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

The evaluation of nutritional composition and 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 the extraction of milk, dried, milled, and pulverized. Five blends of composite flour were prepared by combining wheat flour with 10% to 50% of partially defatted coconut flour, respectively. The 100% wheat flour served as control. The samples were analysed for proximate, mineral, functional, and pasting properties using standard procedures. The proximate analysis indicated 5.52 % moisture, 23.6% protein, 11.14% fibre, 5.4% fat, 5.21% ash, and 49.1% carbohydrate for coconut flour. The ranges of the proximate composition for the flour blends were: moisture (4.79-5.55%), protein (14.9 -19.1%), fibre (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 the 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. The range of values obtained for these parameters was 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%). The pasting characteristics showed significant differences between the 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 suggests their application in diverse food products.

Introduction

Oil seeds are a complimentary nutrient source for human consumption and their production is an important part of agricultural economy of developing countries such as Nigeria. The primary sources of vegetable oil are: almond, canola, castor, coconut, cotton, grape, jojoba, and mustard, among others.
Coconut (*Cocus nucifera*) is commonly known and regarded as a 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 a fine powdery form. Research has shown that coconut flour contains high fibre (Trinidad et al., 2001) and protein content (Chakraborty, 1985), which can make up for low protein and fibre content in various foods. Coconut is however naturally low in digestible carbohydrates and contains no gluten (Ramaswamy, 2014). Refined flours have high concentrations of simple carbohydrates which can be

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

rapidly metabolized and cause destructive blood sugar fluctuations in the body. In opposition to this, coconut flour has been found to have a glycaemic lowering effect, because coconut meat contains simple carbohydrates coupled with high fibre content; it yields flour that is less disruptive to blood sugar levels (Ramaswamy, 2014). Most importantly, it is believed to be 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, for partially or completely substituting 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 that it has a 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, which is being paid with scarce foreign currency in Nigeria, but also to provide a nutritious and healthy source of dietary fibre.

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

Materials and methods

Materials

Mature coconut seeds (*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 was detached using a knife. The endocarp was grated using a manual grater. The grated portion was made into smooth paste using a laboratory Moulinex blender and the milk was 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 a 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 of crude protein, crude lipids, and carbohydrates 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 analysed 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 (10 g) was homogenized in 50 mL of distilled water. The resulting suspensions were decanted and the pH was determined using the pH meter already standardized with buffer solutions of pH 4.0 and 7.0. The least gelation capacity was determined by preparing sample suspensions of 2-20% (dry w/v) in 10 mL of deionised water and mixed thoroughly. The slurries were heated in capped test tubes, in water, at 95± 2 ºC for 1 h. The tubes were immediately cooled in tap water for 30 s to accelerate gel formation. The least gelation concentration (%) was determined as the above concentration, in 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. The 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 errors were 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 Windows, release 16.00; SPSS Inc., Chicago IL, USA. Significance was accepted at $p \leq 0.05$ levels.

Results and discussion

Proximate composition

The proximate compositions of wheat flour and coconut flour are given in Table 2. The protein, fat, ash, fibre, and moisture values of coconut flour were 23.6%, 5.4%, 5.21%, 11.14, and 5.52%, respectively. According to Arancon (1999), the nutrient composition of coconut flour was reported as: protein 13.41%, moisture 2.80%, 10.23% fat, and 19.3% fibre. 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 the coconut residue. Meanwhile, the wheat flour contained the following: protein 14.9%, moisture 4.79%, fat 2.9%, and 0.44% fibre. In general, coconut flour indicated higher levels of protein, ash, fibre, and fat compared to wheat flour.

The proximate composition of wheat-coconut flour blends is 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 lowest, while the blends containing defatted coconut flour had higher protein content. This showed that the addition of coconut flour resulted in the increase of 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. Coconut meal defatting 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 contains no gluten and consequently cannot be used exclusively in baked goods that require leavening. When used, however, a limit of the 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 of sample contributed to the significantly ($p \leq 0.05$) higher fat content of the samples with coconut. Dietary fats that provide essential fatty acids (EFA) have been shown to enhance the taste and acceptability of foods and slow gastric emptying and intestinal motility, thereby prolonging satiety and facilitating 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 the increased level of coconut flour inclusion in the blends, which points to the fact that they are good sources of mineral matter. The fibre content of the blends ranged from 0.44% to 5.12%. Similarly, the fibre content increased significantly ($p \leq 0.05$) with the 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 glycaemic 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 fibres' 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 their 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 programmes. 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 having the lowest, 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. The calcium content of wheat flour was 1.32 mg/kg, which increased gradually as the level of substitution of coconut flour was increased. Similarly, the phosphorus content of the wheat flour blended with coconut flour shows an increasing trend as the level of substitution increased. The maximum potassium content was recorded in the blend at the substitution level of 50% (Sample F).

Table 2. Proximate composition of wheat and coconut flour samples

Sample	Moisture (%)	Protein (%)	Fibre (%)	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 shows mean values of triplicate determination ± standard deviation. Means with different superscript within the same column differ significantly ($p \leq 0.05$)

Table 3. Proximate composition of composite flours

Sample	Moisture (%)	Protein (%)	Fibre (%)	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 shows mean values of triplicate determination ± standard deviation. Means with different superscript within the same column differ significantly ($p \leq 0.05$). 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 shows mean values of triplicate determination ± standard deviation. Means with different superscript within the same column differ significantly ($p \leq 0.05$). 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 shows an increasing trend as the level of substitution increased. The iron content of the flours ranged from 0.50 to 1.22 mg/kg. The highest iron concentration was recorded in the flour substituted with 50% of coconut flour, while the lowest value was recorded in the wheat flour. A 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 ($p \leq 0.05$) 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 a human system gives rise to an increased production of free radicals, as a result of the 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 metalloenzymes (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 0.49 g/mL and 0.44 to 0.75 g/mL, respectively. Loosed and packed bulk densities of composite flour decreased with the increase in the level of substitution of wheat flour with coconut flour. The observed decrease in bulk density (loose and packed) with the increase in the level of substitution of wheat flour with coconut flour was significant with the increase in moisture content (Table 3). The 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 due to an increase in mass. Moisture causes swelling, which means that the same mass of material occupies more volume, thus decreasing 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, the difference in the values of samples D and E was not significant ($p \geq 0.05$). The increase in the WAC of blends after incorporating coconut flour may be due to the increase in amylose leaching and solubility, and the loss of starch crystalline structure (Suresh et al., 2015). Similarly, proteins have 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 the product, as well as in baking applications. The high WAC of composite flours suggests that the flours can be used in the formulation of some foods such as sausages, dough, and bakery products. The oil absorption capacity (OAC) ranged between 1.26 and 3.20 mL/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 the increased level of coconut flour in the mixture. The possible reason for the increase in the OAC of composite flours after the incorporation of coconut flour could be the variations in the presence of non-polar amino acid side chains of proteins, 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 the structural interaction in food, especially in flavour retention, improvement of palatability, and the extension of shelf life, particularly in bakery or meat products where the 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 the 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 (Rašper, 1969). However, the swelling capacity of flours depends on the size of particles, types of variety, and types of processing methods or unit operations (Suresh et al., 2015). The pH value decreased significantly ($p \leq 0.05$) 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 a high pH value imparts a free swelling property to starch (Lund and Lorenz, 1984), which corroborates the increase in swelling power reported in this study. The least gelation concentration (LGC) of the flour samples ranged from 12% to 18%. Least gelation is defined as the lowest protein concentration at which gel remained in the 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 a 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 proteins, carbohydrates, and lipids in different flours, suggesting that the 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 the 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 in Table 6. The pasting properties of these flours are important indices in predicting the pasting behaviour during and after cooking (Rickard et al., 1991). Sample A (100% wheat flour) had the highest peak viscosity of 1349.0 RVU. However, coconut flour addition significantly decreased the peak viscosity to the 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 the composite flour indicates that the flour may be suited for products requiring low gel strength and elasticity (Abioye et al., 2011). The 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 possess the highest ability of all the blends to remain undisrupted when subjected to long periods of constant high temperature and the ability to withstand breakdown during cooking, respectively. The final viscosity of sample A (100% wheat flour) recorded the highest value of 2053.0 RVU. Final viscosity is the most commonly used parameter for determining 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 of decreasing the final viscosity values in the composite flours.

Setback viscosity values have been reported to correlate with the ability of starches to gel into semi solid pastes. In these investigations, setback value was highest for 100% wheat flour at 1112.5 RVU. The flour blend with the 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. The flours produced from 10-50% substitution with coconut flour had higher peak time compared to wheat flour. The 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 the partial substitution of wheat with coconut flour significantly affects 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 shows 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 (°C)
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 shows mean values of triplicate determination ± standard deviation. Means with different superscript within the same column differ significantly ($p \leq 0.05$). 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

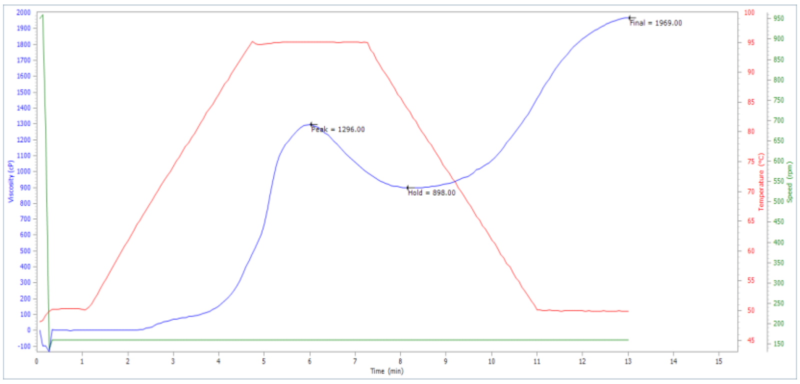

Fig. 1. Influence of heating time on the viscosity of sample A (100% wheat flour)

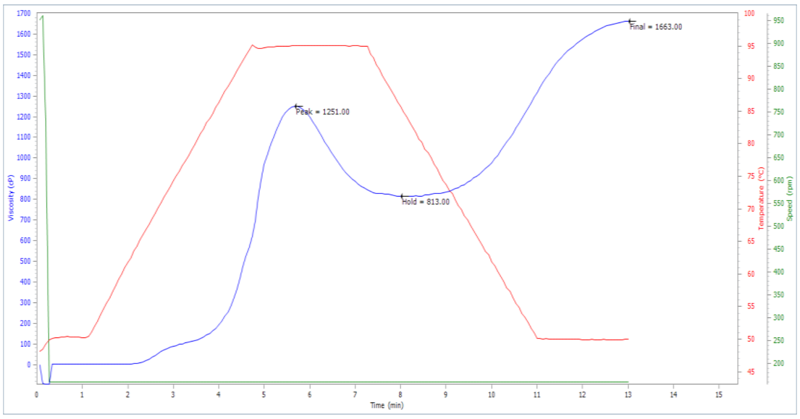

Fig. 2. Influence of heating time on the viscosity of sample B (90% wheat flour and 10% coconut flour)

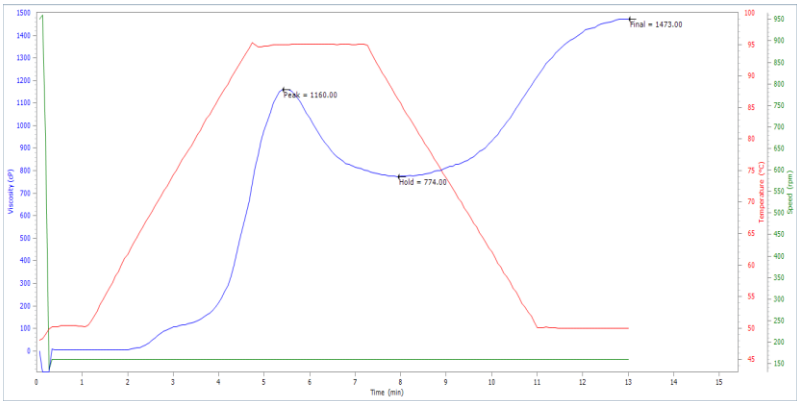

Fig. 3. Influence of heating time on the viscosity of sample C (80% wheat flour and 20% coconut flour)

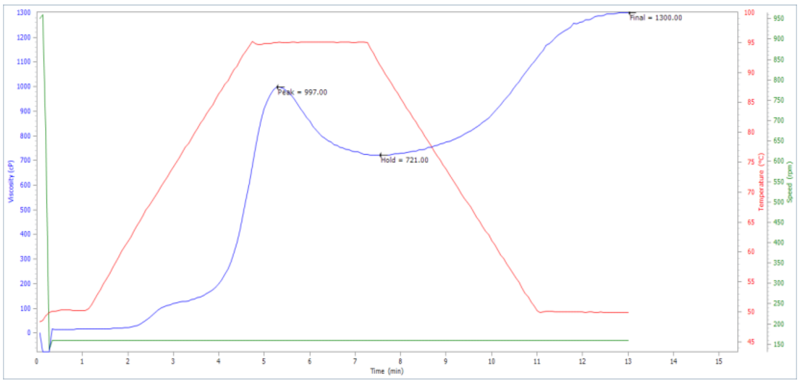

Fig. 4. Influence of heating time on the viscosity of sample D (70% wheat flour and 30% coconut flour)

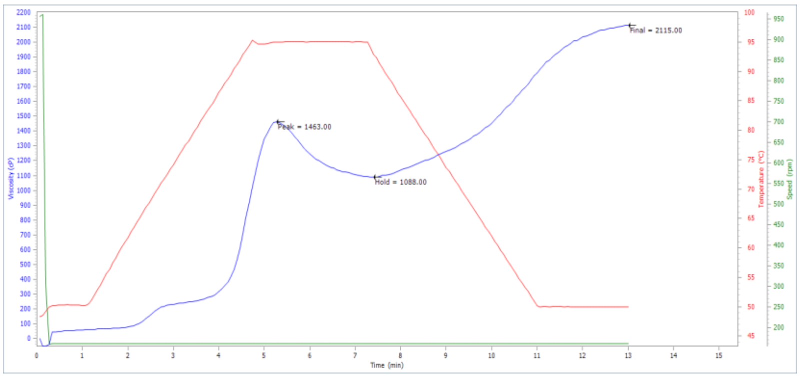

Fig. 5. Influence of heating time on the viscosity of sample E (60% wheat flour and 40% coconut flour)

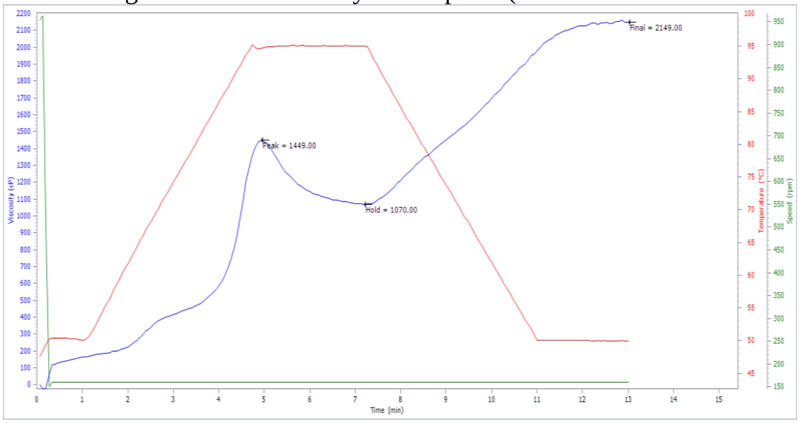

Fig. 6. Influence of heating time on the viscosity of sample F (50% wheat flour and 50% coconut flour)

Conclusions

The study revealed that composite flour with good nutritional value could be produced by replacing wheat flour with coconut flour. There are variations in the functional and pasting properties of wheat-coconut composite flours, which represent 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 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. http://dx.doi.org/10.3923/pjn.2010.373.379

Chakraborty, P. (1985): Functional properties of coconut protein isolate obtained by ultrafiltration. *J. Food Sci. Technol.* 22, 248-54. http://dx.doi.org/10.3390/ijms12010066

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. https://doi.org/10.1016/S0308-8146(99)00041-2

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. https://doi.org/10.1016/j.jfoodeng.2003.11.011

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. https://doi.org/10.12691/ajfst-2-4-1

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. https://doi.org/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. https://doi.org/10.1016/j.foodchem.2008.01.050

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

Lund, D., Lorenz, K.J. (1984): Influence of time, temperature, moisture, ingredients and processing conditions on starch gelatinization. *CRC Rev. Food Sci. Nutr.* 20, 249-273. http://dx.doi.org/10.1080/10408398409527391

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. https://doi.org/10.1016/j.jfoodeng.2008.02.003

Radley, J.A. (1976): Physical Methods of Characterising Starch. In: Examination and Analysis of Starch Products, Springer Netherlands, Radley, J.A. (ed.), Netherlands: Applied Science Publishing Ltd., pp. 91-131. https://doi.org/10.1007/978-94-010-1332-1

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

Rašper, V. (1969): Investigation on starches from major starch crop grown in Ghana. II. Swelling and solubility patterns and amyloclastic susceptibility. *J. Sci. Food Agric.* 20, 642-646. https://doi.org/10.1002/jsfa.2740201103

Rickard, J.E., Asaoka, M.A., Blanshard, J.M.V. (1991): The physicochemical 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. *Am. J. Food Technol.* 8, 207-212. http://dx.doi.org/10.3923/ajft.2013.207.212

Sujirtha, N., Mahendran, T. (2015): Use of defatted coconut flour as a source of protein and dietary fibre in wheat biscuits. *Int. J. Innov. Res. Sci. Eng. Technol.* 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. http://dx.doi.org/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. http://dx.doi.org/10.1016/j.ifset.2004.04.003

Zeleny, L. (1971): Criteria of Wheat Quality. In Wheat: Chemistry and Technology. Pomeranz, Y. (ed.), Minnesota, USA: American Association of Cereal Chemists (AACC), pp. 14 – 49.