Croatian Journal of Food Science and Technology
journal homepage: www.ptfos.unios.hr/cjfst/

Original scientific paper *DOI: 10.17508/CJFST.2019.11.1.03*

Evaluation of nutritional composition, functional and pasting properties of wheat flour-coconut flour blends

FOLASADE MARIA MAKINDE*, AYOBAMI OPEYEMI EYITAYO

Bowen University, Faculty of Agriculture, Department of Food Science and Technology, Iwo, Osun State, Nigeria

ARTICLE INFO

Article history:
Received: February 19, 2018
Accepted: January 18, 2019

Keywords:
wheat,
coconut,
nutrient,
pasting properties,
functionality

ABSTRACT

The feasibility of partially replacing wheat flour with coconut flour in baked products was investigated. Matured coconut (*Cocos nucifera*) endocarp was grated for extraction of milk, dried, milled and pulverized. Five blends of composite flour were prepared by combining wheat flour with 10% to 50% partially defatted coconut flour respectively. The 100% wheat flour served as control. The samples were analyzed for proximate, mineral, functional and pasting properties using standard procedures. Proximate analysis indicated 5.52 % moisture, 23.6% protein, 11.14% fiber, 5.4% fat, 5.21% ash and 49.1% carbohydrate for coconut flour. The ranges of proximate composition of flour blends were moisture (4.79-5.55%), protein (14.9 -19.1%), fiber (0.44 - 5.12%), fat (2.9 -5.3%), ash (0.68-2.13%), carbohydrate (62.7-76.2%) and energy (315.26-335.28 kCal). The values for moisture, protein, fat, fibre and ash increased with increasing levels of coconut substitution except for carbohydrate and energy contents. There were significant differences ($p \leq 0.05$) in calcium, magnesium, potassium, phosphorus, iron and zinc concentrations of the samples. Values obtained for these parameters ranged from 1.32-2.59 mg/kg, 2.60-3.83 mg/kg, 12.10-16.89 mg/kg, 12.40-18.50 mg/kg, 0.50-1.22 mg/kg and 0.30-1.23 mg/kg, respectively. The ranges of functional properties were loosed bulk density (0.28-0.49 g/mL) packed bulk density (0.44-0.75 g/mL), pH (5.77-6.57), swelling capacity (3.89-6.56%), water absorption capacity (0.89-3.97 ml/g),oil absorption capacity (1.26-3.20 ml/g) and gelation (12.0-18.0%). Pasting characteristics showed significant differences between 100% wheat flour and coconut substituted samples. The results revealed modifications in nutritional, functional and pasting properties in blends containing fractions of partially defatted coconut flour which suggest their application in diverse food products.

Introduction

Oil seeds are complimentary nutrient source for human consumption and their production is an important part of agricultural economy of developing countries such as Nigeria. Primary sources of vegetable oil are: almond, canola, castor, coconut, cotton, grape, jojoba, mustard among others.
Coconut (*Cocus nucifera*) is commonly known and regarded as perfect diet because it contains several biologically active components namely sugars, proteins, free amino acids, vitamins, minerals and growth promoting factors (Kaliyamoorthy et al., 2015). Coconut is an important source of vegetable oil that can be eaten and also used industrially for the production of various products. Coconut flour is a product obtained from dried coconut meat that has been hygienically defatted and milled into fine powdery form. Research has shown that the coconut flour contains high fiber (Trinidad et al., 2001) and protein content (Chakraborty, 1985) which can make up for low protein and fiber content in various foods. Coconut is however naturally low in digestible carbohydrate and contains no gluten (Ramaswamy, 2014). Refined flours are concentrated in simple carbohydrates which are rapidly metabolized and cause destructive blood sugar fluctuations in the

*Corresponding author E-mail: sademakin@yahoo.com

body. In opposition to this, coconut flour has been found to have a glycemic lowering effect, because coconut meat has simple carbohydrate content coupled with a high fiber; it yields flour that is less disruptive to blood sugar levels (Ramaswamy, 2014). Most importantly, it is believed as a "nutraceutical food" because it provides many health benefits beyond its nutritional content.

The identified qualities of coconut flour are indeed an advantage especially for local industries to partially or completely substitute wheat flour. Coconut plays an important role in the economy of Nigeria. Coconut production in Nigeria in 2014 was estimated at 267,520 tonnes (FAOSTAT, 2013), representing 0.04% of the world production. Meanwhile, wheat, the basic ingredient in baked goods is imported into Nigeria involving huge expenditure of foreign exchange as reported by Igbabul et al. (2014). The importance of wheat flour is mainly due to the fact it has unique ability to form a cohesive gluten network when worked with water. However, the continued increase in demand for confectioneries has necessitated the use of available local raw materials as substitutes for wheat flour. It is worthy to note that as little as 5% substitution of wheat flour with coconut flour has the potential not only to reduce wheat importation paid with scarce foreign currency in Nigeria, but also a nutritious and healthy source of dietary fiber.

Having considered the potentials of coconut flour as a food ingredient, it is important to note that its combination with other flour (composite flour) in preparation of starchy meals often alter their compositions, and may therefore change the functional properties and pasting characteristics of the final product. Therefore, this research was conducted to assess the nutritional composition, functional and pasting properties of wheat-coconut composite flour with the view to expanding the utility of coconut.

Materials and methods

Materials

Mature seeds of coconut (*Cocos nucifera)* were purchased from a local market in Iwo, Osun State, Nigeria. Refined wheat flour was procured from Nigeria Flour Mills, Lagos, Nigeria. All reagents used were of analytical grade.

Sample preparation

Dehusked coconuts were manually cracked and the endocarp detached using a knife. The endocarp was grated using manual grater. The grated portion was made into smooth paste using laboratory Moulinex blender and the milk separated using muslin cloth. The residue was dried in an air oven at 60°C for 10 h, to a moisture content of 7%. The dried coconut residue lumps were milled using Brabender roller mill (Brabender, Germany). The resulting partially defatted coconut flour was stored in a glass container at room temperature until needed.

Preparation of flour

Different mixtures of wheat flour and coconut flour were used in this study. Partially defatted coconut meal flour was mixed with wheat flour at the levels of 10%, 20%, 30%, 40% and 50% as shown in Table 1 while 100% wheat flour served as the control.

Table 1. Blends of wheat flour and coconut flour used in composite flour formulation

Sample	Wheat flour (%)	Coconut flour (%)
A	100	0
B	90	10
C	80	20
D	70	30
E	60	40
F	50	50

Analyses

Proximate composition

The proximate composition of the wheat flour, coconut flour and composite samples were determined using standard procedures (AOAC, 2012). Carbohydrate content was determined by difference. The energy value was estimated (kcal/g) by multiplying the percentage crude protein, crude lipid and carbohydrate by the recommended factor (2.44, 8.37 and 3.57 respectively) as described by Ekanayake *et al*. (1999).

Mineral composition

Ash was determined by combustion of the sample in a muffle furnace at 550°C for 12 h (AOAC, 2012). The residue was dissolved in HNO_3 with 50 g/L of $LaCl_3$ and the mineral constituents (Ca, K, Mg, Fe and Zn) were analyzed separately, using an atomic absorption spectrophotometer (Hitachi Z6100, Tokyo, Japan). Phosphorus content (P) was determined by the phosphomolybdate method (AOAC, 2012).

Determination of functional properties

Bulk density (loose and packed); water and oil absorption capacities and swelling power were determined using the procedures described by Sasulki *et al*. (1996). The pH of the samples was measured with a pH meter. Each sample (10g) was homogenized in 50 ml of distilled water. The resulting suspensions were decanted and pH determined using pH meter already standardized with buffer solutions of pH 4.0 and 7.0. Least gelation capacity was determined by preparing sample suspensions of 2-20% (dry w/v) in 10mL of deionised water and mixed thoroughly. The slurries were heated in capped test tubes in water at 95± 2ºC for 1h. The tubes were immediately cooled in tap water for 30 sec to accelerate gel formation. Least gelation concentration (%) was determined as the concentration above which the sample remained in the bottom of the inverted tube.

Determination of pasting properties

The pasting behaviour was measured in a Rapid Visco Analyzer (Model: RVA-4, Newport Scientific Pty. Ltd., Sydney, Australia, 1995) and Thermocline for windows software was used to evaluate the pasting properties. Viscogram profile/pasting curves show the relationships between time, viscosity, and temperature during cooking processes.

Statistical analysis

Determinations were carried out in triplicates and the error reported as standard deviation from the mean. Analysis of Variance (ANOVA) was performed and the least significant differences were calculated with the SPSS software for window release 16.00; SPSS Inc., Chicago IL, USA. Significance was accepted at $p \leq 0.05$ levels.

Results and discussion

Proximate composition

The proximate composition of wheat flour and coconut flour are given in Table 2. The protein, fat, ash, fiber and moisture value of coconut flour was 23.6%, 5.4%, 5.21%, 11.14 and 5.52%, respectively. According to Arancon (1999), nutrient composition of coconut flour was reported as; protein 13.41%, moisture 2.80%, 10.23% fat and 19.3% fiber. The variation could be explained by the fact that the nutritional quality of coconut flour depends on the components retained after the extraction of coconut milk or oil from coconut residue. Meanwhile, wheat flour contained protein 14.9%, moisture 4.79%, fat 2.9% and 0.44% fiber. In general, coconut flour indicated higher levels of protein, ash, fiber and fat compared to wheat flour.

The proximate composition of wheat-coconut flour blends are shown in Table 3. There was an increase in the moisture content of the composite flour samples with defatted coconut flour substitution in the range of 5.07 to 5.55% compared to the control (4.79%). The crude protein content of wheat flour was the least, while the blends containing defatted coconut flour had higher protein content. This showed that the addition of coconut flour resulted in increase in the protein content of the composite flours. Gunathilake et al. (2009) also reported that partial substitution of wheat flour by non-wheat flours, such as coconut, increases the protein content. Defatting of coconut meal has the potential of increasing its protein content because the crude fat and soluble carbohydrates were removed in the extraction process. According to Zeleney (1971) a minimum protein content of 11.0% in wheat flour is necessary for the production of yeast-leavened baked goods. The importance of the protein level was due to its gluten fraction in that gluten was responsible for the elasticity of the dough by causing it to extend and trap the carbon dioxide generated by yeast during fermentation. When gluten coagulates under the influence of heat during baking, it serves as the framework of the loaf, which becomes relatively rigid. Coconut flour contained no gluten and consequently could not be used solely for baked goods that require leavening. When used, however, a limit of substitution level with wheat flour was necessarily imposed on the extent to which the flour could be used as a substitute for wheat flour. Similarly, the fat content of the blends increased as the proportion of coconut flour increased. The reported 5.4% fat content of coconut flour per 100 g sample contributed to the significantly ($p \leq 0.05$) 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). It is however imperative to note that the fat content of the flour samples was low which points to the fact that they could be stored for a long period without the problem of peroxidation which is a major cause of fat instability. The ash content of the samples increased significantly ($p \leq 0.05$) with increased level of coconut flour inclusion in the blends which points to the fact that they are good sources of mineral matter. The fiber content of the blends ranged from 0.44% to 5.12%. Similarly, the fibre content increased significantly ($p \leq 0.05$) with increased level of coconut flour inclusion in the blends. The partial substitution of wheat flour by defatted coconut flour also increased the fibre content of biscuits as reported by Sujirtha and Mahendran (2015). Coconut flour is extremely high in fibre with almost double the amount found in wheat bran as reported by Ramaswamy (2014). Most importantly, due to the high fibre content, coconut flour does not spike blood sugar as quickly as grain- based flours. Low glycemic index food e.g. high dietary fibre food, has been shown to reduce post-prandial blood glucose and insulin responses and improve the overall blood glucose and lipid concentrations in normal subjects (Collier *et al*., 1988). Dietary fibre's viscose and fibrous structure can control the release of glucose with time in the blood, thus helping in the proper control and management of diabetes mellitus and obesity (Jenkins et al., 1982). Although raw grains are high in fibre, common food refinement processes altogether obliterate this content resulting in loss in refined flours. As a result of the discrepancy, food manufacturers and pharmaceutical companies now market laboratory prepared fibre additives for flour enrichment and supplementation programs. In essence, coconut flour could serve as cheap source of wholesome fibre in human diet. The carbohydrate content of the wheat flour was the highest, while the blends containing coconut flour had lower carbohydrate contents. The energy values of the samples shown ranged from 315.26 to 335.28 kCal, with the blend containing 50% coconut flour being the least, while the blend containing 10% coconut flour had the highest value. The higher energy value of wheat flour compared to composite samples could be attributed to higher carbohydrate content of the wheat flour.

Mineral composition

Table 4 shows the mineral composition of wheat-coconut flour blends. Calcium content of wheat flour was 1.32mg/kg which increased gradually as the level of substitution of coconut flour was increased. Similarly, the phosphorus content of wheat flour blended with coconut flour show an increasing trend as the level of substitution increased. Maximum potassium content was recorded in the blend at a substation level of 50% (Sample F).

Table 2. Proximate composition of wheat and coconut flour samples

Sample	Moisture (%)	Protein (%)	Fiber (%)	Ash (%)	Fat (%)	Carbohydrate (%)
Wheat flour	4.79 ^{a}±0.05	14.93^{a} ±0.11	0.44^{a}±0.10	0.68^{a} ±0.02	2.92 ^{a} ±0.03	76.24^{b} ±0.12
Coconut flour	5.52^{b}±0.03	23.59^{b}±0.15	11.14^{b}±0.03	5.21^{b} ±0.05	5.43^{b} ±0.02	49.10^{a} ±0.06

Data are mean values of triplicate determination ± standard deviation. Means with different superscript within the same column differ significantly (p≤0.05)

Table 3. Proximate composition of composite flours

Sample	Moisture (%)	Protein (%)	Fiber (%)	Ash (%)	Fat (%)	Carbohydrate (%)	Energy (kCal/100g)
A	4.79±0.05^{a}	14.93±0.11^{a}	0.44±0.10^{a}	0.68±0.02^{a}	2.92±0.03^{a}	76.24±0.12^{f}	333.05±0.13^{e}
B	5.07±0.03^{b}	16.55±0.07^{b}	1.03±0.01^{b}	0.97±0.01^{b}	4.63±0.04^{b}	71.75±0.05^{e}	335.28±0.07^{f}
C	5.24±0.07^{c}	16.99±0.03^{c}	2.81±0.02^{c}	1.24±0.01^{c}	4.81±0.02^{c}	68.91±0.03^{d}	327.73±0.03^{d}
D	5.36±0.03^{d}	17.57±0.05^{d}	3.27±0.02^{d}	1.73±0.02^{d}	5.03±0.03^{d}	67.04±0.02^{c}	324.30±0.05^{c}
E	5.43±0.02^{e}	18.13±0.02^{e}	4.01±0.03^{e}	1.97±0.03^{e}	5.19±0.07^{e}	65.27±0.04^{b}	320.69±0.02^{b}
F	5.55±0.05^{f}	19.14±0.03^{f}	5.12±0.02^{f}	2.13±0.02^{f}	5.33±0.01^{f}	62.73±0.02^{a}	315.26±0.03^{a}

Data are mean values of triplicate determination ± standard deviation. Means with different superscript within the same column differ significantly (p≤0.05). A-100% wheat flour; B-90% wheat flour + 10% coconut flour; C-80% wheat flour + 20% coconut flour; D-70% wheat flour + 30% coconut flour; E-60% wheat flour + 40% coconut flour; F-50% wheat flour + 50% coconut flour

Table 4. Mineral concentration of composite flours (mg/kg)

Sample	Calcium	Magnesium	Potassium	Phosphorus	Iron	Zinc
A	1.32±0.03^{a}	2.60±0.01^{a}	12.10±0.09^{a}	12.40±0.11^{a}	0.50±0.02^{a}	0.30±0.03^{a}
B	1.38±0.01^{b}	2.80±0.02^{b}	12.36±0.19^{b}	14.70±0.05^{b}	0.56±0.01^{b}	0.39±0.01^{b}
C	2.30±0.01^{c}	3.21±0.03^{c}	13.04±0.14^{c}	15.50±0.07^{c}	0.64±0.01^{c}	0.51±0.01^{c}
D	2.57±0.91^{d}	3.69±0.03^{d}	14.36±0.05^{d}	16.70±0.05^{d}	0.98±0.03^{d}	0.64±0.02^{d}
E	3.32±0.02^{f}	3.77±0.01^{e}	16.60±0.03^{e}	17.40±0.07^{e}	1.12±0.01^{e}	0.80±0.02^{e}
F	2.59±0.02^{e}	3.83±0.01^{f}	16.89±0.05^{f}	18.50±0.03^{f}	1.22±0.01^{f}	1.23±0.01^{f}

Data are mean values of triplicate determination ± standard deviation. Means with different superscript within the same column differ significantly (p≤0.05). A-100% wheat flour; B-90% wheat flour + 10% coconut flour; C-80% wheat flour + 20% coconut flour; D-70% wheat flour + 30% coconut flour; E-60% wheat flour + 40% coconut flour; F-50% wheat flour + 50% coconut flour

Similarly, the magnesium content of wheat flour blended with coconut flour show an increasing trend as the level of substitution increased. The iron content of the flours ranged from 0.50 to 1.22 mg/kg. Highest iron concentration was recorded in the flour substituted with 50% coconut flour while the lowest value was recorded in the wheat flour. Similar trend was observed in biscuits formulated using defatted coconut flour as reported by Sridevi Sivakami and Sarojini (2013). The zinc content of the blends increased significantly (p≤0.05) with increased substitution with coconut flour. In effect, the substitution of wheat flour with coconut flour at a level up to 50% drastically improved the calcium, phosphorus, potassium, magnesium, iron and zinc contents of the blends. These micronutrients in coconut flour play a vital role in supporting the human body antioxidant system. It is worthy to note that hyper metabolism in human system gives rise to an increased production of free radicals, as a result of increased oxidative metabolism. Such increase in free radicals will cause oxidative damage to the various components of the human cell, especially the polyunsaturated fatty acids in the cell membrane, or to the nucleic acids in the nucleus (Evans and Halliwell, 2001). Fortunately, micronutrients have important functions in this aspect. They act directly to quench free radicals by donating electrons, or indirectly as a part of metallo enzymes (a diverse class of enzymes that require a catalytic metal ion for their biological activity) such as superoxide dismutase (zinc, copper) to catalyse the removal of oxidizing species as reported by Matsui *et al*. (2008).

Functional properties of composite flours

The functional properties of wheat-coconut composite flours are presented in Table 5.The loosed and packed bulk densities of the flour blends ranged from 0.28 to 0.49g/mL and 0.44 to 0.75 mL, respectively. Loosed and packed bulk densities of composite flour decreased with increase in the level of substitution of wheat flour with coconut flour. The observed decrease in bulk density (loose and packed) with increase in the level of substitution of wheat flour with coconut flour was significant with the increase in moisture content (Table 3). Formation of an open-bed structure supported by inter-particle forces might have resulted in decreased bulk density of the flours with increased moisture (Fitzpatrick *et al*., 2004). This decrease occurred mainly because of the increased volume of flours rather than an increase in mass. Moisture causes swelling, which means that the same mass of material occupies more volume, thus decreasing the bulk density. However, the observed low loosed bulk density of composite flours suggests their suitability in the formulation of food for babies where high nutrient density to low bulk is desired though such products will not offer packaging advantage compared to wheat flour.

Water absorption capacities (WAC) of the blends increased progressively as the level of coconut flour was increased, however, difference in the values of sample D and E was not significant (p≥0.05). The increase in WAC of blends after incorporating coconut flour may be due to increase in the amylose leaching and solubility and loss of starch crystalline structure (Suresh *et al*., 2015). Similarly, protein has both hydrophilic and hydrophobic groups and therefore they can interact with water in foods. Thus, the observed variation in different flour blends may be due to different protein concentration, their degree of interaction with water and conformational characteristics (Butt and Batool, 2010). Water absorption capacity is important with regards to the consistency of product as well as in baking applications. High WAC of composite flours suggests that the flours can be used in formulation of some foods such as sausage, dough and bakery products. Oil absorption capacity (OAC) ranged between 1.26 to 3.20mL/g among all the flours. The flour samples containing coconut flour had higher OAC values as compared to wheat flour. Similarly, oil absorption capacity values increased with increased level of coconut flour in the mixture. The possible reason for increase in the OAC of composite flours after incorporation of coconut flour could be variations in the presence of non-polar amino acid side chains of protein which might bind the hydrocarbon side chain of the oil among the flours as reported by Jitngarmkusol *et al*. (2008). This is an indication that the blends would be useful in structural interaction in food especially in flavour retention, improvement of palatability and extension of shelf life particularly in bakery or meat products where oil absorption property is of prime importance.

The swelling capacity of different flour blends ranged from 3.89% to 6.56%. It was observed that the value increased as the percentage of substitution of wheat flour with coconut flour increased. It is worthy to note that swelling capacity is an evidence of non-covalent bonding between molecules within starch granules and also a factor of the ratio of α-amylose and amylopectin ratios (Rasper, 1969). However, the swelling capacity of flours depends on size of particles, types of variety and types of processing methods or unit operations (Suresh *et al*., 2015). The pH value decreased significantly (p≤0.05) as the as the percentage of substitution of wheat flour with coconut flour increased. Sample A had the highest pH value (6.57) while sample F recorded the lowest value (5.77). The results showed that all the samples had relatively high pH values. However, it is important to note that high pH value imparts a free swelling property to starch (Lund, 1984), which corroborate increase in swelling power reported in this study. Least gelation concentration (LGC) of the flour samples ranged from 12% to 18%. The least gelation is defined as the lowest protein concentration at which gel remained in inverted tube. As the percentage of incorporation of coconut flour in wheat flour increased, gelling properties decreased. Sample A (100% wheat flour) and sample B (90% wheat flour + 10% coconut flour) formed gel at a significantly low concentration (12.0%) while samples C and D formed gel at very high concentration (16.0%). However, sample E (50% wheat flour + 50% coconut flour) required a significantly higher concentration (18.0%) for gel formation. This is an indication that gelling capacity of wheat flour reduces as the level of coconut flour substitution increases. The variation in the gelling properties may be ascribed to ratios of the different constituents such as protein, carbohydrates and lipids in different flours, suggesting that interaction between such components may also have a significant role in functional properties (Aremu et al., 2007). The lower the LGC, the better the gelling ability of protein ingredient in food formulations. Meanwhile, the observed low gelation concentration of samples E and F as composite flours may be an asset for the formation of curd or as an additive to other gel forming materials in food products.

Pasting properties of composite flour

The pasting properties of the wheat-coconut composite flour samples are shown on Tables 6. Pasting properties of these flours are important indices in predicting the pasting behaviour during and after cooking (Richard *et al*., 1991). Sample A (100% wheat flour) had the highest peak viscosity of 1349.0RVU. However, coconut flour addition significantly decreased the peak viscosity to range of 1085.0 to 1245.0 RVU. The decrease in viscosity could be due to the high fat content from coconut flour. The relatively low peak viscosity in the higher level of coconut in composite flour indicates that the flour may be suited for products requiring low gel strength and elasticity (Abioye *et al*., 2011). Results revealed that sample E recorded the highest trough viscosity (964.5 RVU) while sample B had the highest breakdown viscosity value (427.0 RVU). These properties indicate that the samples possesses the highest ability of all the blends to remain undisrupted when subjected to long periods of constant high temperature and ability to withstand breakdown during cooking respectively. The final viscosity of sample A (100% wheat flour) recorded the highest value of 2053.0 RVU. The final viscosity is the most commonly used parameters to determine a particular starch-based sample quality. It gives an idea of the ability of a material to gel after cooking. Substitution of wheat flour with coconut flour was observed to have the influence the decreasing the final viscosity values in the composite flours.

Setback viscosity values have been reported to correlate with ability of starches to gel into semi solid pastes. In these investigations set back value was highest for 100% wheat flour at 1112.5 RVU. The flour blend with 30% inclusion of coconut flour, recorded the lowest setback value of 616.0 RVU. It is important to note that high setback viscosity recorded in wheat and composite flour samples suggests their susceptibility to retrogradation. Flours produced from 10-50% substitution with coconut flour had higher peak time compared to wheat flour. Wheat flour (sample A) had higher pasting temperature of 87.63°C compared to composite flour samples. The plot of viscosity of the flour samples against heating time was as shown in Fig.1, Fig. 2, Fig. 3, Fig. 4, Fig. 5 and Fig. 6 respectively. The variations in these values could be attributed to the differences in chemical constituents of starch and the nature of bonding within the starch structure as reported by Radley (1976).The study revealed that partial substitution of wheat with coconut flour significantly affect the pasting properties of the composite flours and clearly reflected the sensitivity of wheat starch to that of coconut flour.

Table 5. Functional properties of composite flour

Sample	Bulk density (g/mL) Loosed	Bulk density (g/mL) Packed	WAC (mL/g)	OAC (mL/g)	SC (%)	GC (%)	pH
A	0.49±0.03^{e}	0.75±0.03^{d}	0.89±0.04^{a}	1.26±0.44^{a}	3.89±0.44^{a}	18	6.57±0.16^{c}
B	0.42±0.03^{d}	0.59±0.01^{c}	1.33±0.32^{ab}	1.58±0.24^{ab}	4.53±0.32^{ab}	16	6.16±0.03^{b}
C	0.37±0.02^{cd}	0.57±0.02^{c}	2.26±0.36^{bc}	2.08±0.21^{bc}	5.41±0.36^{abc}	14	5.95±0.04^{ab}
D	0.34±0.02^{c}	0.51±0.01^{b}	2.36±0.61^{c}	2.34±0.05^{c}	5.67±0.69^{abc}	14	5.88±0.09^{a}
E	0.30±0.02^{ab}	0.45±0.01^{a}	2.45±0.06^{c}	2.37±0.06^{c}	6.29±0.74^{bc}	12	5.84±0.03^{a}
F	0.28±0.01^{a}	0.44±0.01^{a}	3.97±0.37^{d}	3.20±0.37^{d}	6.56±1.01^{c}	12	5.77±0.04^{a}

Data are mean values of triplicate determination ± standard deviation. Means with different superscript within the same column differ significantly (p≤0.05). WAC-Water absorption capacity; OAC-Oil absorption capacity; SC- Swelling capacity; GC-Gelation capacity. A-100% wheat flour; B-90% wheat flour + 10% coconut flour; C-80% wheat flour + 20% coconut flour; D-70% wheat flour + 30% coconut flour; E-60% wheat flour + 40% coconut flour; F-50% wheat flour + 50% coconut flour.

Table 6. Pasting properties of composite flour

Sample	Peak Viscosity (RVU)	Trough Viscosity (RVU)	Breakdown Viscosity (RVU)	Final Viscosity (RVU)	Setback Viscosity (RVU)	Pasting Time (min)	Pasting Temperature (ºC)
A	1349.0±4.32^{f}	940.5±6.19^{e}	408.5±1.93^{e}	2053.0±6.22^{f}	1112.5±5.13^{f}	5.97±0.03^{f}	87.63±0.32^{f}
B	1245.0±3.29^{d}	818.0±4.03^{c}	427.0±1.13^{f}	1684.5±4.33^{c}	866.5±1.11^{c}	5.70±0.02^{e}	87.20±0.44^{d}
C	1125.0±4.01^{b}	750.5±4.77^{a}	374.5±1.12^{d}	1434.0±3.97^{b}	683.5±1.07^{b}	5.47±0.04^{d}	86.83±0.13^{c}
D	1085.0±3.66^{a}	775.0±5.16^{b}	310.0±0.93^{b}	1391.0±6.02^{a}	616.0±1.23^{a}	5.27±0.02^{c}	87.58±0.41^{e}
E	1291.5±5.01^{e}	964.0±3.33^{f}	327.5±0.87^{c}	1846.0±4.11^{d}	822.0±0.97^{d}	5.20±0.03^{b}	77.45±0.22^{b}
F	1204.0±4.67^{c}	927.0±4.01^{d}	277.0±0.33^{a}	1903.0±3.77^{e}	976.0±0.99^{e}	4.97±0.02^{a}	65.65±0.50^{a}

Data are mean values of triplicate determination ± standard deviation. Means with different superscript within the same column differ significantly ($p \le 0.05$). A-100% wheat flour; B-90% wheat flour + 10% coconut flour; C-80% wheat flour + 20% coconut flour; D-70% wheat flour + 30% coconut flour; E-60% wheat flour + 40% coconut flour; F-50% wheat flour + 50% coconut flour

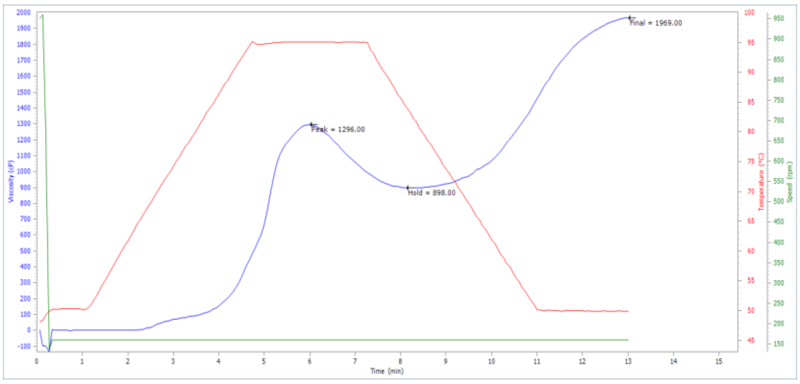

Fig. 1. Influence of heating time on the viscosity of sample A (100% wheat flour)

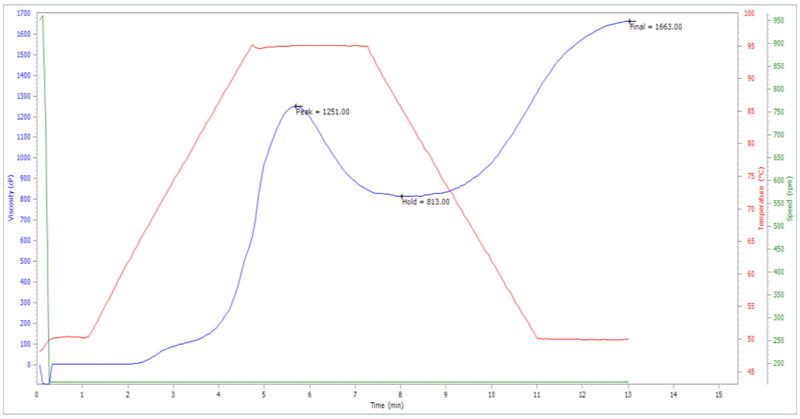

Fig. 2. Influence of heating time on the viscosity of sample B (90% wheat flour and 10% coconut flour)

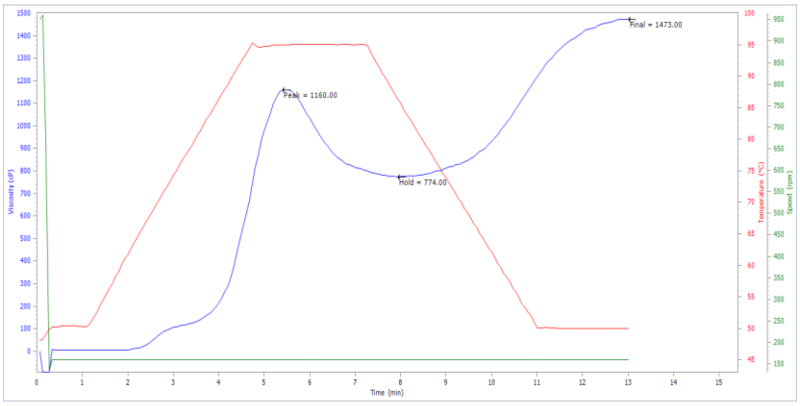

Fig. 3. Influence of heating time on the viscosity of sample C (80% wheat flour and 20% coconut flour)

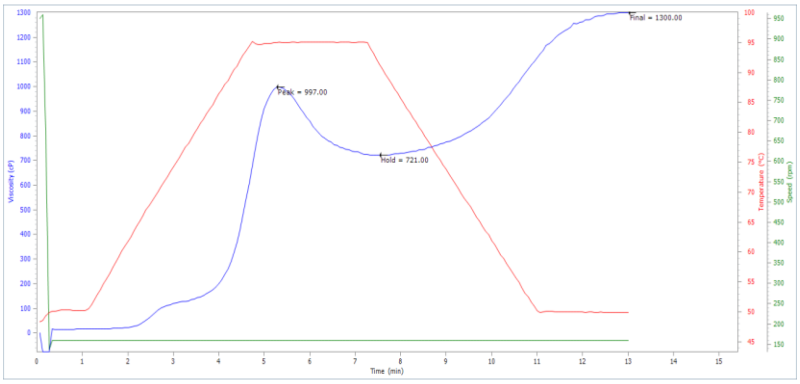

Fig. 4. Influence of heating time on the viscosity of sample D (70% wheat flour and 30% coconut flour)

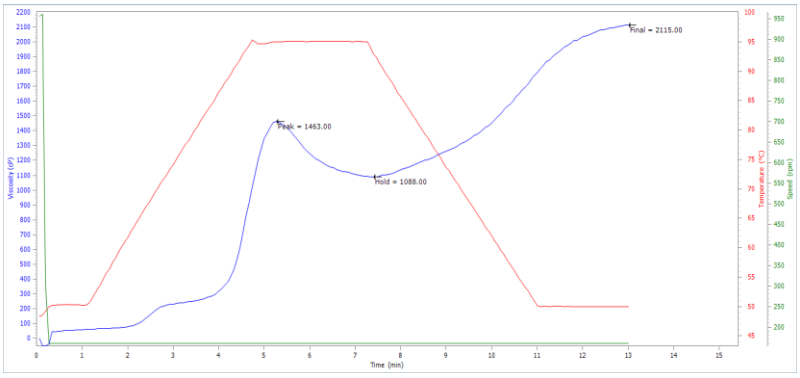

Fig. 5. Influence of heating time on the viscosity of sample E (60% wheat flour and 40% coconut flour)

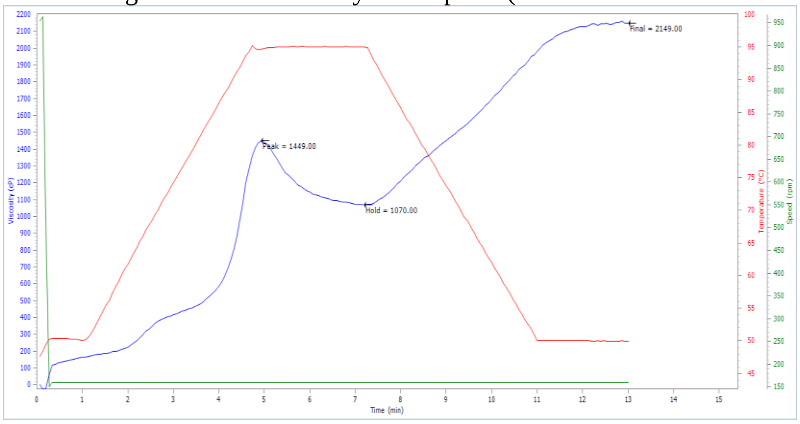

Fig. 6. Influence of heating time on the viscosity of sample F (50% wheat flour and 50% coconut flour)

Conclusions

The study revealed that composite flour with good nutritional value could be produced by replacing wheat flour with coconut flour. There exist variations in the functional and pasting properties of wheat- coconut composite flours which are desirable characteristics for the manufacture of various food products. Coconut flour has great potential as a functional ingredient in partially replacing wheat flour in the diets of infants and other vulnerable groups, particularly in the developing countries.

References

Abioye, V.F., Ade-Omowaye, B.I.O., Babarinde, G.O., Adesigbin, M.K. (2011): Chemical, physico-chemical and sensory properties of soy-plantain flour. *Afr. J. Food Sci*. 5 (4), 176-180.

AOAC (2012): Official Methods of Analysis. AOAC International (19th ed.), Gaithersburg, M.D. USA.

Arancon, R.N. (1999): Coconut flour. *Coco info International* 6(1), 1–8.

Aremu, M.O., Olaofe, O., Akintayo, E.T. (2007): Functional properties of some Nigerian varieties of legume seed flours and flour concentration effect on foaming and gelation properties. *J. Food Tech.* 5 (2), 109-115.

Butt, M.S., Batool, R. (2010): Nutritional and functional properties of some promising legumes proteins isolates. *Pakistan J. Nutr.* 9(4), 373–379.

Chakraborty, P. (1985): Functional properties of coconut protein isolate obtained by ultrafiltration. *J. Food Sci. Technol.* 22, 248-54.

Collier, G.R., Giudici, S., Kalmusky, J., Wlever, T.M.S., Helman, G., Wesson, V. (1988): Low glycemic index starchy foods improve glucose control and lower serum cholesterol in diabetic children. *Diabetes Nutr. Metab.* 1−9.

Ekanayake, S., Jansz, E.R., Nair, B.M. (1999): Proximate composition, mineral and amino acid content of mature *Canavalia gladiata* seeds. *Food Chem.* 66,115-119.

Evans, P., Halliwell, B. (2001): Micronutrients: Oxidant/antioxidant Status. *Br. J. Nutr.* 85, 67-74.

FAO (2010): Fats and fatty acids in human nutrition - Report of an expert consultation. FAO Food and Nutrition Paper 91. Rome: Food and Agriculture Organization of the United Nations. pp. 55.

FAOSTAT (2013): Food and Agriculture Organization of the United Nations. Coconuts, Production/Crops. *Statistical Division (FAOSTAT)*.

Fitzpatrick, J.J., Iqbal, T., Delaney, C., Twomey, T., Keogh, M.K. (2004): Effect of powder properties and storage conditions on the flowability of milk powders with different fat contents. *J. Food Eng.* 64, 435-444.

Gunathilake, K.D.P.P., C. Yalegama, C., Kumara, A.A.N. (2009): Use of coconut flour as a source of protein and dietary fibre in wheat bread. *Asian Journal of Food and Agro-Industry* 2(03), 382-391

Igbabul, B., Num, G., Amove, J. (2014): Quality evaluation of composite bread produced from wheat, maize and orange fleshed sweet potato flours. *American J. Food Sci. Technol.* 24, 109-115.

Jenkins, D. J. A., Ghafari, A., Wolever, T. M. S., Taylor, R. H., Barker, H. M., Filden, H., Jenkins, A. L. (1982): Bowling Ac. Relationship between the rate of digestion of foods and post-prandial glycemia. *Diabetologia,* 22 (6), 450-455. doi:10.1007/BF00282589.

Jitngarmkusol, S., Hongsuwankul, J., Tananuwong, K. (2008): Chemical composition, functional properties and microstructure of defatted macademice flours. *Food Chem*. 110, 23-30.

Kaliyamoorthy, J., Rajasekaran, S., Nagarajan, M., Vijayarengan, P. (2015): Bioactive enzyme activity and medicinal properties of tender coconut (*Cocos nucifera* L.). *International Journal of Modern Biochemistry*, 4(1): 10-14.

Lund, D. (1984): Influence of time, temperature, moisture, ingredients and processing conditions on starch gelatinization. *CRC Rev. Food Sci. Nutr.* 20, 249-273.

Matsui, K., Gut, J.A.W., De Oliveira, P.V., Tadini, C.C. (2008): Inactivation kinetics of polyphenol oxidase and peroxidase in green coconut water by microwave processing. *J. Food Eng*. 88, 169-176.

Radley, J.A. (1976): Examination and Analysis of Starch Products. Applied Science Publishing Limited, London.

Ramaswamy, L. (2014): Coconut flour - a low carbohydrate, gluten free flour. *International Journal of Ayurvedic and Herbal Medicine* 4(1), 1426-1436.International

Rasper, V. (1969): Investigation on starches from major starch crop grown in Ghana. II. Swelling and solubility patterns and amyloelastic susceptibility. *J. Sci. Food Agric.* 20, 642-646.

Richard, J.R., Asaoka, M.A., Blan Shard, J.M.V. (1991): The physiochemical properties of cassava starch. *Trop. Sci.* 3, 189-207.

Sasulki, F.W., Garrant, M.D., Slinkard, A.E. (1996): Functional properties of fern legume flour. *Insti. Food Sci. & Techn. J.* 9, 66-69.

Sridevi Sivakami, P.L., Sarojini, K.S. (2013): Formulation of value added biscuits using defatted coconut flour. *American Journal of Food Technology* 8:207-212.

Sujirtha, N., Mahendran, T. (2015): Use of defatted coconut flour as a source of protein and dietary fibre in wheat biscuits. International *Journal of Innovative Research in Science, Engineering and Technology* 4(8), 7344-7352.

Suresh, C., Samsher, S., Durvesh, K. (2015): Evaluation of functional properties of composite flours and sensorial attributes of composite flour biscuits. *J. Food Sci. Technol.* 52(6), 3681-3688. doi:10.1007/s13197-014-1427-2.

Trinidad, P.T., Divinagracia, H.V., Aida, C.M., Faaridah, C.A., Angelica, S.M., Modesto, T.C., Askali, C.A., Loyola, A.S., Masa, D.B. (2001): Coconut flour from residue: A good source of dietary fibre. *Indian Coconut Journal 32*(6), 9-13.

Zeleny, L. (1971): Criteria of Wheat Quality. In Wheat: Chemistry and Technology. Pomeranz, Y (ed) Vol. 3 AACC, St. Paul, Minnesota. pp. 14 – 49.