EVALUATION OF SOME PHYSICAL–CHEMICAL PROPERTIES OF WHEAT, CASSAVA, MAIZE AND COWPEA FLOURS FOR BREAD MAKING

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ABSTRACT

Both the physical and chemical characteristics of flours affect their quality and the subsequent products from them. The comparative evaluation of particle size, moisture content, bulk density, color, water absorption capacity, pasting viscosity, fat and protein contents of wheat, cassava, maize and cowpea flours were determined using standard methods. Composite breads were produced from 50:30:20, 60:20:20, 70:20:10; 80:10:10, 85:10:5 and 90:5:5 ratio of wheat–cassava/maize–cowpea flours, respectively. Breads produced were subjected to sensory and proximate analyses. The particle size, moisture content, bulk density, water absorption capacity, fat and protein contents of wheat, cassava, maize and cowpea flours are as follows: 154–343 μm, 13.3–14.9% db, 327.4–497.5 kg/m^3, 31.9–221.8 g/g, 1.01–2.3% and 2.6–19.39%. Wheat flour had the lowest pasting temperature of 56.1C. Significance differences at P < *0.05 were recorded between most of the properties of the flours. Composite bread of 85% wheat, 10% cassava, 5% cowpea; 90% wheat, 5% cassava, 5% cowpea; and 90% wheat, 5% maize, 5% cowpea were accepted by a sensory evaluation panelist. Substitution with cowpea fruit improved the protein content of the bread.*

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PRACTICAL APPLICATIONS

In developing countries such as Nigeria, this study is one of the efforts directed toward identifying nonwheat sources that could be used as substitutes to wheat flour in bread making, and hence affects savings in foreign exchange by reducing wheat importation. Published works on physical and chemical properties of cassava, maize and cowpea flours provides information for researchers on this area of study. With these, the behavior of flours can be predicted. All varieties of the three crops used for the experiment are commercially cultivated in Nigeria; hence the research findings can be easily adapted in commercial bread production. These will result in increased demand for the crops and processing equipment, and subsequently job opportunities will be created. The nutritive value of commercial bread will also be enhanced by the addition of cowpea flour.

INTRODUCTION

Bread is a widely consumed baked product traditionally produced from wheat flour. Wheat cultivation thrives best in temperate regions worldwide but is susceptible to disease in warm, humid tropics (Brown 2000). Because of the global economic recession, attention is focused on substituting wheat flours in bread and other baked foods with locally cultivated crops. Cassava *(Manihot esculentae)*, maize (*Zea mays*) and cowpea (*Vigna unguiculata*) are commercially cultivated in Nigeria. Cassava, when analyzed, contain 65% moisture, 32–35% starch, 0.7–2.5% proteins, 0.2–0.5% fat and 0.1–1.3% ash (FIIRO 2006). It also contains toxic cyanide glycosides, which are broken down at acidic pH to liberate free hydrogen cyanide. Products that are derivable from cassava include *gari, fufu,* cassava chips, cassava pellets, ethanol, monosodium glutamate, glucose syrup, adhesive, cold starch and unfermented flour. Maize has a wide range of production adaptability. Foods produced from it include; roasted maize, *langbe, guguru, aadun, tanfirin, tuwo massara, nni oka, ukpo oka, kokoro, kanu massara, fura, abari, kango, abodo, ogi, eko* and *kanjika* (Akubor 2005). According to Enwere (1998), maize is richer in oil than any other cereal crop except oat and millet. It is high in calorie, carbohydrate, potassium, sodium, chlorine and sulphur. When considered as a whole, protein in maize is low in lysine, tryptophan but fair in sulphur containing amino acids such as methione and cysteine (Adebayo and Emmanuel 2001). Cowpea is the most important legume food popular in West Africa (McWatters *et al.* 2004). The crop is well adapted to climate and geographical conditions in that region of the world. It contains substantial quantities of lysine, an essential amino acid lacking in most cereals. When blended with cereal grains, cowpea gives mixtures with complementary amino-acid profiles and improved protein quality (Bressani 1985).

Flours are produced essentially from a size reduction process aimed at grinding and separating components of materials. Wheat flour production involves breaking, scratching and the reduction systems, which are undertaken in sets of roller mills. The break opens the grain and removes the endosperm from bran to a little extent, while the "scratch" separates the particles of bran from clean wheat. As a result of this sharing and scrapping, starch granules become physically injured, i.e., starch damage occurs (Brown 2000). Nonwheat cereals require dry extraction milling to remove fiber and fat. Impact milling has often been used for maize, sorghum, millet, rice and cowpea (Kent 1980).

The investigation into the use of nonwheat flours in baking dates back to ancient times when bread-like products were made from flours of cereals (maize, sorghum, rice and millet), roots and tubers (cassava, yam and potatoes), legumes and oil seeds (melon, soybean, groundnut and cowpea). This was first seen as an emergency measure in industrialized countries during the two world wars when wheat supplies were limited (Crabtree and James 1982). The alternative to wheat flour from local sources has become an increasingly important objective of the Food and Agricultural Organization policy. Efforts were directed on steps to identify those nonwheat sources that could be used in developing countries to extend the usage of wheat flour in bread making, and hence affect savings in foreign exchange by reducing wheat importation. Also, this was used as a means of developing local agro-business, which would encourage farmers to grow more of those crops found suitable. Such nonwheat flours and their baked products should not only be economical to produce and distribute, but must be acceptable. Some reported studies on the use of cereals, tubers or legumes as composite flours for bread making are: wheat–sorghum composite (Keregero and Mtebe 1994); wheat–beniseed composite (Afolabi *et al.* 2001), wheat–cowpea composite (Mcwatters *et al.* 2004); wheat–plantain–soybean (Olaoye *et al.* 2006); wheat–plantain (Horsfall *et al.* 2007); wheat–potatoes (Anjum *et al.* 2008); and wheat–cassava (Shittu *et al.* 2008). It can be deduced from these reported works that the qualities of bread depend on the proportional composition of the composites and flour properties.

The processes undertaken in the food industry primarily change the state of a raw material because of their effect on the physical, chemical, thermal and biological properties of the foodstuffs. Such changes include the expansion of materials, change in solubility and textural strength. Both the physical and chemical characteristics of flours affect their quality and the subsequent products from them. Some of the quality factors are particle size, density, color, protein content, fat, flavor, moisture content, pasting characteristics, solubility and water absorption capacity. Thus, the aim of this work was to comparatively study some physical–chemical properties of wheat, cassava, maize and cowpea flours as they affect composite breads. These flours have been reported to be useful as a whole or as composites for bread baking (Satin 1988; McWatters *et al.* 2004).

MATERIALS AND METHODS

Materials Preparation

Commercial whole-wheat flour and maize flour were procured from Flour Mills of Nigeria PLC (Lagos, Nigeria). TMS-50395 cassava tuber and IT 93-129-4 variety of cowpea were sourced from the International Institute of Tropical Agriculture (Ibadan, Nigeria). Cassava was processed into cassava flour using the standard method reported by Crabtree and James (1982). Cowpeas were manually cleaned to remove impurity and soaked in water at room temperature (30C) for 10 min to soften the hull, which was manually removed and washed off. The cleaned cotyledons were dried in an air-draught cabinet drier at 65C for 4 h and milled into flour using a hammer mill.

Particle Size Distribution Analysis

The particle size of flour samples were determined using a set of eight Endicott test sieves (Endicott Ltd., London, UK) ranging from 600 μm to 53 μm sieve sizes arranged in decreasing order of pore size. About 100 g of each sample was sieved for 15 min on an Endecott's sieve shaker (Endicott Ltd.). The flour retained on each sieve and in the receiver pan was weighed and expressed as the percentage of total flour. Appropriate calculations were made; cumulative graphs and histograms were drawn to obtain the average particle size and the most common particle size of each flour sample.

Moisture Content and Bulk Density Determination

Moisture content was determined by drying 5 g of samples for 15 min in a Carter-Simon oven (Simon-Carter Co., Minneapolis, MN) set at 155C. The dried samples were weighed and the difference in weight before and after drying was assumed to be moisture loss. The ratio of moisture loss to weight of dried flour percentage was recorded as moisture content dry basis. In determining the bulk density, a dish of known volume was washed, dried and weighed with its lid. Each flour sample was filled into the dish, tapped thrice and then weighed. Bulk density was calculated from the volume and weight of the flour sample. Six determinations were carried out for each sample and mean values were calculated.

Determination of Color

Color was measured using Disk-spinning method with Macbeth Munsell colorimeter. Appropriate Munsell color disks were selected and their nominal values were noted. The five disks were arranged in an interwoven mesh placed on one side of the instrument against the flour sample on the other. Munsell light was turned on and the arranged disks spun by a motor at high speed. Visual color match was observed between the sample and the spun disks. The exposed portion of each disk was adjusted until the color match was observed. Each measurement was in triplicate and the average was employed in obtaining the CIE Chromaticity coordinates x, y and reflectance Y. These values were converted to Munsell notation using appropriate graphs and tables. The results were expressed as Hue, Value and Chroma.

Amylograph Pasting Viscosity Analysis

The amylograph pasting viscosity of wheat, cassava, maize and cowpea flours were determined using the Brabender Amylograph (Barbender, GmbH & Co., Duisburg, Germany). A mixture of flour and water (530 g) was prepared in an amylograph bowl at 10% solid concentration (dry basis). The suspension was heated up to 90C from 30C, held at this temperature for 15 min and cooled to 50C. The amylogram was evaluated as described by Banigo *et al.* (1974).

Determination of Water Absorption Capacity

The water absorption capacity was determined according to the method described by Akubor (2005). One-gram sample was mixed with 10-mL distilled water (specific gravity 0.904 kg/m^3) and allowed to stand at ambient temperature (31 ± 2C) for 30 min, and then centrifuged at 3,000 rpm for 30 min using centrifuge model 800D (Hettich, Universal 11, Herford, Germany). Water absorption capacity was expressed as percent water bound per gram flour. Protein content of the flours was determined by micro-Kjeldahl using KJELPLUS instrument (Pelican Industries, Shanghai, China). The fat content was determined by AOAC (2002) method using Soxhlet extractor (Soxtec System HT 1043 Extraction unit, Tecator, Inc., Herndon, VA).

Bread Making

Composite flours were prepared using wheat–cassava–cowpea and wheat–maize–cowpea combinations to produce two different mixtures. Trial experiments were made to get suitable combinations for composite bread making. The ratio of the mixtures were varied: 50:30:20, 60:20:20, 70:20:10;

TABLE 1.
RECIPE USED FOR DOUGH PREPARATION

Ingredient	WE	CA	MA	CO	WCACO	WMACO
Flour (g)*	100	100	100	100	100	100
Water (mL)‡	58	112	140	67	70	64
Sugar (g)†	6.0	10	10	10	10	10
Salt (g)†	1.5	2.0	0.8	1.5	1.5	1.5
Yeast (g)†	1.5	1.0	1.5	1.5	1.5	1.5
Oil/Fat (mL)‡	2.0	2.0	2.0	2.0	2.0	2.0

* Accuracy of measurement is 2.0 g.
† Accuracy of measurement is 0.05 g.
‡ Accuracy of measurement is 0.1 mL.
WE, % wheat; CA, % cassava; MA, % maize; CO, % cowpea; WCACO, wheat–cassava–cowpea; WMACO, wheat–maize–cowpea.

80:10:10, 85:10:5 and 90:5:5 percentage proportion of wheat–cassava/maize–cowpea flours, respectively. Each mixture was blended in a Kenwood food processor (Kenwood Limited, Havant, Hampshire, UK) operated at 2,000 rpm for 5 min. Bread doughs were produced using the recipe on Table 1. The ingredients were mixed for 5 min in Brabender Farinograph mixer (Brabender, GmbH & Co., Duisburg, Germany) rotating at 31.3 rpm. This was followed by a rest period of about 15 min to permit the relation of stresses that occurred during mixing. The dough was molded into cylindrical shape to fit into a 0.2-mm thick aluminium container (internal diameter of 20 mm and height of 200 mm). Dough height was made up to a specified ring mark, with adequate allowance for dough swelling during baking. The doughs were prepared, cooked in baking pans at 38C and 85% relative humidity for 40 min, and then introduced centrally into the baking oven. This setup system was introduced into the oven after it had attained and maintained baking temperature (about 165C) for 45 min.

Chemical Analysis and Sensory Evaluation of Bread

Breads produced from the composite flours were subjected to sensory evaluation. Coded samples of the breads were served to 25 members/trained panelists positioned in partitioned booths. The taste, aroma, texture and overall acceptability of the breads were evaluated under amber light while appearance was under bright illumination. These attributes were rated on a 10-point hedonic score scale as: 1–2 poor, 3–4 fair, 5–7 very good and 8–10 excellent. Samples receiving an overall quality score of ≥7 were considered acceptable (Iwe 2002). The percentage proportion of moisture, fat, protein and carbohydrate of the accepted composite breads was carried out using recommended standard methods (AOAC 2002).

Statistical Analysis

A 2×6 factorial experimental design was employed. Levels of flour substitution and types were varied. Maize and cassava flour substitutions were the main treatments. Three replicates of all the experiments were carried out. Descriptive statistics (mean, standard deviation), correlations (Pearson) and analysis of variance (ANOVA) (F-value, level of significance at 0.05) of collected data were done using SPSS 14.0 software package (SPSS, Inc., Chicago, IL). Wheat flour and bread (100%) were used as control.

RESULTS AND DISCUSSION

Particle Size

The particle size distribution of flour samples is shown as Fig. 1. The mean particle sizes were 154, 228, 330 and 343 µm while the most frequently occurring particle sizes were 128, 256, 256 and 277 µm for wheat, cassava, maize and cowpea flours, respectively. Significance differences were recorded at 95% confidence level between wheat and cassava flours, and wheat and maize flours particle size (Table 2). Wheat flour intended for baking bread, biscuit and other pastry products, requires a particle size of about 130 µm

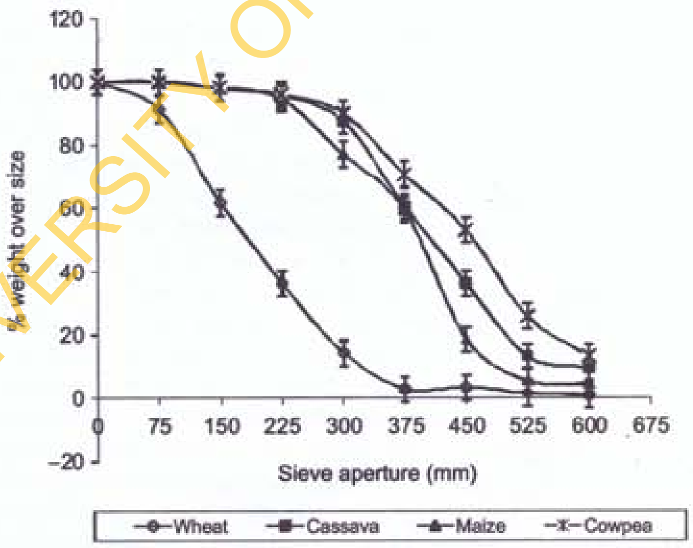

FIG. 1. PARTICLE SIZE DISTRIBUTION OF THE FLOURS

TABLE 2.
SUMMARY OF PHYSICAL–CHEMICAL PROPERTIES OF THE FLOURS

Properties	Flours			
	Wheat	Cassava	Maize	Cowpea
Particle size (μm)	154 ± 6.3^{a}	228 ± 9.1^{b}	330 ± 8.4^{bc}	343 ± 12.3^{c}
Moisture content (%db)	13.9 ± 0.5^{a}	13.3 ± 0.2^{a}	14.1 ± 0.2^{ab}	14.9 ± 1.5^{b}
Bulk density (kg/m^3)	497.5 ± 5.2^{a}	327.4 ± 3.8^{b}	491.5 ± 2.9^{a}	496 ± 61.7^{a}
Color (HV/C)	0.9G9.1/0.3^{a}	0.9G9.13/0.3^{a}	0.9G9.05/0.3^{a}	0.9G9.3/0.4^{a}
Water absorption (g/g)	31.9 ± 9.1^{a}	221.8 ± 52.8^{d}	168.5 ± 31.0^{c}	89.5 ± 27.9^{b}
Fat (%)	1.06 ± 0.01^{a}	1.01 ± 0.01^{a}	2.3 ± 0.06^{c}	1.95 ± 0.03^{b}
Protein (%)	11.7 ± 2.5^{c}	5.4 ± 1.9^{b}	2.6 ± 1.8^{a}	19.39 ± 3.6^{d}
Pasting temperature (C)	56.1 ± 1.8^{a}	62.1 ± 3.6^{ab}	67 ± 2.7^{bc}	70.8 ± 17.9^{bc}
Pasting temperature at peak viscosity (C)	84.3 ± 20.1^{ab}	80.1 ± 13.8^{a}	88.1 ± 11.2^{b}	83.4 ± 28.6^{a}
Peak viscosity (BU)	430 ± 12.3^{a}	$1{,}610 \pm 24.5^{d}$	740 ± 13.9^{b}	$1{,}402 \pm 305.8^{c}$
Viscosity at 90C hold (BU)	340 ± 67.2^{a}	720 ± 78.9^{b}	760 ± 218.0^{b}	$1{,}219 \pm 406.2^{c}$
Viscosity at 50C (BU)	590 ± 83.0^{a}	890 ± 101.7^{b}	$1{,}100 \pm 452.7^{c}$	$2{,}017 \pm 299.5^{d}$
Stability index (BU)	90 ± 2.8^{b}	890 ± 34.0^{c}	60 ± 6.5^{a}	$1{,}136 \pm 345.9^{d}$
Retro gradient tendency (BU)	160 ± 17.3^{a}	720 ± 41.7^{b}	$2{,}440 \pm 83.8^{d}$	$1{,}934 \pm 460.2^{c}$
Consistency (BU)	250 ± 23.7^{b}	170 ± 17.9^{a}	$2{,}500 \pm 102.4^{d}$	798 ± 115.7^{c}

Values with the same superscript in the row are not significantly different at $P < 0.05$.
Data used are mean of three replicates.
BU, Brabender units.

(UNECA 1985). This result shows that the wheat flour is within the range expected for normal bread flour. The large particle size of maize flour is attributed to the fact that maize grains are harder and more difficult to mill than wheat grains (Mittal and Kaul 1983). Cassava contains fibers, which to some extent are difficult to fine mill. Consequently, the cassava flour was not as fine as the wheat flour. Relatively high moisture content might influence its size reduction. Also, it must be noted that the degree of fineness in milling operation depends on the type and efficiency of the applied machine. Shelton and D'Appolonia (1985) reported that milling influences the extent of starch damage and this has been linked to water absorption of flour and starch liquefaction by alpha-amylase (Evers and Stevens 1985). Reporting the Tropical Product Institute's experience with composite flours, Crabtree and James (1982) indicated that a particle size of about 180 μm, free of fiber, would produce good composite breads. This is because, for baking purposes, large particle-sized flours would adhere to the surface of dough, giving the final loaf a rough and speckled appearance. Gritty fragments occurring in internal crumb are an indication of the presence of fiber in flour. This could puncture the expanding gas cells during fermentation, thus giving a reduced loaf volume.

Moisture Content

The flour samples had moisture content in the range of 13–15% db (Table 2), which is within the range for the effective storage of flour (Whiteley 1971). Moisture content of 12–15.5% has been specified for cereal flour storage. Failure to store flour under this conditions leads to moisture absorption from the atmosphere, which eventually leads to caking (Kent 1980).

Bulk Density

Bulk density is a function of the closeness of packaging. Wheat, maize and cowpea flour recorded values of 497.9, 491.5 and 496 kg/m^3, respectively, for bulk density (Table 2). At $P < 0.05$, significance difference was recorded between wheat and cassava flour bulk densities, while nonsignificant effect was recorded for wheat and maize flours. Although the flour samples had different particle size distribution, it is probable that the similarity in their chemical composition might explain the identical values obtained for their bulk density (Sefa-Dedeh 1989). Cassava flour, which had a medium particle size distribution (Fig. 1), had the lowest bulk density value. This could be attributed to the relatively lower protein and fat contents of cassava. Contrary to Peleg and Hollenbach (1983) emphasis of density variation of particulates only on moisture content and particle size, it could be inferred that they are some other parameters affecting the bulk density of flours. The bulk density of the flours could be used to determine their handling requirement, because it is the function of mass and volume.

Color

Values for the Munsell color notation are presented in Table 2. The "Hue" value was 0.91 G for the four flour samples reflecting greenness. Kurimoto and Shelton (1988) also reported negative "a" value (denoting greenness) with Hunterlab Tristimulus colorimeter. The large particle size of maize flour (330 μm) and cowpea (343 μm) resulted in their rough surface and hence the reduced level of daylight reflectance, 9.05 and 8.95, respectively, from sample surface. The ANOVA of color showed nonsignificant difference at $P < 0.05$. The order of whiteness was cassava, wheat, maize and cowpea. The color of the crumb depends largely on flour color (FMBRA 1985); it could be inferred that cassava bread would have a whiter crumb than cowpea, maize or wheat bread. Flour color is of importance because it determines to a large extent the subsequent color of the breadcrumb. Unattractive or unusual colors of bread can dissuade a customer from making a purchase, thereby ignoring other factors. However, the color of flour could either be natural (e.g., presence of bran and germ) or induced by a processing method. Generally, the color of flour is affected by particle size, extraction rate, flour treatment, temperature and time of drying (Priestley 1979).

Amylograph Pasting Viscosity

The plot of viscosity of the flours against heating time showed a quadratic graph (Fig. 2). Pasting temperature (T_g) was 56.1, 62.1, 66.0 and 70.8C, respectively, for wheat, cassava, maize and cowpea flours; while corresponding values for peak viscosity (V_m) were 430, 1,610, 740 and 1,402 Brabender units (BU), respectively (Table 2). Cowpea flour was the least stable with a value of 1,136 BU as its stability index, while wheat, maize and cassava flours had values of 90, 60 and 890 BU, respectively. Maize flour recorded the highest consistency value of 2,500 BU, followed by cowpea, wheat and cassava flours with values of 798, 250 and 170 BU, respectively (Table 2). It is apparent therefore that there are significant differences ($P < 0.05$) in the pasting viscosity of the flour samples, which are consistent with earlier reports (Idowu 1988). These observations could be attributed to the differences in chemical composition of starch (amylose: amylopectin) and the nature of bonding within the starch structure (Radley 1976). Kurimoto and Shelton (1988) also reported that starch damage influences dough rheology and the baking quality of flour. The rheological behavior of dough has been reported to depend on its flour composition. According to Olatunji *et al.* (1980), the

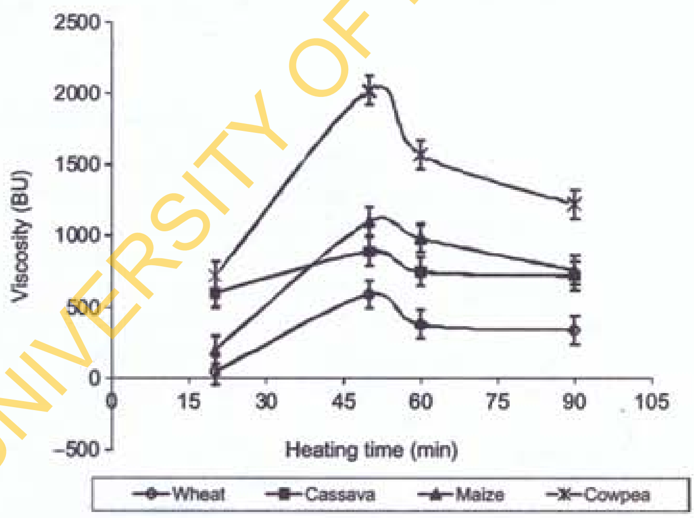

FIG. 2. INFLUENCE OF HEATING TIME ON VISCOSITY OF THE FLOURS

substitution of wheat flour beyond 20% with nonwheat flours results in significant changes and adversely affects rheological properties such as stability, extensibility, resistance to extension and recovery of the dough.

Water Absorption Capacity

Cassava flour has the highest water absorption capacity of 221.8% while wheat flour has the least at 31.9% (Table 2). There are significant differences in water absorption capacities of the flours at 5% confidence level. The observed variation in the volume of water requirement for bread dough making in Table 1 may be associated with the water absorption capacity of flours. Bhupendar (2005) reported inverse relationship between flour–water requirement for bread dough and water absorption capacity of varieties of wheat flour. The baking quality of flours is a function of water absorption capacity (Shittu *et al.* 2008).

Protein and Fat Content

The protein contents of the flours vary from 2.6 to 19.39% (Table 2). Both fat and protein contents of the flours significantly differ at $P < 0.05$. It has long been established that the bread-making performance of flours depends on the quantity and quality of their proteins. The variation in protein content of wheat flour significantly affects the mixing characteristic of dough and loaf volume of bread (Bhupendar 2005). No significant difference was recorded between the fat content of wheat and cassava flours. Maize flour has the highest fat of 2.3%.

Statistical Analysis

The moisture content of the flours did not correlate well with the particle size (–0.28). This observation may be associated with the milling of the flours at optimum moisture content. The grinding and sieving at optimum grain moisture content gives the best milling results (McCabe *et al.* 2005). It should be noted that the optimum milling moisture content of crop varies. However, high correlations were recorded between the values of moisture content – bulk density (0.96), particle size – peak viscosity (–0.88) and particle size – peak viscosity (0.70) of the flours. Moderate correlation exists between the particle size and density (–0.54). The analysis confirmed the interdependence of some physical and rheological properties of the flours. It also explained why flours' protein can be either by physical characteristics of flours or rheological properties or the combination of the two attributes as reported by Horsfall *et al.* (2007).

Sensory Evaluation of the Bread

Mean scores of the sensory attributes of the composite bread are shown in Tables 3 and 4. There is significant difference between the overall acceptability of the control (100% wheat) and the composite breads. Bias tendency for

TABLE 3.
MEAN SENSORY SCORES OF WHEAT–CASSAVA–COWPEA AND WHEAT–MAIZE–COWPEA COMPOSITE BREAD

Parameters					
Sample	Appearance	Taste	Aroma	Texture	Overall Acceptance
A (50:30:20)	4.2 ± 0.2^a	6.1 ± 1.6^a	7.2 ± 0.8^a	5.8 ± 0.4^b	5.8 ± 1.2^a
B (60:20:20)	4.8 ± 0.1^b	6.2 ± 0.3^a	7.5 ± 0.7^a	6.4 ± 0.4^c	6.2 ± 1.1^a
C (70:20:10)	5.1 ± 0.2^b	6.2 ± 0.4^a	7.6 ± 1.1^a	6.5 ± 0.4^c	6.4 ± 1.0^{ab}
D (80:10:10)	6.0 ± 0.2^c	6.4 ± 0.3^a	7.6 ± 0.5^a	7.3 ± 1.3^d	6.8 ± 0.8^b
E (85:10:5)	7.5 ± 0.4^d	7.5 ± 0.9^b	7.8 ± 0.3^{ab}	7.3 ± 0.8^d	7.5 ± 0.2^c
F (90:5:5)	8.0 ± 0.5^d	7.6 ± 0.2^b	8.1 ± 0.7^b	7.9 ± 0.1^{de}	7.9 ± 0.4^c
G (100%W)	8.7 ± 0.6^e	8.9 ± 0.7^c	8.7 ± 0.7^b	8.5 ± 0.3^e	8.7 ± 0.2^d
H (50:30:20)	3.9 ± 0.6^a	5.2 ± 0.8^d	7.3 ± 0.8^a	4.6 ± 0.9^a	5.3 ± 1.4^a
I (60:20:20)	4.1 ± 0.4^a	5.6 ± 0.1^d	7.2 ± 0.1^a	5.0 ± 1.3^a	5.5 ± 1.3^a
J (70:20:10)	4.1 ± 0.7^a	6.2 ± 0.9^a	7.2 ± 0.5^a	5.8 ± 0.3^b	5.8 ± 1.3^a
K (80:10:10)	5.3 ± 1.2^b	6.5 ± 0.4^a	7.4 ± 0.6^a	5.8 ± 0.1^b	6.3 ± 0.9^a
L (85:10:5)	5.9 ± 1.1^c	7.1 ± 0.4^b	7.4 ± 1.1^a	6.8 ± 0.9^b	6.8 ± 0.6^b
M (90:5:5)	7.6 ± 0.9^d	7.7 ± 0.7^b	7.4 ± 0.4^a	7.3 ± 0.6^d	7.5 ± 0.2^c

Values with the same superscript in the column are not significantly different at $P < 0.05$.
Samples A to F are ratios of substitution of wheat–cassava–cowpea.
Data used are mean of three replicates.
G is whole wheat.
Samples H to M are ratios of substitution of wheat-maize-cowpea.

TABLE 4.
SOME PROPERTIES OF HIGHLY RATED BREADS

Flours	Moisture (%)	Fat (%)	Protein (%)	Carbohydrate (%)	Volume (cm^3)	Weight (g)
G (100% wheat)	33.7^a	3.4^a	10.6^b	47.7^b	72.6^c	83.6^a
E (85% wheat, 10% cassava, 5% cowpea)	37.1^b	3.7^{ab}	11.9^c	42.4^a	62.4^a	179.9^b
F (90% wheat, 5% cassava, 5% cowpea)	36.2^b	3.9^b	12.3^d	42.6^a	68.3^b	181.3^{ab}
M (90% wheat, 5% cassava, 5% cowpea)	34.8^a	4.2^b	9.7^a	46.7^b	66.8^b	184.1^b

Values with the same superscript in the column are not significantly different at $P < 0.05$.
Data used are mean of three replicates.

familiar product might influence judgement of the panelists. However, samples E (85% wheat, 10% cassava, 5% cowpea), F (90% wheat, 5% cassava, 5% cowpea) and M (90% wheat, 5% maize, 5% cowpea) ratings were within acceptable quality standard (≥7). For all the samples, the aroma rating was high. The flavor of the ingredients used in dough making might have suppressed the flours' odor. Sharp differences were noticed in the scores of appearances and texture. The appearance of baked product is a function of the properties of flour. As mentioned earlier, the presence of fiber in flour could puncture expanding gas cells during fermentation, thus giving a reduced loaf volume (Crabtree and James 1982). As stated by Brown (2000), it is the gluten contained in wheat that serves to solidify the dough, giving it its characteristic dome-shaped top. Composite breads give flat or depressed shape because the structures formed cannot withstand the baking conditions. Nonetheless, the extent of collapse can be reduced when narrow baking pans are employed (Akobundu *et al.* 1988). The texture of the bread may be linked with starch damages during milling and the degree of fineness of the flour.

Properties of the Accepted Composite Bread

The physical–chemical properties of the four samples of bread rated above 7 points are shown are Table 4. Significant differences were noticed between the moisture, fat, protein, carbohydrate, weight and volume of the breads at $P < 0.05$. Sample G (100% wheat) has the biggest volume while sample M's (90% wheat, 5% maize, 5% cowpea) weight is the heaviest. Differences in the samples weight are not significant at $P < 0.05$. Bread loaf is rated by the average consumer in Nigeria quantitatively by appearance, weight and volume. It must be noted that sample F (90% wheat, 5% cassava, 5% cowpea) has the highest protein content (12.3%), but it did not produce the biggest volume. This is confirming the fact that flours' performance on bread making does not only depend on the quantity of protein but quality. Similarly, Mcwatters *et al.* (2004) reported reduction in loaf volume as a result of dilution of wheat gluten by cowpea protein. Oladunmoye *et al.* (2004) mentioned that low gluten in the protein content of hydrated maize flour hinders its visco-elastic properties.

CONCLUSION

The physical and chemical properties of wheat, cassava, maize and cowpea flours determine the performances in bread making. Most of the studied properties of the flours differ significantly at $P < 0.05$. Each of the flours has advantages that are beneficial in composite bread making. Examples of such are: (1) wheat flour possesses high quality protein; (2) the water absorption capacity of cassava is high; (3) maize flour has high fat content; and (4) cowpea contains high quantity of protein. The protein content of wheat–cassava and wheat–maize composite flours can be increased by the inclusion of cowpea flour.

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