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Physical and Functional Properties of Breakfast Cereals from Blends of Maize, African Yam Bean, Defatted Coconut Cake and Sorghum Extract

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Abstract
The physical and functional attributes of ready-to-eat breakfast cereals produced from blends of maize (*Zea mays*), African yam bean (*Sphenostylis stenocarpa*) (AYB), defatted coconut (*Cocos nucifera*) cake and sorghum (*Sorghum bicolor* L. Moench) malt extract, were evaluated. Six samples were formulated by mixing the AYB+ maize composite flour with graded levels of defatted coconut (100:0, 90:10, 80:20, 70:30, 60:40, 50:50), sugar, salt and water. The samples were mixed and toasted at 280°C for 5mins each in a non-stick metallic pan, cooled and packaged. The results revealed the following ranges of physical and functional properties; pH (4.70- 6.56), bulk density (0.29 - 0.71g/ml), water absorption capacity (68.31- 76.39%), oil absorption capacity (0.87- 1.32%), foam capacity (2.48- 3.49%), viscosity (19.73-31.08%), gelation temperature (121-157°C), emulsification capacity (5.79-9.86 g/100g), wettability (15.67-23.22 sec.) and invitro-protein digestibility (66.30- 82.2%). It is evident that there are significant variations of physical and functional attributes with addition of defatted coconut fibre in the formulations.
Keywords: Bulk density, water absorption capacity, foam capacity, viscosity, invitro-protein digestibility, gelation capacity

1. Introduction

Ready-to-eat breakfast cereals are increasingly gaining acceptance in most developing countries, and gradually displacing most traditional diets that serve as breakfast due to convenience, improved income, nutritional values, status symbol and job demands especially amongst urban dwellers. According to Jones (2003) ready-to-eat (RTE) cereals facilitate independence because of their ease of preparation which means that children and adolescents can be responsible for their own breakfast or snacks. Such foods may need to be reconstituted, pre-heated in a vessel or allowed to thaw if frozen before consumption, or they may be eaten directly without further treatment (Okaka, 2005). Their consumption has also been extended to non-breakfast hours and often serve as in-between meals. A study has clearly shown that 42% of 10-year-olds and 35% of young adults consumed cereal at non-breakfast occasions (Haines et al., 1996), and could be taken dry as snack food, with or without cold or hot milk, based on their location, availability of resources and habits.

In recent times, food product developers have incorporated legumes into traditional cereal formulations as nutrient diversification strategy as well as an effort to reduce the incidence of malnutrition among vulnerable groups. Results from previous studies indicated that most cereals are limited in some essential amino acids especially threonine and tryptophan even though rich in lysine (especially the yellow maize) (Onweluzo and Nnamuchi, 2009). Whole maize contains about 11% protein, 4% fat, 3% fibre, 65% of starch and other carbohydrates and 1.5% of minerals (Ihekoronye and Ngoddy, 1985). Thus maize cannot effectively provide the nutrients required by the body, especially in the morning when the supply of nutrients from the previous day is exhausted. On the other hand, sorghum starch has been shown to possess the same functional characteristics with corn starch (Perez-Sira et al., 1997). It has better agronomic properties due to high drought tolerance and could prove to be a beneficial crop in future with increase in world population (Singh and Singh, 1995). Sorghum starch could be modified by malting inorder to generate an extract that will improve product acceptability. Cereals such as maize and sorghum are rich in sulphur-containing essential amino acids such as methionine, cysteine and tryptophan, while the storage proteins of most oil seeds and legumes are relatively low in sulphur-containing amino acids, but very high in another essential amino acid, lysine compared to cereals (Rockland and Radke, 1981; Kanu et al., 2009). Relative to lysine and sulphur amino acid contents, legume and cereal proteins are nutritionally complementary, depending on the contents of the second limiting amino acids, i.e., threonine in cereals and tryptophan in legumes (Duranti, 2006). Hence, the call for blending legumes with cereals in food product development. Therefore, a combination of such food stuffs will improve the nutritional value of the resulting blend compared to the individual components alone. Animal products such as meat, eggs, milk, and cheese are known to contain the essential amino acids that could complement this deficiency in cereal foods. However, consumption of proteins from plant sources (legumes) is encouraged (Ofuya and Akhidue, 2005), since combination of legumes and grains provide high quality cheaper protein that contains all essential amino acids in proper proportion, because their amino acids complement each other (Okaka, 2005). The relatively lower cost of vegetable protein in comparison with animal protein and preference of some people for protein of plant origin to that of animal sources has led to this increasing industrial demand for legume proteins (Arogundade et al., 2011). Hence, the rising use of vegetable proteins by food industries in the production of formulated food products of high nutritional quality with assorted physical and functional attributes, from lesser known legumes together with other conventional legumes that could be used for combating protein malnutrition prevalent in the third world. This can be achieved by the consumption of the legumes whole and in various processed forms (Arisa and Aworh, 2007). The source of vegetable protein ranges from the highly utilized and popular legumes such as soybeans to the lesser known ones like African yam beans (*Sphenostylis stenoscarpa)* (AYB) (Udensi et al., (2010). The protein in the tuber of AYB is more than twice the protein in sweet potato (*Ipomea batatas*) or Irish potato (*Solanum tuberosum*) and higher than those in yam and cassava (Amoatey et al., 2000). Moreover, the amino acid values in AYB seeds are higher than those in pigeon pea, cowpea, and Bambara groundnut (Uguru and Madukaife, 2001). However, the ultimate success of utilizing plant protein in food formulation depends largely upon the functionality (Maruatona, 2008) which is the property of a food ingredient that determines its usefulness in food systems (Fennema, 1996) , as well as their physical attributes, which may be customized by incorporating other raw materials. Other raw materials used for snacks production are also changing to include non-traditional raw materials that are good sources of fiber and micronutrients (Dueik, 2013). Dietary fibers isolated from various plants have diverse functional properties namely solubility, viscosity, gel forming ability, water-binding capacity, oil adsorption capacity, and mineral and organic molecule binding capacity, which affect product quality and characteristics (Tungland and Meyer, 2002). Trinidad et al. (2006) observed an increasing trend in dietary fiber content of the test foods fed at increasing level of dietary fiber from coconut flour supplemented foods. Coconut flour is usually obtained from coconut cake, which is the byproduct of coconut milk production that is posing a tremendous disposal challenge to processors, who are currently searching for its novel use (Jena and Das, 2007). Coconut presscake has been dried and milled into flour for use in preparation of several food products (Hagenmier, 1983). A combination of seed legumes, cereals and dietary fibre source is likely to yield products with nutritionally higher quality than that produced from individual component. These components also have the potentials to blend properly giving a desirable mouth feel and taste appeal due to their functional and physical attributes. The main lines of innovation in the agri-foodstuffs industry are focused on obtaining foods that preserve their sensory characteristics and bioactive compounds using appropriate techniques Sanchez-Bel, (2012). This study was therefore aimed at determining some physical and functional properties of breakfast cereals produced from blends of maize, AYB and defatted coconut flours.

2. Materials and Methods

2.1 Materials

Maize grains, African yam bean (AYB) seeds and mature coconuts as well as other ingredients such as sugar, salt, sorghum were purchased from Ogige market, Nsukka in Enugu State, Nigeria.

2.2 Preparation of samples

Maize grains (5kg) were cleaned, sorted and milled into flour using attrition mill (Ihekoronye and Ngoddy 1985). The brown African yam bean seeds (5kg) milled into flour using attrition mill as described in Okafor and Usman, 2013. Freshly dehusked coconuts (*Cocus nucifera*) weighing 4kg were properly cleaned and cracked to expel the containing coconut juice/water. The coconut flesh (meat) was removed from the shell with the aid of a sharp pointed knife. The brown colour of the skin was scraped off with a knife. The coconut flesh was milled with an attrition mill and the slurry was defatted according to the method of Sanful (2009). The obtained cake was dried, milled, sieved using 0.5mm mesh sieve, packaged in polyethylene bags prior to use. Cleaned and sorted white sorghum (*Sorghum bicolor L.*) seeds (5kg) were steeped in tap water for 18 h and germinated on floor for three days at room temperature (30±2^{o}C) and used to produce sorghum malt extract as described by Okafor and Aniche, (1980). AYB and maize composite flour was prepared by mixing 40% maize with 60% AYB flour. The defatted coconut flour was then used to substitute 10, 20, 30, 40 and 50% of the maize –AYB blend. The blends were roasted at 280°C in a Teflon surface with continuous stirring till dried ready-to-eat granules of each of the five samples were obtained as explained in Okafor and Usman, (2013). A control sample was produced from 100% maize and African yam bean composite flour. The flow chart for production of the breakfast cereals is presented in Fig. 1.

2.3 Evaluation of physical properties of the breakfast cereals

pH determination. The pH of the food samples was measured with a Mettler Delta 350 pH meter using the method described by Onwuka (2005). The sample homogenate was prepared by blending l0g sample in l00ml of deionized water. The mixture was filtered and the pH of the filtrate measured.

Bulk density determination. Bulk density was determined for each of the formulated samples using the method described by Onwuka, (2005). Each sample was filled into l0ml measuring cylinder. The bottom of the cylinder was gently tapped on a laboratory bench until there is no further diminution of the sample after filling to l0ml mark. Bulk density was estimated as mass per unit volume of the sample (g/ml).

2.4 Evaluation of functional properties of the breakfast cereals
The water and fat absorption capacities, foam and emulsification capacities as well as gelatinization temperature, wettability and viscosity of the breakfast cereals were determined using the methods described by Onwuka (2005). Oswald viscometer was used to measure the viscosity of 10% of each sample, which was suspended in distilled water and mechanically stirred for 2 hours at room temperature

2.5 Invitro-protein digestibility determination
The invitro-protein digestibility of each sample was determined using the method described by Kanu et al. (2009).

2.6 Experimental design and statistical analysis
The experiment followed a completely randomized design (CRD). One way analysis of variance (ANOVA) was conducted, and the means were separated by Duncan's new multiple range test (DNMRT) using the Statistical Package for Social Sciences (SPSS) version 16. The level of significance was accepted at 0.05 probability level.

3. Results and Discussion
3.1 Physical properties of the breakfast cereals
The physical properties of the developed breakfast cereals are shown in figures 2 and 3.
3.1.1 pH.
The pH values of the products (Fig. 2) which ranged from 4.70$\pm$0.01 to 6.56$\pm$0.01 showed that there were no significant ($p>0.05$) differences between samples 70:30, 60:40 and 50:50 (African yam bean-maize composite: defatted coconut flour formulations), as well as between samples 90:10 and 80:20 (African yam bean-maize composite: defatted coconut flour formulations), while there was significant ($p<0.05$) difference in the pH of 100:0 formulation and the other samples. Agunbiade and Ojezele, (2010) recorded 4.88 for pH of fortified breakfast cereal from maize, sorghum, AYB and soybeans. The low acid pH range observed in this study may be due to partial hydrolysis which probably occurred during soaking of the legume. The higher pH values recorded for the samples with high level of defatted coconut flour (20-50%) may be as a result of the low acid nature of coconut, whose pH ranges from 5.5 to 7.8 (Anon, 2013). Food products developed with coconut flour provide health benefits like lowering of blood cholesterol or preventing cancer, aside from its nutritional contribution (Capanzana, et al., 2013). The high pH value of these breakfast cereals will help to balance the consumer's body pH. McCarron, (2011) reported that eating low acid foods will help to avoid or at least lessen the likelihood of encountering many health problems associated with an overly acidic system that are linked to heart disease, obesity, cancer, fatigue, allergies and premature aging.
3.1.2 Bulk density.
The bulk density of the breakfast cereals (Fig. 3) ranged from 0.17$\pm$0.01g/ml to 0.29$\pm$0.01g/ml with the highest value found in the sample 100:0 formulation. There was a gradual reduction of the bulk density with increase in the addition of defatted coconut flour content although samples 90:10, 80:20, 70:30 (African yam bean-maize composite: defatted coconut flour) were not significantly ($p>0.05$) different from each other. Higher values of bulk density (2.45$\pm$0.10 and 2.60$\pm$0.05) were recorded by Agunbiade and Ojezele, (2010) for fortified breakfast cereals made from maize, sorghum, AYB and soybeans. Sivetz and Desrosier, (1979) reported bulk density ranges of 0.31–0.40g/ml and 0.20–0.43 g/ml for roasted ground coffee and instant coffee powder respectively. The bulk densities suggest that the samples may require different packaging space. The less the bulk density, the more packaging space is required (Agunbiade and Ojezele, 2010). However, Rao, (2007) observed that considerable variation in the magnitudes of bulk densities can result due to vibration, different particle sizes, and other factors. Sivetz and Desrosier, (1979) further revealed that due to the presence of greater wall support, the bulk density of roasted and ground coffee is lower in vessels less than 30 cm than in larger diameter vessels, while finer grinds form denser beds. The dielectric loss factor of granulated foods has been shown to be dependent on bulk density (Calay et al., 1995). Sahin and Sumnu, (2006) established a directly proportional relationship between them, hence, the lower the bulk density, the lower the loss factor observed.

3.2 Functional properties of the breakfast cereals
The functional properties of the breakfast cereals are presented in Table 2 and Figs. 4-7.
3.2.1 Water absorption capacity (WAC).
The water absorption capacity (WAC) of the formulated breakfast cereals (Table 1) ranged from 68.31$\pm$0.01 to 76.39$\pm$0.01%. The WAC increased with increase in defatted coconut flour inclusion. This may be due to the hygroscopic properties of coconut, thus, swelling on exposure to moisture (Wasserman, 2010). Similar values

were recorded from treated and untreated sorghum and pigeon pea breakfast cereals (Mbaeyi, 2005). On the other hand, water absorption capacity of the breakfast cereals may equally be associated with the nature of starch granules after toasting. According to Greer and Stewart (1959), water absorbtion capacity is influenced by the degree of disintegration of native starch granules. Considering the temperature of toasting that was approximately 280ºC and variation of starch content of each formulation with increasing addition of coconut fiber, damaged starch is likely to increase and will require more fluid such as water or milk on reconstitution.

3.2.2 Oil absorption capacity.

The oil absorption capacity (FAC) of the breakfast cereals (Table 1) varied in trend as those obtained for water absorption capacity. The values ranged from 0.87$\pm$0.01to 1.32$\pm$0.01% with the highest value recorded for the 100:0 formulation. There were significant differences ($p<0.05$) among all the samples. The FAC decreased with increasing addition of defatted coconut flour. The hydrophobicity of proteins is known to play a major role in fat absorption. This helps to resist physical entrapment of oil by the capillary of non-polar side chains of the amino acids of protein molecules (Chau and Cheung, 1998).

3.2.3 Foam capacity

The foam capacity of the samples (Table 1) ranged from 2.48$\pm$0.01 to 3.49$\pm$0.01% with the highest value observed with 100:0 formulation. There was a gradual decrease in foam capacity with increasing addition of defatted coconut flour. This value was higher than those recorded for flour obtained from boiled AYB (1.98%). Padmashree *et al*. (1987) also reported the decreasing effect of processing conditions on foam capacity with processed cowpea flour. The more pronounced reduction in foam capacity in heat-treated (boiling and roasting) sample has been attributed to protein denaturation (Lin et al., 1974). It is also an indication of precipitation of proteins due to temperature and some heat treatment.

3.2.4 Viscosity

The viscosity of the products (Table 1) ranged from 19.73$\pm$0.01 to 31.08$\pm$0.01cps, with the 50:50 formulation having the least value. The viscosity of the breakfast cereals decreased with increasing addition of defatted coconut flour. The generally low viscosity observed may be due to less disruption of intermolecular hydrogen bonds that brought about noticeable swelling of the granules and gelation (Ihekoronye and Ngoddy, 1985). Swelling of the granules was observed to be slight in cold water, compared to when placed in hot water. The breakfast cereals would be consumed depending on preferences or situations in various ways such as in cold water, hot water, cold and hot milk. The presence of defatted coconut flour enhanced water absorbtion and softening of the breakfast cereals. This is supported by Wasserman (2010), who reported that coconut fiber has a high water absorption capacity and easily dissolves in liquids, but does not thicken or gel.

3.2.5 Wettability

The wettability test in Fig. 4 showed that the particles of the formulated samples were totally hydrated between 15.67 to 23.22 seconds. This may be due to the small particle sizes of the samples, as well as the hygroscopic nature of the defatted coconut flour, which hastened hydration of the samples. The breakfast cereals wettability increased by allowing more water penetration within its matrix with increasing addition of defatted coconut flour. This may be due to increased fiber content that has been shown to retain water (Biswas et al., 2011), as a result of added defatted coconut flour. The toasting process and continuous stirring which helped to dehydrate and agglomerate the particles upon gelatinization into small aggregates also contributed in making them to be readily covered by fluid during rehydration. The particles sank, absorbed water and dispersed upon stirring. Hence, the characteristics such as wettability, sinkability, dispersibility, and solubility required from instantized products (APV, 2000; Hogekamp and Schubert, 2000), were met within some seconds.

3.2.6 Gelation temperature

The gelation temperature of the breakfast cereals in Fig. 4 ranged from 121^{o}C to 157^{o}C. Gelation temperature of the samples generally decreased with increasing addition of defatted coconut flour. Increasing fiber content appears to delay gelation and subsequently its temperature, implying that lesser amount of energy will be spent in processing the samples with higher levels of coconut fibre addition. However, Wasserman, (2010) observed that defatted coconut; even when dissolved in water does not thicken or gel. Thus, higher heat energy is required to attain significant gelation. Gelling temperature might be associated with the relative ratio of amylase and amylopectin (Ayenor, 1985), in the composite flour. Case et al. (1996) reported that waxy and regular maize gelatinize at 62-72°C, whereas high-amylose starches begin to swell below 100°C, temperatures greater than 130°C are required to fully disperse these starches. This is because more amylose molecules are involved in the crystalline regions of the high amylose starch than in waxy and regular starches (Shi et al., 1998). Case et al. (1996) equally observed that low amylopectin starch formed acceptable gels throughout the temperature ranges of 250 to 330°F.

3.2.7 Emulsification capacity

The emulsification capacity (EC) of the samples in Fig. 4 revealed values ranging from 5.77 to 7.41%, with the highest value recorded for 100:0 formulation. Addition of defatted coconut flour led to reduction of the emulsification capacity. The EC is the ability of proteins to diffuse at the oil-water interface and to develop interlinkages with water and hydrophilic amino acids and oil with hydrophobic amino acids simultaneously (Asharaf et al., 2012). The disparity in the EC values could be a reflection of their content of protein molecules that hangs oil and water droplets. The lower EC values of other samples could be as a result of their lower protein contents, which decreased from 18.26% in the control to the least value of 15.68% in 50:50 sample (Okafor and Usman, 2013)**.** On the other hand, Arawande and Borokini, (2010) reported emulsion capacities of 71.73±0.44%, 28.73±0.12% and 46.40±0.22% for Jack bean, pigeon pea and cowpea respectively, with corresponding protein contents of 26.20±0.40 %, 24.46±0.32% and 24.13±0.31%.

3.2.8 In-vitro protein digestibility

The invitro-protein digestibility shown in Fig. 5, ranged from 66.30±0.01 to 82.2±0.01%. The 50:50 formulation had the highest digestibility value. Invitro-protein digestibility reveals the dynamics of protein breakdown, which equally expresses the usefulness of the food to the body relative to its protein quality Sultana *et al.* 2010. The values recorded in this study shows that more protein was digested with increasing addition of coconut flour. This may be connected to the fact that fiber is known to aid digestion, and this might have led to the increase in digestibility of the proteins. Brulé and Savoie, (1988) studied the invitro protein digestibility of casein, field peas, peanut meal, wheat flour, rapeseed and soya bean concentrate and their blends (ratio 1:1) and observed that wheat flour had the lowest *in vitro* digestibility (30% in 6 h) while the other sources had similar digestibilities (40%). Implying that combination of ingredients and production processes may increase invitro protein digestibility of the ensuing products, probably due to reduction of anti-nutritional factors amongst other factors. In-vitro protein digestibility is affected by many factors such as genotype, tannin content (Elsheikh et al., 1999) and thermal treatment (Wu et al., 1974) that makes proteins better available after heat treatment due to increased accessibility of protein to enzymatic attack (Van der Poel, 1990). On the other hand, the low digestibility of bean proteins has been attributed to factors such as the resistance of the major storage protein (phaseolin) to proteolysis and to the presence of fibre, tannins and other polyphenolic compounds in dry seeds, anti-nutritional compounds which can modify the digestibility, (Aw and Swanson, 1985) altering the liberation of amino acids and high excretion of endogenous nitrogen. The high level of invitro protein digestibility of the samples indicates the bioavailability of their proteins critical for the supply of amino acids in the products as well as their utilization on consumption.

4. Conclusion

Addition of defatted coconut flour to the formulation increased the pH value of the breakfast cereals. The bulk density reduced with increase in the addition of defatted coconut flour content although the samples 90:10, 80:20, 70:30 (African yam bean-maize composite: defatted coconut flour) formulations were not significantly ($p>0.05$) different from each other. The WAC increased with increase in defatted coconut flour inclusion. The FAC decreased with increasing addition of defatted coconut flour. The foam capacity, gelation temperature, emulsification capacity and viscosity of the breakfast cereals decreased gradually with increasing addition of defatted coconut flour. Wettability of the breakfast cereals increased with increasing addition of defatted coconut flour. The values recorded in this study shows that more protein was digested with increasing addition of coconut flour. These physical and functional properties of the products could influence their acceptability and efficient utilization.

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Table 1. Functional properties of breakfast cereals from blends of AYB+maize: defatted coconut flour

Sample	WAC (%)	FAC (%)	FC (%)	Viscosity (cps)	GC (%)
100:0	68.32 ± 0.01^{f}	1.32 ± 0.01^{a}	3.49 ± 0.01^{a}	31.08 ± 0.01^{a}	89.66 ± 0.01^{a}
90:10	70.29 ± 0.01^{e}	1.13 ± 0.01^{b}	3.43 ± 0.01^{a}	30.56 ± 0.01^{a}	84.29 ± 0.01^{b}
80:20	71.24 ± 0.01^{d}	1.07 ± 0.01^{c}	3.25 ± 0.01^{ab}	26.41 ± 0.01^{b}	81.4 ± 30.01^{c}
70:30	74.81 ± 0.05^{c}	0.96 ± 0.01^{d}	2.80 ± 0.01^{b}	24.22 ± 0.01^{c}	78.56 ± 0.01^{d}
60:40	75.43 ± 0.01^{b}	0.93 ± 0.01^{e}	2.63 ± 0.01^{e}	21.98 ± 0.01^{d}	77.34 ± 0.01^{e}
50:50	76.39 ± 0.06^{a}	0.87 ± 0.01^{f}	2.48 ± 0.01^{f}	19.73 ± 0.01^{e}	75.32 ± 0.01^{f}

Values are means ±SD of triplicate determinations. Means differently superscripted along the vertical columns are significantly different ($p<0.05$).

Sample ratio: AYB+ Maize**:** defatted coconut fiber
WAC: water absorption capacity FAC: oil absorption capacity
FC: foam capacity GC: gelation capacity

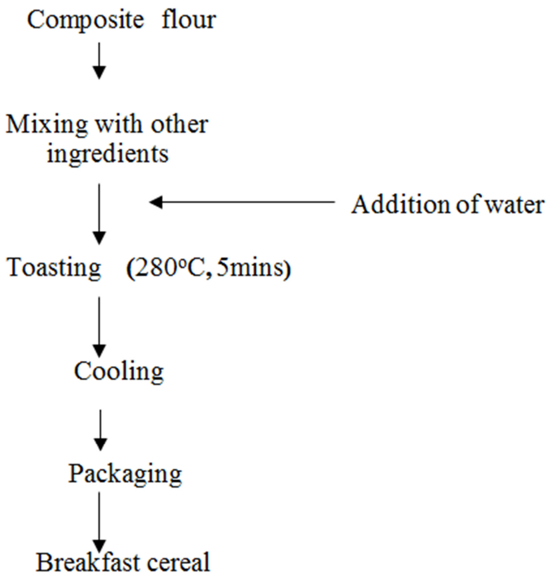

Figure 1. Production of breakfast cereals from blends of African yam bean + maize: defatted coconut flour

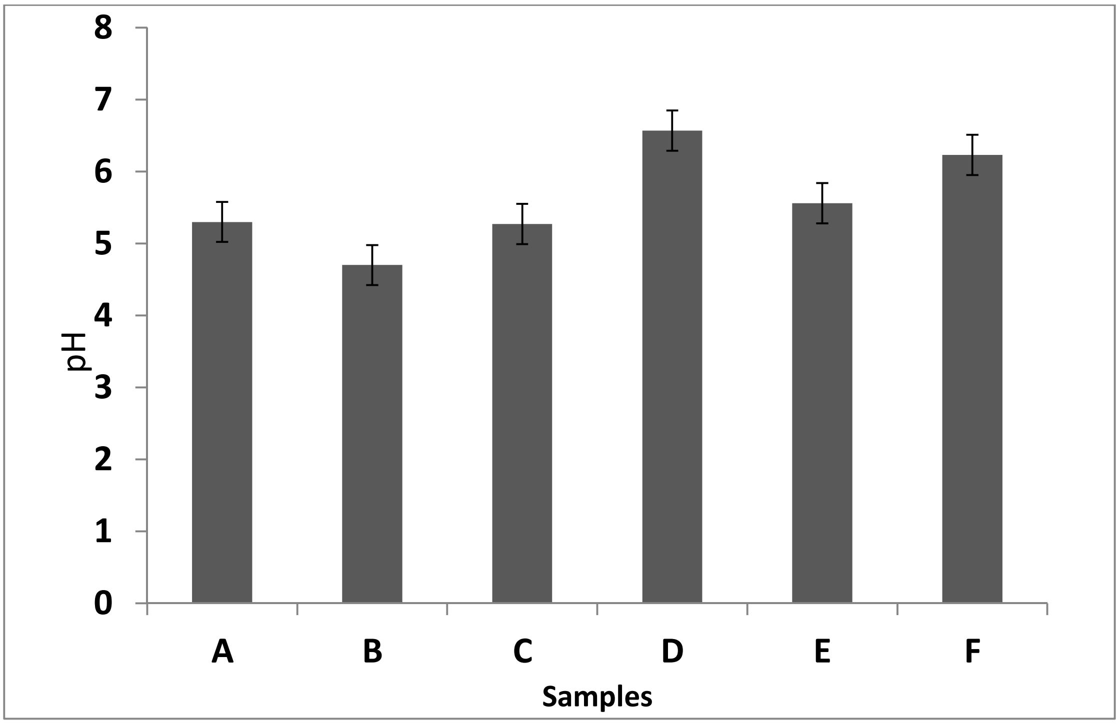

Figure 2. pH values of breakfast cereals from blends of AYB+Maize: coconut fiber
LEGEND
A= 100:0 B=90:80 C=80:20 D=70:30 E=60:40 F=50:50
Sample ratio: AYB+Maize: Defatted coconut flour

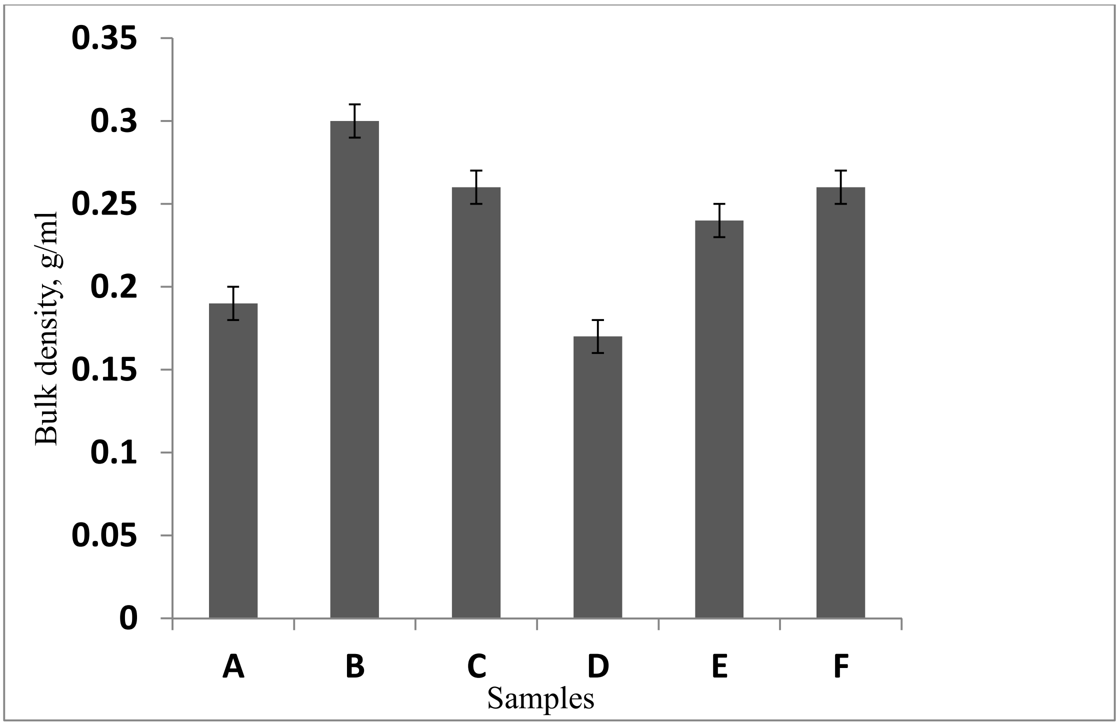

Figure 3. Bulk density of breakfast cereals from blends of AYB+Maize: coconut fiber

LEGEND
A= 100:0 B=90:80 C=80:20 D=70:30 E=60:40 F=50:50
Sample ratio: AYB+Maize: Defatted coconut flour

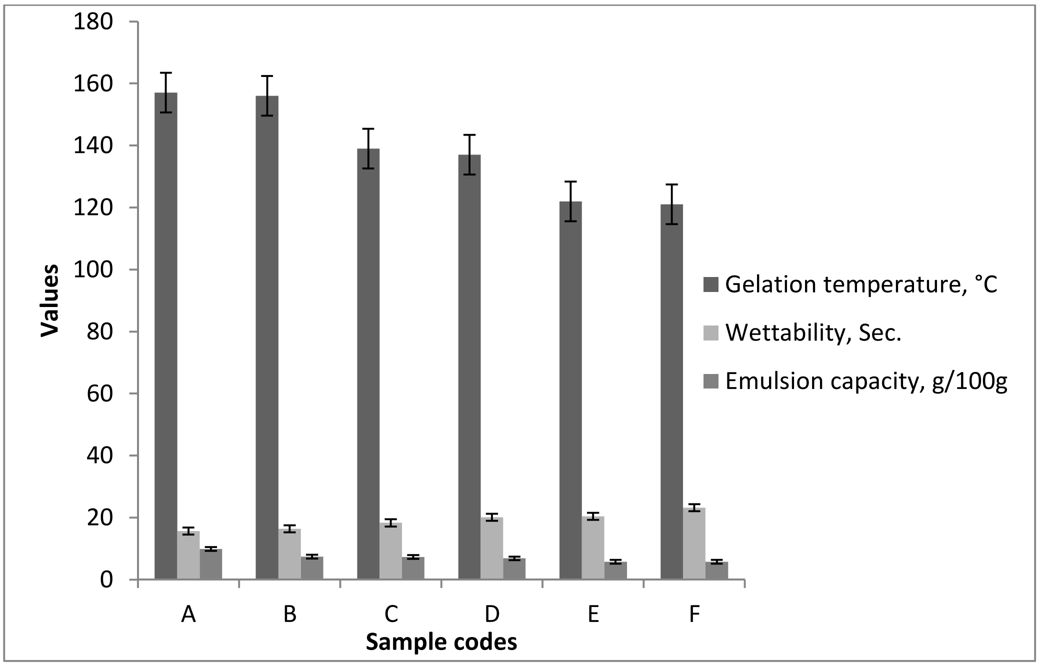

Figure 4. Some functional properties of breakfast cereals from blends of Maize+ AYB: coconut fiber

LEGEND
A= 100:0 B=90:80 C=80:20 D=70:30 E=60:40 F=50:50
Sample ratio: AYB+Maize: Defatted coconut flour

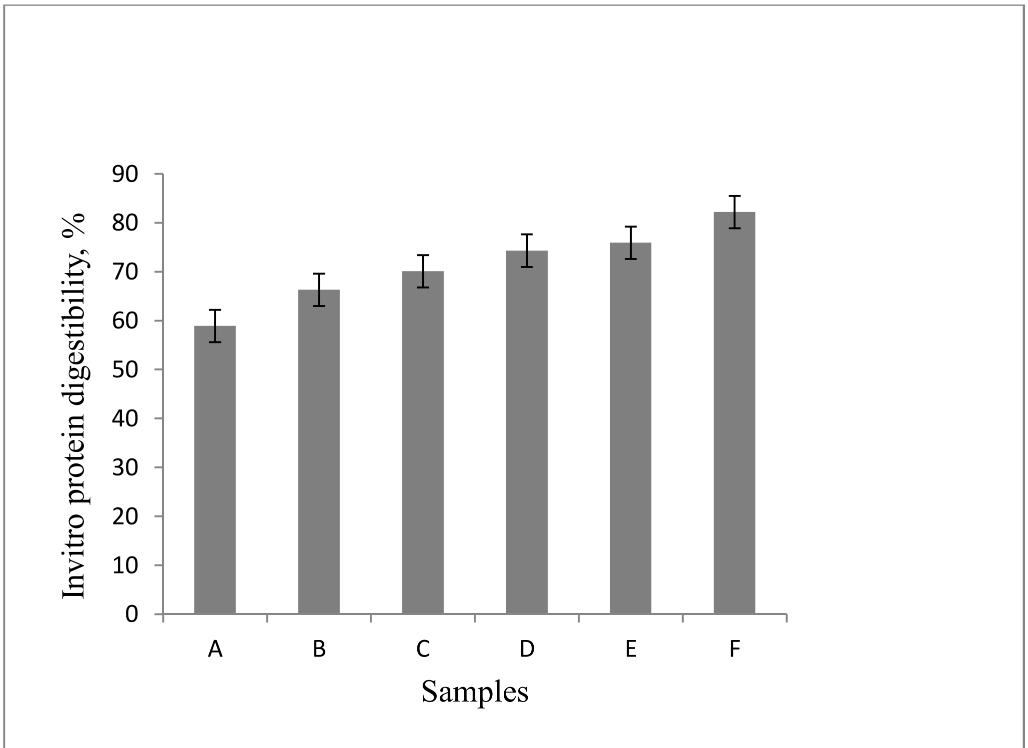

Figure 5. In-vitro protein Digestibility values obtained for formulated Breakfast Cereal samples.
LEGEND
A= 100:0 B=90:80 C=80:20 D=70:30 E=60:40 F=50:50
Sample ratio: AYB+Maize: Defatted coconut flour