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Full Length Research Paper

Nutritional organization, useful properties and sensory assessment of breads taking into account mixes of "orarudi" (Vigna sp) and wheat flour

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The proximate composition, functional and physical properties, as well as sensory evaluation of breads based on blends of wheat and 'orarudi' (*Vigna* sp) flour were investigated. Batches of 'orarudi' (*Vigna* sp) were separately put in a container and subjected to natural lactic acid fermentation in deionized water in a ratio of 1:3 (w/v) at 28 ± 2°C for 24 h. The fermented samples were manually dehulled and the cotyledons dried at 55 ± 2°C in a drought air oven, hammer milled into flour (500 µm mesh screen) and stored in a refrigerator (5 ± 2°C). The blends were formulated thus, the 'orarudi' flour (ORF) substituted 5, 10, 15, and 20% wheat flour (WF). The 100% WF served as the control. The parameters investigated were evaluated using standard methods. The data obtained were statistically analyzed. The results showed that fermentation and food supplementation enhanced both the proximate, minerals and vitamin contents of the experimental breads. The physical parameters indicated that fermentation and type of supplements had negative effect on the test breads relative to the control. The results revealed that the experimental breads had higher nutrient quality than the 100% wheat bread, probably due .to food-to-food fortification/supplementation.

Key words: Nutritional composition, functional properties, breads, composites, fermentation, nutrient quality.

INTRODUCTION

Consumption of baked products is greatly increasing due to the ever increasing urbanization, the products' cost competitiveness, their ready-to-eat convenience, availability of various products (bread, biscuit, cake, cookies) with varying taste and textural characteristics as well as their high nutritional profile and longer shelf life (Onoja et al., 2011; Mastromatteo et al., 2013). In particular, bread is an important food product that is cherished across the entire continents because of its sensorial and textural properties. Bread has been used as human food since ancient times and has been contributing over 50% of dietary energy due to its high carbohydrate content (Reebe et al., 2000; Dhingra and Jood, 2000; Onoja, 2007, 2011; Akubor, 2008; Mastromatteo et al., 2013). It is rich in both macro and micro nutrients, especially, proteins, carbohydrates, fibre as well as iron, magnesium, sodium, phosphorus, and some vitamins (B-vitamins). It has been shown that the rate of bread carbohydrate digestion greatly affects the absorption of glucose and consequently regulates the metabolic reactions that alter the glycemic and lipidemic postprandial responses in humans (Usha et al., 1989; Boby and Leelamma, 2003). For example, it has been reported that the slower digestion and absorption of bread carbohydrates helps maintain regular blood glucose which helps prevents non-communicable diseases associated with hyperglycemia and hyperlipidemia (Englyst et al., 2003). Moreover, many researchers have reported that the amylose/amylopectin ratios, the starch granule structure as well as protein matrix characteristics, all play an important role in determining the pattern of their hydrolysis and digestibility, and consequently affect the glycemic index of bread (Englyst et al., 2003; Mastromatteo et al., 2013). In addition, protein as well as starch/carbohydrate contents have been shown to influence both the loaf volume and the appearance of the bread (Honda and Jood, 2005). Nevertheless, these baked foods do not have sufficient essential nutrients required for good health (FAO/WHO, 2004).

Supplementation of cereal-based foods with legume for the production of bakery products to improve their nutrient quality has been reported (Impar, 1977; Nout, 1977; Macwatters, 1982; Natalie, 1988; Dhingra and Jood, 2000; Onoja, 2007; Akubor, 2008). These works showed that composite flour produced bakery products that were higher in nutrient quality compared with the 100% wheat products. This is because legume protein is high in lysine, an essential limiting amino acid in most cereals. Cereals on the other hand, are high in methionine and cystine which are deficient in legumes (FAO, 2004). Therefore, blending legume with cereal will provide desirable protein pattern that would help to enhance nutritional status of the population. Moreover, the high mineral and vitamin contents of these food crops are responsible for the increased nutritive quality of the supplemented products (Hotz and Gibson, 2007; Uwaegbute and Anyika, 2008). In particular, the functional properties of the composite flour have been found to be suitable for the production of bakery products (Hamad and Fields, 1979; Raidi and Klevin, 1983; Honda and Jood, 2005; Akubor, 2008). Due to their high fibre content, legumes have also been included within the group of functional foods due to their hypocholesterolemic and hypoglycemic effects (Usha et al., 1989; Boby and Leelamma, 2003).

The production of any food product depends on its raw material availability. The major problem facing the bakery industry in sub-Saharan Africa is the total dependence on importation of wheat to sustain its production. It is, therefore, imperative that alternatives to wheat which is traditionally used for bakery products be developed either as an extension or a replacement. Nigeria is a rich agricultural country but a higher percentage of food produced is wasted through post-harvest losses (Oyenuga, 1968). The application of fermentation to produce legume flour for bakery products will help to enhance nutrient quality and decrease anti-nutrients. There is no available report in the literature on the use of composite flour produced from 'orarudi' *(Vigna* sp) and wheat flour (WF) for the production of bakery products, notably, bread. The study was conducted to investigate the use of flour blends from these food crops for the production of bread. In particular, the functional, physical and sensory properties were evaluated; in addition, proximate, mineral and vitamin composition was determined. The characteristics of the test breads were compared with the 100% WF.

MATERIALS AND METHODS

Wheat (*Triticum aestivum*) flour was purchased from Nsukka main market. The 'orarudi' (*Vigna* sp), a special type of beans grown in Nsukka area (that lies latitude 6° N and longitude 7° E) was equally bought from Nsukka main market, Enugu State, Nigeria. Milk, water, compressed yeast, margarine, sugar and salt were bought from the local market.

Preparation of 'orarudi' flour (ORF)

Two kilograms (2 kg) of 'orarudi' (*Vigna* sp) grains were cleaned by sorting to remove extraneous materials, washed under running water and shade dried. The different batches were separately put in a container and subjected to natural lactic acid fermentation in deionized water in a ratio of 1:3 (w/v) at 28 ± 2°C for 24 h. The fermented samples were dried at 55 ± 2°C in a hot drought air oven (Gallenkamp, BS Mode l 250 size 2 UK), decorticated/dehulled and milled in hammermill into fine flour (500 µm mesh screen) and stored in a refrigerator (5 ± 2°C, 50% RH) until used for the production of breads.

Preparation of wheat (*Triticum aestivum*) flour

Two kilograms (2 kg) of white wheat (*T. aestivum*) flour (about 72% extraction rate) was purchased already milled as sold in Nsukka main market. The flour was made by Nigerian Flour Mills (Golden Penny). The bread produced from the 100% WF served as the control.

Evaluation of functional properties of flour

Water and oil absorption capacities were determined following the methods of Sosulski et al. (1976). Foaming capacity (FC) and foam stability (FS) were determined by the method of Sathe et al. (1982). The volume of foam at 30 s of whipping was expressed as FC. The volume of foam was recorded 1 h after whipping to determine FS as percent of the initial foam volume. Bulk density was determined by the method of Onimawo and Egbekwun (1998). Emulsion activity (EA) and emulsion stability (ES), least gelation concentration (LGC), swelling power and solubility was determined by the method of Okaka and Potter (1977).

Formulation of flour blends

The four (4) blends were formulated by replacement as follows:

ORF was used to substitute 5, 10, 15, and 20% WF. The 100% white WF served as the control flour.

Bread baking process

The bread samples were prepared using straight dough method as described by Ceserani et al. (1995). The recipe of the doughs included: 200 g of the composite flour, 125 ml (milk and water mixed), 5 g of compressed yeast, 10 g of margarine, 5 g of sugar and 2 g of salt. Each appropriately weighed composite flour (screened with 500 µm mesh) and Ingredients were thoroughly mixed in a mixer using a modified straight dough mixing method to produce the dough. The mixer was operated at a low speed for 5 min followed by high speed mixing for 20 min. The dough obtained after the mixing process was weighed, cut into uniform sizes, manually kneaded, molded, brushed with egg and covered with a cheese cloth and left to proof (ferment) at 35°C and 85% relative humidity for 36 min in a thermostatically controlled oven. The leavened dough was carefully transferred to the thermostatically controlled baking oven at 180°C for 35 min. The breads produced were cooled to ambient temperature and packaged in polyethylene bags for analyses. The baking process was performed in triplicate.

Chemical analysis

The breads were analyzed for proximate, mineral, vitamin and physical properties using standard methods (AOAC, 2005). The Kjeldahl method was used to estimate the protein nitrogen (N) which was then multiplied by the factor 6.25 to get the percent protein content (N × 6.25%). Ash was estimated by incinerating 1 g of the sample at between 550 to 600°C for 6 h in a muffle furnace until ash was obtained. Fat was estimated by extraction with petroleum ether using Tecator apparatus.

Subsequent extractions and weighing were continued until a constant weight was obtained. The carbohydrate content was obtained by difference, thus: 100 – (% protein + % fat + % ash + % fibre + % moisture). Energy values were calculated using Atwater's factor (% protein × 4 + % CHO × 4 + % fat × 9 kcal). Mineral estimation was done using wet digestion with nitric and perchloric acids. The values were then read out in Atomic Absorption Spectrophotometer (Latta and Eskin, 1980). The vitamins B_1, B_2 and niacin content were estimated according to the method of Pearson (1976). All analyses were performed in triplicate.

Physical properties

The physical characteristics of the breads investigated included height, breadth, weight, length, oven spring, proofing ability and specific volume were determined according to the method described by Ceserani et al. (1995). The height, breadth and length were measured by a metal rule. The weight was determined using a weighing balance. The proofing ability was measured by subtracting the initial height of the dough before proofing from the final height after proofing and multiplying the value by 100. Specific volume was determined using the formula by Ceserani et al. (1995). Thus,

$$\text{Specific volume } (cm^3/g) = \frac{L \times B \times H}{W}$$

Where L = Bread length; B = bread breadth; H = bread height; W = bread weight.

Oven spring was estimated as the difference in dough height before and after baking.

Sensory evaluation

Using a 9 point Hedonic scale (Retapol et al., 2006), where 9 represented the highest score and 1 the lowest was employed to evaluate the product for flavor, texture (crumb, crust), color (crumb, crust) and the general acceptability. A- 40 person taste panel randomly selected from students and lecturers of the Home Science Department, University of Nigeria (Nsukka), participated in the tasting sessions. Loaf samples were sliced evenly without removing the crust. Each sample was placed on white plates and identified with random three-digit numbers. Each judge (panel member) was seated in an individual compartment free from noise and distraction. The properly coded breads were served to the panelists for evaluating taste, flavor, color (crumb, crust), texture (crumb, crust), mouth feel and the general acceptability. Each judge was presented with a glass of water after each tasting session to rinse the mouth in order to prevent a carry-over effect.

Statistical analysis

The Statistical Package for Social Sciences (SPSS, version 17) was used to analyze the data. The Duncan's New Multiple Range Tests (DNMRT) was used to test the significance of the difference among means. The significance was accepted at a $p < 0.05$. (Steel and Torrie, 1980).

RESULTS

Functional properties

The functional properties of the flour are presented in Table 1. The ORF had significantly ($p < 0.05$) higher water absorption capacity (WAC) (132.23%) than the WF (126.67%). There was a similar trend in the oil absorption capacity (OAC) between the flour (Table 1). On the other hand, the EA and ES slightly differed ($p < 0.05$). The FC of the WF (11.2%) was significantly ($p < 0.05$) lower than the ORF (17.76%), while FS showed similar trend for the two flours (WF: 39.57%; ORF: 51.52%) ($p < 0.05$). The bulky density did not differ significantly ($p > 0.05$) between the two flours (0.58%; 0.47%). The swelling power of ORF (3.55%) was significantly ($p < 0.05$) lower than the WF (13.23%). The solubility of the two flour differed (7.88%; 10.34%) for WF and ORF, respectively. The LGC characteristics between the two flour differed ($p < 0.05$).

Proximate composition of the breads

The proximate composition of the breads produced from the flour blends and the control is presented in Table 2. The moisture content of the samples varied. The control sample had the highest value that differed from the test groups ($p < 0.05$) (Table 2). The protein content of breads produced from the flour blends and the control ranged from 8.20 to 14.56%. The wheat and orarudi (WOR_4) blend had the highest protein content (14.56%) that was significantly different ($p < 0.05$) from the rest including the control (8.20%). The control had much higher ($p < 0.05$)

Table 1. Functional properties of wheat and 'orarudi' flour.

Flour/property	Wheat Flour(WF)	'Orarudi' Flour (ORF)
Water absorption capacity(%)	$126.67^{b} \pm 0.01$	$132.23^{a} \pm 0.02$
Oil absorption capacity (%)	$130.26^{a} \pm 0.03$	$135.44^{b} \pm 0.01$
Emulsion activity (%)	$14.54^{b} \pm 0.01$	$16.58^{a} \pm 0.03$
Emulsion stability (%)	$6.84^{a} \pm 0.01$	$7.07^{a} \pm 0.01$
Foaming capacity (%)	$11.20^{b} \pm 0.03$	$17.76^{a} \pm 0.02$
Foam stability (%)	$39.57^{b} \pm 0.01$	$51.52^{a} \pm 0.03$
Bulk density (g/cm^3)	$0.58^{a} \pm 0.01$	$0.47^{a} \pm 0.02$
Swelling power (%)	$13.23^{a} \pm 0.01$	$3.55^{b} \pm 0.01$
Solubility (%) least gelation	$7.88^{b} \pm 0.03$	$10.34^{a} \pm 0.02$
concentration (%.W/N)	$9.20^{b} \pm 0.01$	$5.98^{a} \pm 0.02$

Data are means of 3 determinations. Values in the same row with different superscripts are significantly different ($p \leq 0.05$).

Table 2. Proximate composition and energy content of breads prepared from different blends and the control (per 100 g sample).

Parameters/composites/ratios	WOR_1 95:5	WOR_2 90:10	WOR_3 85:15	WOR_4 80:20	Wheat bread 100
Moisture (%)	$12.32^{d} \pm 0.02$	$13.88^{d} \pm 0.03$	$31.12^{b} \pm 0.01$	$30.35^{d} \pm 0.01$	$33.72^{a} \pm 0.03$
Protein (%)	$9.72^{d} \pm 0.01$	$11.23^{c} \pm 0.02$	$13.30^{b} \pm 0.01$	$14.56^{a} \pm 0.01$	$8.20^{e} \pm 0.02$
Total CHO (%)	$69.41^{b} \pm 0.01$	$75.70^{c} \pm 0.01$	$74.40^{d} \pm 0.01$	$73.30^{d} \pm 0.03$	$82.40^{a} \pm 0.02$
ASH (%)	$3.44^{d} \pm 0.02$	$4.80^{c} \pm 0.01$	$5.60^{b} \pm 0.02$	$5.84^{a} \pm 0.03$	$3.42^{d} \pm 0.02$
FAT (%)	$3.25^{b} \pm 0.01$	$2.60^{c} \pm 0.01$	$2.42^{d} \pm 0.02$	$2.30^{d} \pm 0.01$	$3.46^{a} \pm 0.02$
Total fibre (%)	$1.76^{d} \pm 0.01$	$2.56^{c} \pm 0.01$	$4.78^{b} \pm 0.01$	$6.10^{a} \pm 0.01$	$1.14^{e} \pm 0.01$
Energy (kcal)	$381.73^{b} \pm 0.03$	$371.12^{c} \pm 0.03$	$368.02^{d} \pm 0.02$	$367.10^{d} \pm 0.03$	$391.74^{a} \pm 0.02$

*Data are means of 3 determinations. Values in the same row with different superscripts are significantly different ($p \leq 0.05$). Energy calculation was based on Atwater factor (protein x 4, CHO x 4, Fat x 9 kcal). CHO by difference that is, 100 - {protein + fat + ash + fibre}. W = wheat, OR = 'orarudi' (*Vigna* sp), CHO = carbohydrate. Blend1 (WOR_1), Blend2 (WOR_2), Blend 3 (WOR_3), Blend4 (WOR_4) and 100% wheat bread (control).

carbohydrates (82.40%) than the rest. The experimental breads variation ranged between 73.30 and 78.40%. The ash content of the WOR_1 and the control were similar ($p > 0.05$) but differed significantly ($p < 0.05$) from the other test breads. The values varied from 3.44 to 5.84%. The control had the highest fat content (3.46%) compared with the test samples ($p \leq 0.05$). The WOR_1 bread had higher fat content (3.25%) relative to the other test samples ($p \leq 0.05$). The control had the least total fibre

(1.14%) that differed significantly ($p < 0.05$) from the test samples. The experimental breads ranged from (1.76% to 6.10%). The energy content of the control bread (391.74 kcal) was the highest compared with the test samples ($p < 0.05$). The values of the test samples ranged from 367.10 to 381.73 kcal.

Physical properties

The physical properties of the breads are shown in Table 3. The control bread had the lowest weight (136.20 g) than the test breads and was significantly ($p < 0.05$) different. The values for the test breads ranged from 139.0 to 145.20 g. The WOR_4 bread had the highest weight (145.20 g). The control had the highest width value (5.30 cm) relative to the test breads. The WOR_1 bread had the highest height compared with the other test samples ($p < 0.05$). Similarly, the control (WF bread) had the overall highest height (6.90 cm) that differed significantly ($p < 0.05$) from the test breads. The loaf lengths (dimensions) of the test samples differed significantly ($p < 0.05$) from the control (15.20 cm). The oven spring of both the test breads and the control were similar ($p > 0.05$). The spread ratios of both the control sample and the WOR_1 bread were similar ($p > 0.05$) and were higher than other samples. The value of the specific volume for the control bread was the highest (3.86%) which was significantly ($p < 0.05$) different from the test samples. The proofing ability of the control bread (96%) was higher than other test breads.

Minerals and vitamins content

Table 4 presents the mineral and vitamin composition of the breads. The mineral content of the test breads were

Table 3. Physical properties of the experimental breads and the control.

Blends/ratios/parameters	WOR_1 95:5	WOR_2 90:10	WOR_3 85:15	WOR_4 80:20	Wheat bread 100
Weight (g)	$139.0^b \pm 0.03$	$140.60^c \pm 0.01$	$142.0^a \pm 0.02$	$145.20^b \pm 0.01$	$136.20^d \pm 0.03$
Width (cm)	$4.90^a \pm 0.01$	$4.62^b \pm 0.01$	$4.60^b \pm 0.01$	$4.65^b \pm 0.02$	$5.30^a \pm 0.01$
Height (cm)	$5.82^b \pm 0.01$	$4.60^d \pm 0.03$	$4.70^d \pm 0.01$	$5.30^c \pm 0.02$	$6.90^a \pm 0.03$
Length (cm)	$14.30^b \pm 0.03$	$11.90^c \pm 0.02$	$10.40^d \pm 0.01$	$10.60^d \pm 0.01$	$15.20^a \pm 0.02$
Oven spring (cm)	$0.83^a \pm 0.01$	$0.76^b \pm 0.01$	$0.72^c \pm 0.01$	$0.71^c \pm 0.01$	$0.90^a \pm 0.01$
Spread ratio	$7.10^b \pm 0.02$	$6.40^b \pm 0.02$	$5.32^c \pm 0.01$	$5.30^c \pm 0.01$	$6.69^b \pm 0.03$
Specific volume (%)	$2.56^b \pm 0.01$	$1.20^c \pm 0.01$	$1.30^c \pm 0.02$	$1.42^c \pm 0.01$	$3.86^a \pm 0.01$
Proofing ability (%)	$91^b \pm 0.03$	$89^c \pm 0.14$	$85^d \pm 0.12$	$78^e \pm 0.16$	$96^a \pm 0.03$

*Data are means of 3 determinations. Values in the same row with different letter superscripts are significantly different ($p \leq 0.05$). W = wheat, OR = 'orarudi '(*Vigna* sp). Blend1 (WOR_1), Blend2 (WOR_2), Blend3 (WOR_3), Blend4 (WOR_4) and 100% wheat bread (control).

Table 4. Mineral and vitamin composition* of breads produced from the blends and the control (per 100 g sample).

Blends/ratios/parameters (mg)	WOR_1 95:5	WOR_2 90:10	WOR_3 85:15	WOR_4 80:20	Wheat bread 100
Fe	$0.16^e \pm 0.01$	$0.46^d \pm 0.02$	$1.62^b \pm 0.01$	$1.92^a \pm 0.01$	$1.06^c \pm 0.01$
Cu	$0.38^d \pm 0.01$	$0.42^c \pm 0.01$	$0.48^b \pm 0.01$	$0.64^a \pm 0.01$	$0.38^d \pm 0.01$
Ca	$43.20^d \pm 0.02$	$48.26^c \pm 0.01$	$66.00^b \pm 0.03$	$87.30^a \pm 0.01$	$42.50^d \pm 0.04$
P	$67.26^d \pm 0.12$	$75.40^b \pm 0.14$	$74.30^c \pm 0.12$	$84.42^a \pm 0.03$	$66.40^d \pm 0.02$
I_2	$0.01^a \pm 0.001$	$0.01^a \pm 0.001$	$0.01^a \pm 0.001$	$0.01^a \pm 0.001$	$0.01^a \pm 0.00$
K	$178.30^c \pm 0.13$	$182.20^b \pm 0.12$	$181.20^b \pm 0.02$	$188.40^a \pm 0.03$	$177.56^c \pm 0.02$
Mn	$0.29^b \pm 0.01$	$0.30^b \pm 0.01$	$0.32^b \pm 0.01$	$0.33^b \pm 0.02$	$0.31^b \pm 0.01$
Na	$728.20^c \pm 0.13$	$736.30^b \pm 0.16$	$738.26^b \pm 0.12$	$744.12^a \pm 0.11$	$722.20^d \pm 0.22$
Zn	$0.62^d \pm 0.01$	$0.64^d \pm 0.02$	$0.58^d \pm 0.02$	$0.66^d \pm 0.01$	$0.63^d \pm 0.01$
Mg	$23.20^c \pm 0.12$	$24.20^b \pm 0.23$	$23.23^c \pm 0.24$	$28.40^b \pm 0.13$	$20.20^d \pm 0.0112$
Cd	$0.001^c \pm 0.0001$	$0.002^c \pm 0.0001$	$0.001^c \pm 0.0001$	$0.002^c \pm 0.0001$	$0.001^c \pm 0.0001$
Cr	$0.034^a \pm 0.01$	$0.034^a \pm 0.01$	$0.033^a \pm 0.02$	$0.036^a \pm 0.02$	$0.033^a \pm 0.01$
B_1	$0.28^c \pm 0.01$	$0.29^c \pm 0.02$	$0.34^b \pm 0.02$	$0.42^a \pm 0.01$	$0.078^d \pm 0.01$
B_2	$0.27^b \pm 0.02$	$0.26^b \pm 0.01$	$0.26^b \pm 0.01$	$0.32^a \pm 0.01$	$0.075^c \pm 0.02$
Niacin	$1.11^c \pm 0.01$	$1.14^c \pm 0.01$	$1.44^b \pm 0.01$	$1.56^a \pm 0.01$	$0.52^d \pm 0.01$

*Data are means of 3 determinations. Values in the same row with different letter superscripts are significantly different ($p \leq 0.05$). Data expressed as mg/100g product. W = wheat, OR = 'orarudi' (*Vigna* sp). Blend1 (WOR_1), Blend2 (WOR_2), Blend 3 (WOR_3), Blend4 (WOR_4) and 100% wheat bread (control).

comparable with the control. The vitamins (B_1, B_2 and niacin) content of the samples were moderate relative to the bakery products.

Sensory evaluation

Table 5 presents the mean sensory evaluation scores of the breads. The control bread had higher general acceptability, followed by WOR_1 sample. There was a significant ($p < 0.05$) difference in crumb and crust color among the test products. The judges preferred the crust color of the WOR_1 bread to the other test samples ($p < 0.05$) including the control. Although some of the sensory attributes of the breads from the other test blends were lower than those of the control and the WOR_1 bread, they were, however, acceptable. All the test samples recorded over 60% of overall acceptance. However, there was a slight difference in the degree of acceptance amongst the breads.

DISCUSSION

The higher WAC of ORF compared to WF might be ascribed to the higher amounts of hydrophilic constituents particularly, proteins, carbohydrates and fiber it contains. Kinsella (1987) and Akubor (2008) showed that WAC mainly depends on the amount and nature of the hydrophilic constituents present in the samples. In particular, it has been reported that WAC of dough is influenced by the protein content and quality as well as the extent to which the starch is damaged mechanically (the greater the damage the more the absorption (Bushuk and Hlynka, 1964). Also, it has been shown that fiber is characterized by high water holding capacity as reported

Table 5. Mean sensory attributes of breads made from different blends and the control.

Blends/ratios/parameters	WOR$_1$ 95:5	WOR$_2$ 90:10	WOR$_3$ 85:15	WOR$_4$ 80:25	Whole wheat 100
Loaf shape	$8.40^{b} \pm 0.01$	$7.60^{c} \pm 0.02$	$7.60^{c} \pm 0.03$	$6.40^{d} \pm 0.01$	$8.80^{a} \pm 0.02$
Mouth feel	$8.82^{a} \pm 0.02$	$7.60^{b} \pm 0.03$	$7.40^{c} \pm 0.01$	$7.10^{d} \pm 0.01$	$8.80^{a} \pm 0.12$
Taste	$8.60^{a} \pm 0.01$	$7.40^{c} \pm 0.02$	$7.60^{b} \pm 0.01$	$6.20^{d} \pm 0.03$	$8.70^{a} \pm 0.02$
Flavor	$7.80^{b} \pm 0.02$	$7.20^{c} \pm 0.01$	$7.30^{c} \pm 0.02$	$6.40^{d} \pm 0.01$	$8.20^{a} \pm 0.13$
Crust					
Color	$8.60^{a} \pm 0.02$	$7.66^{c} \pm 0.01$	$7.56^{c} \pm 0.03$	$5.10^{d} \pm 0.01$	$8.20^{b} \pm 0.02$
Texture	$7.20^{c} \pm 0.01$	$7.10^{d} \pm 0.02$	$7.60^{b} \pm 0.01$	$5.60^{e} \pm 0.01$	$7.80^{a} \pm 0.03$
Crumb					
Color	$8.46^{b} \pm 0.02$	$7.10^{d} \pm 0.11$	$7.40^{c} \pm 0.02$	$6.20^{e} \pm 0.01$	$8.60^{a} \pm 0.03$
Texture	$7.60^{b} \pm 0.03$	$7.26^{c} \pm 0.01$	$6.60^{d} \pm 0.01$	$6.20^{e} \pm 0.03$	$7.98^{a} \pm 0.02$
General acceptability	$8.50^{b} \pm 0.01$	$7.66^{c} \pm 0.03$	$6.66^{d} \pm 0.04$	$6.40^{d} \pm 0.01$	$8.60^{a} \pm 0.02$

*Data are means of 3 determinations. Values in the same row with different superscripts are significantly different ($p<0.05$). Values were based on a 9 – point Hedonic scale (where 9 represented the highest and 1 the lowest). W = wheat, OR = 'orarudi' (*Vigna* sp). Blend1(WOR$_1$), Blend2(WOR$_2$), Blend 3(WOR$_3$), Blend4(WOR$_4$) and 100% wheat bread (control).

by Houoway and Grieg (1984). The low fat contents of the blends may have enhanced their WAC. Fat has been shown to decrease the hydration capacity of flour used in the formulation of the blends and the control. It has been reported that WAC is critical in bulking and consistency of products as well as in baking processes (Akubor et al., 2013). Many researchers have reported that water also plays a significant role in the major changes that take place during the baking process which include starch gelatinization, protein denaturation, yeast and enzyme inactivation, as well as flavor and color formation (Bushuk and Hlynka, 1964; Pomeranz, 1985; Czuchajowska et al., 1988). Moreover, water content and its distribution has been shown to affect the shelf life of bread which is directly caused by microbial spoilage, softness of crumb, crispness of the crust, crumb hardening, crumbliness, etc associated with staling and overall lowered acceptability by the consumers (Pomeranz, 1985).

The higher OAC of ORF suggested that it contained higher amounts of a polar amino acids (normally present in legume proteins) than WF. Akubor et al. (2013) attributed OAC mainly to the physical entrapment of oils depicting the role at which proteins complex with fat in food formulations. It is suggested that OAC is important in bakery products (Onimawo and Egbekwun, 1998) and this study showed that WF and ORF would have potential for bakery products. Fat acts as flavor enhancer and increases the mouths feel of foods. It has also been shown to increase the leavening power of the baking powder in the dough and improves the texture of the baked products particularly, bread (Dhingra and Jood, 2000). The EA and ES were low, with the ORF exhibiting the highest activity. The low protein content of WF and high fiber levels in ORF may have discouraged the formation and stabilization of emulsions (Kinsella, 1987). The high protein content of legumes including ORF may explain its good ability to form and stabilize foams. Akubor et al. (2013) noted that FC and FS depends on protein concentration, protein solubility, swelling power, among other factors. Foams are used to improve texture, consistency and appearance of foods. Therefore, blending WF with ORF would improve their applications in baking processes.

The WF and the ORF had comparable bulk densities probably due to their similar particle sizes. Bulk density has been reported to be a function of particle size because particle size is inversely proportional to bulk density (Onimawo and Egbekwun, 1998). The low bulk density of the flour is beneficial for cost effectiveness in packaging design. The LGCs of the flour was significantly ($p < 0.05$) lower in the ORF than WF. Sathe et al. (1982) associated the variations in the gelling properties of flour to the different ratios of protein, carbohydrate and fat that makes up the flour. Interaction among these components was also noted to play a significant role in functional properties as it affects gelation. The rate of gelling and gel firmness was reported to be influenced by temperature, time of heating and protein content (Houoway and Grieg, 1984; Kinsella, 1987). Flour like WF and ORF with low values of LGC could be good thickening agents and might be useful in products which require thickening and gelling such as complementary foods.

The high protein values of the test breads could be ascribed to the synergistic effect of mutual food supplementation. It could as well be attributable to synthesis of new proteins from hydrolyzed free amino acids during fermentation by microflora enzymes. It is known that when legumes supplement cereals, they provide a protein quality comparable to or higher than that of animal (Impar et al., 1977; Hotz and Gibson, 2007). The higher protein for the WOR_4 blend over the other blends is probably due to its lower level of carbohydrates. The protein drop in other test samples could be attributed to a dilution of protein by the increased level of carbohydrates in them. In particular, the WOR_1 blend having the lowest protein value (9.72%) showed the highest carbohydrates value (78.4%). This observation agrees with the findings of other researchers (Sathe, 1982; Kibite and Evans, 1984). The high carbohydrate levels of the test breads though lower than the control (WF) might be ascribed to either individual food materials and/or microflora enzyme hydrolysis that led to the synthesis of complex carbohydrates from other nutrients carbon skeletons due to fermentation and synergistic effect of food supplementation. This condition was also applicable to other nutrients (Odunfa, 1985; Hotz and Gibson, 2007). The high ash content of the test breads and the control was an indication that the products are good sources of mineral (Reebe et al., 2000). The low lipid level was expected since legumes and cereals store energy in form of starch rather than lipids. The low lipid values are beneficial as it guarantees longer shelf life for the breads because it has been reported that the higher the lipid content of a given food, the higher are the chances for rancidity (Beuchat and Worthington, 1974).

The mineral and vitamin contents of the test breads relative to the control suggest their superiority over the control. For instance, iron complexes with tannin and phytate present in beans but during the fermentation of these foods, these complexes are broken down by the hydrolyzing enzymes to improve the availability of iron (Hamad and Fields, 1979; Reebe et al., 2000; Dhingra and Jood, 2000; Honda and Jood, 2005; Akubor, 2008). The improved phosphorus level might be due to the release of phosphorus from its organic complex by the microflora enzymes and this could address the problem of osteoporosis in the elderly (Reebe et al., 2000). However, fermentation negatively influenced the physical characteristics of the test breads produced relative to the control as observed in the higher weight and dull color of the experimental breads compared with the control. The fibre levels are good and the products could be potential candidate in the management of diabetes (Usha et al., 1983; Boby and Leelamma, 2003; Englyst et al., 2003). The width and length of the test samples had comparable values however, they were lower than the control. This is because the spread of bread was affected by the competition of the ingredients for the available water. Flour which absorbs water during mixing will tend to reduce it (Raidi and Klevin, 1983; Singh et al., 1991). The WF used in producing control bread might have absorbed more water than the test blends.

The low level of gluten in the composite flour no doubt affected the weight, height, proofing ability, specific volume and the oven spring of the test products as less carbon IV oxide (CO_2) would be retained (less bubbles) by the dough. It has been shown that crumb firmness is influenced by crumb structure which is closely related to the gluten content, the degree of starch gelatinization and moisture redistribution (Mastromatteo et al., 2013). Moreover, during fermentation, fat, protein and carbohydrate are hydrolyzed (diluted) and would influence the products and resulting in the above observations. The present findings were in agreement with those for fermented wheat - cowpea blend (Akubor, 2008), fermented composite flour blend (Onoja, 2007), African yam-bean/wheat blend (Onyechi and Nwachi, 2008). Fermentation and supplementation affected the physical properties (Table 3) of the products when compared with the control.

The preference of crumb and crust color, texture, flavor, mouth feel and taste of bread from WOR_1 blend and the control could be due to their soft crumb with large bubbles, and good crust firmness that resulted in pleasant appearance. It has been shown that flour constituents, particularly protein is critical for the loaf volume and appearance (Kihlberg et al., 2004). WOR_3 and WOR_4 recorded lower scores of general acceptability compared with other test samples, but were still above 60% of the sensory score. This observation could be due to higher incorporation of the legume (orarudi) resulting in firmer crumb with few large bubbles (characteristic of composite bread) as well as beany flavor associated with beans (Patel et al., 2005). The bread from the control and WOR_4 that had better flavor, taste and color than others were much more acceptable. This phenomenon is expected because it has been reported that appearance of food evokes the initial response however, the flavor determines the ultimate final acceptance or rejection by the consumer (Retapol and Hooker, 2006). Although the other test samples had lower overall score, they were higher in nutrient quality/density. This high acceptability of the test breads are in agreement with the reports of other researchers like Hamad and Fields (1979) and Onoja (2007) who equally reported higher acceptability of corn chips, rice chips and bakery products from fermented composite flour.

CONCLUSION AND RECOMMENDATIONS

Fermentation and supplementation improved nutrient quality of the products. Supplementation of cereals with legume to produce enriched reads increased acceptability in the experimental bread. The selected blends could be incorporated into the traditional dishes of those who prefer natural enhancement of nutrients than artificial fortification. The blends and their products have greater promise for increased use of other under-utilized food crops in Nigeria ecosystem. Future study should focus on the shelf life of the products.

Conflict of Interest

The author(s) have not declared any conflict of interest.

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