1yr infant to > 65yrs adult, ranges from 0.2 to 1.0mg (Belitz *et al.* 2009). Implying that vitamin B_1 content of the snacks was affected by heat during baking and drying processes as well as by formulation. The result also shows that vitamin B_1 content which is essential for carbohydrate metabolism, healthy appetite and functioning of the nerves increased with addition of cashew nut.

Table 4. Micronutrient composition of the extruded snacks

Samples	Pro vitamin A mg	Vitamin B_1 mg	Vitamin B_2 mg	Vitamin B_3 mg	Iron mg
2Q	5.34 ± 0.00^c	0.130 ± 0.01^a	0.088 ± 0.00^c	0.273 ± 0.00^b	4.33 ± 0.02^b
2R	2.42 ± 0.02^a	0.143 ± 0.00^b	0.014 ± 0.00^a	0.277 ± 0.00^b	2.61 ± 0.03^a
2S	2.72 ± 0.01^b	0.334 ± 0.01^d	0.042 ± 0.00^b	0.157 ± 0.00^a	4.83 ± 0.45^c
2T	2.45 ± 0.06^a	0.316 ± 0.11^c	0.020 ± 0.00^a	0.251 ± 1.13^{ab}	4.25 ± 0.12^b
2U	6.01 ± 0.01^d	0.423 ± 0.01^e	0.114 ± 0.00^d	0.477 ± 0.03^c	5.86 ± 0.28^d

Values represent mean $\pm$ S.D (n=3). Values bearing the same superscript within the same column are not significantly ($p>0.05$) different from each other.
2Q = Breadfruit, cashew nut, defatted coconut and other ingredients; 2R = Breadfruit, defatted coconut and other ingredients; 2S = Breadfruit, roasted cashew nut and other ingredients; 2T = Breadfruit, roasted cashew nut, whole coconut and other ingredient; 2U = Breadfruit, cashew nut, defatted coconut, vitamins and other ingredients.

The vitamin B_2 content of the snacks, which is also important in carbohydrate and protein metabolism, ranged from 0.020 to 0.114mg. Vitamin B_2 which is water-soluble and sensitive to heat, may have been reduced by the post cold extrusion baking and drying processes. The values were however lower than the recommended daily intake of vitamin B_2 that ranges from 0.3 to 1.6mg (Belitz *et al.* 2009), but higher than the values (0.023mg/100g to 0.028mg/100g) reported by Ologunde, Omosebi, Ariyo, Olunlade & Abolaji, (2011) for cashew nuts from three Nigerian states. There were no significant ($p>0.05$) differences between samples 2R and 2T, while significant ($p<0.05$) differences existed between them and other samples. Vitamin B_3 (niacin) which is needed for carbohydrate and protein metabolism, ranged from 0.16 to 0.48mg. The ranges were far below the recommended daily intake which ranges from 2 to 18mg for infants <1 yr old and adults (Belitz *et al*. 2009). The iron content of the snacks ranged from 2.61 to 5.86 mg, while the recommended daily intake of iron is about 15mg. From the result above, there is an appreciable amount of iron obtained, which may be as a result of increase in the quantity of cashew nut used in the formulation iron is essential for the formation of haemoglobin of the red blood cells. Iron deficiency has been identified as the most common nutritional deficiency disease on the planet, with pregnant women and infants and young children being the two most vulnerable demographic groups (Theuer, 2008). This situation which may be combated by altering dietary practices (Ziegler & Fomon, 1996), will be alleviated by frequent consumption of iron rich foods, including snacks such as these. Fortification of sample 2U snack formulation with vitamin premix led to 12.58 - 148% increase in concentration of the micronutrients compared to other samples. In general, the extrusion, baking and drying processes had little effect on the micro-nutrient composition of the snacks especially vitamin A and iron, but affected the water soluble vitamins (B_1, B_2 and B_3) that are regarded as the most sensitive to heat (Cheftel, 1986).

3.5 Sensory evaluation

The sensory evaluation scores of the snacks are presented in Table 5. The result shows that the samples with coconut were highly rated except sample 2T whose color was darkened due to roasting of cashew nut in its formulation. The samples were not significantly (p>0.05) different in terms of aftertaste, texture, mouthfeel, crust color, appearance and overall acceptability. The taste of samples 2R, 2S and 2T were not significantly (p>0.05) different from each other, while sample 2Q was rated highest and differed significantly (p<0.05) in taste from samples 2T and 2S. This could probably be due to addition of unroasted cashew nut and defatted coconut flour in its formulation, which improved its taste and that of sample 2R. Roasting process may have caused evaporation of volatile aromatic components. In terms of flavor, samples 2Q and 2R were similar, while samples 2R, 2S and 2T were not significantly (p>0.05) different from each other. The reason may be due to variation and proportion of ingredients as well as inclusion of roasted cashew nut, which may have lost some of its flavor during roasting process. Besides, samples 2Q and 2R also contains coconut which has natural flavor that was strengthened by additional flavor used in the formulation. The crumb color of the samples differed significantly (p<0.05) among the samples. Samples 2Q, 2R and 2S had similar crumb color, while that of samples 2R, 2S and 2T were similar. Sample 2Q containing breadfruit, cashew nut, defatted coconut and other ingredients was the most acceptable followed by sample 2R, while samples 2S and 2T shared similar acceptability ratings. None of the samples were rejected by the assessors implying that the developed products would attract immense patronage if marketed.

Table 5. Sensory evaluation of the cold extruded, baked and dried snacks

Samples	Taste	Aftertaste	Flavour	Texture	Crumb colour	Mouthfeel	Crust colour	Appearance	Overall acceptability
2Q	8.90 ± 0.32^{a}	8.00 ± 0.66^{a}	8.40 ± 0.69^{a}	8.20 ± 0.63^{a}	8.50 ± 0.70^{a}	8.30 ± 1.05^{a}	8.10 ± 0.99^{a}	8.20 ± 0.63^{a}	8.60 ± 0.69^{a}
2R	8.10 ± 0.88^{ab}	8.10 ± 0.87^{a}	8.10 ± 0.99^{ab}	7.90 ± 0.73^{a}	7.90 ± 0.87^{ab}	7.60 ± 1.07^{a}	8.10 ± 0.73^{a}	8.00 ± 0.81^{a}	7.80 ± 0.91^{a}
2S	7.50 ± 1.18^{b}	7.40 ± 1.17^{a}	7.30 ± 1.05^{b}	7.40 ± 1.34^{a}	7.70 ± 1.05^{ab}	7.60 ± 0.96^{a}	8.10 ± 1.19^{a}	7.40 ± 1.17^{a}	7.70 ± 0.82^{a}
2T	7.50 ± 1.10^{b}	7.80 ± 1.03^{a}	7.20 ± 1.20^{b}	7.30 ± 1.05^{a}	7.00 ± 1.41^{b}	7.50 ± 1.08^{a}	7.40 ± 1.26^{a}	7.90 ± 0.90^{a}	7.70 ± 1.15^{a}

Values represent mean + S.D (n=20). Values bearing the same superscript within the same column are not significantly (p>0.05) different from each other.
2Q = Breadfruit, cashew nut, defatted coconut and other ingredients; 2R = Breadfruit, defatted coconut and other ingredients; 2S = Breadfruit,
roasted cashew nut and other ingredients; 2T = Breadfruit, roasted cashew nut, whole coconut and other ingredients

4. Conclusion

Acceptable product of adequate nutritional and organoleptic quality were successfully produced by cold extrusion, baking and drying processes from African breadfruit, coconut and cashew nut composite flour along with other ingredients. Most of the proximate constituents increased with increasing addition of breadfruit as well as cashew nut, whereas the crude fibre content increased with increasing addition of coconut in the blends.

The nutrient composition of the snacks especially the protein and fat content renders the snacks a valuable nutrient resource. The snacks could help to reduce protein energy malnutrition prevalent in developing countries and add variety to the predominantly carbohydrate-based snack foods in the market. Vitamin fortification of sample 2Q (breadfruit, cashewnut, and coconut) yielded sample 2U (breadfruit, cashewnut, coconut and vitamins) with 12.58-14.8% increase in its micronutrient concentration compared to other samples.

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