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Full Length Research Paper

Evaluation of maize-soybean flour blends for sour maize bread production in Nigeria

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Examination of the functional properties of three different flours/meals and two blends of maize meal and soybean-flour (ratios 9:1 and 8:2, maize:soybean) were carried out. Properties examined included amylose content, bulk density, dispersibility, swelling power, water absorption capacity and visco-elastic properties. The effect of the different flour/meal samples on the properties of sour maize bread were evaluated by baking bread samples with the different flours/meals using a mixed starter culture of *Lactobacillus plantarum* and *Saccharomyces cerevisiae*. All flour/meal samples differed, sometimes significantly ($p \leq 0.05$) in their functional properties. Significant positive correlations existed among the functional properties of the flours at the 1% level (2-tailed). The maize meal/soy flour blends MSA (maize meal and soybean flour mixed in ratio 9:1) and MSB (maize meal and soybean flour mixed in ratio 8:2) did not differ significantly from each other in functional properties except for amylose content. MSA was adjudged the best flour blend for sour maize bread production as its bread had the highest score for overall acceptability (6.1) and other sensory parameters evaluated.

Key words: Flour blend, functional properties, maize meal, sour maize bread, soybean flour.

INTRODUCTION

Bread is an important staple food, the consumption of which is steady and increasing in Nigeria. It is however, relatively expensive, being made from imported wheat that is not cultivated in the tropics for climatic reasons. Wheat importation represents an immense drain on the economy while also suppressing and displacing indigenous cereals, with a resultant detrimental effect on agricultural and technological development

The need for strategic development and use of inexpensive local resources in the production of popular foods such as bread has been recognized by organizations such as the Food and Agricultural Organization (FAO), the International Institute for Tropical Agriculture (IITA), Nigeria and the Federal Institute for Industrial Research, Oshodi (FIIRO), Nigeria. This led to the initiation of the composite flour program, the objective of which was to seek ways of substituting flours, starches and protein concentrates from indigenous crops such as cassava, maize, yam, sorghum and millet, for as much wheat as possible in baked products.

Although there is now a substantial amount of composite bread technology available, such breads still require at least 70% wheat flour to be able to rise and hence, implementation of such pre-commercial inventions has been limited (Satin, 1988; Eggleston, Omoaka, and Thedioha, 1992). Attempts have also been made at producing wheat-less bread specialties from 100% local flours in several African countries but there was the problem of how to improve coherence between starch granules without impairing the capacity of dough/batter to rise. Ingredients that have been used as binders include egg white, margarine, xanthan gum, gliadin and the active surface emulsifier, glycerol mono-stearate. However, few of these gluten substitutes are locally available, or in certain cases the equipment necessary to produce them is relatively expensive and introduces another cost element that may end up outweighing the

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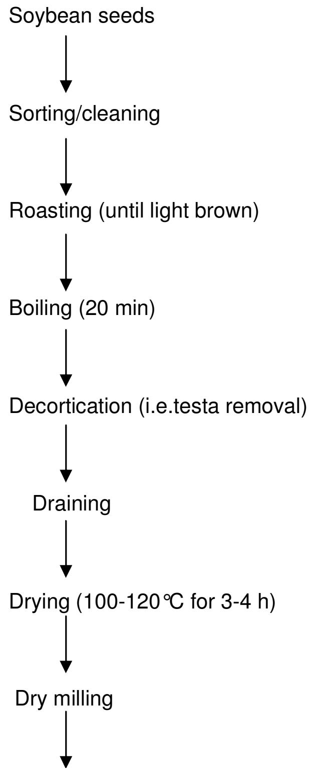

Figure 1. Flow diagram for the production of cooked soy flour (Adapted from IITA, 1990).

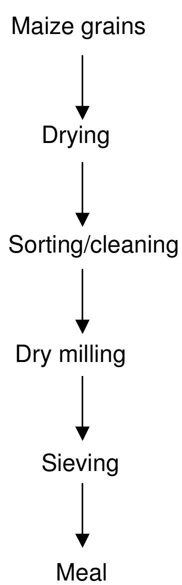

Figure 2. Flow diagram for the production of maize meal (Okoruwa, 1995).

savings on wheat importation.

In choosing the appropriate flour type for non-wheat baking practices, it is important to give full consideration to the realities of the local agricultural resources prevalent in the area in question. Materials grown in the tropics include cereals (maize, sorghum and millet), starchy tubers (cassava, sweet potato and yam), while oil seeds (soybean, bean seed/cowpea and groundnut) can be used as protein quality improvers. Many nations all over the world have for instance developed their own bread specialties based on their available agricultural resources. Germany is associated with pumpernickel, France with long flute, Italy with crisp bread sticks, Scotland with honest scones, Norway with flatbread, India with *Idli* and Israel with corn-rye and *challah* (Bureng and Olatunji, 1992).

Since the diet of an average Nigerian consists of foods that are mostly carbohydrate based, there is a need for strategic use of inexpensive high protein resources that complement the amino acid profile of the staple diet in order to enhance their nutritive value. Newer protein sources are being explored as protein complements of which oilseeds occupy a prominent place (Wang and Kinsella, 1976; Sanni et al., 2002). Addition of oilseed flour to bread has been shown to improve protein quality and overall nutritive value (Amarjeet et al., 1995). Soybean meal, for example, complements the amino acid profile of wheat flour primarily by increasing the amount of lysine, while amaranth grain has an essential amino acid pattern quite similar to the FAO/WHO reference pattern for amino acid in human nutrition (FAO/WHO, 1973). The amino acid profiles of soybean and amaranth grain also show relatively high levels of lysine, an essential amino acid notoriously deficient in common cereal grains (Becker et al., 1981; Bressani et al., 1992). Although the protein content of legumes is about 20-25%, traditional processing methods decrease the protein content down to between 14 and 17% (Kordylas, 1991). However, it has been reported that processing such as malting and toasting of cereal and soybean produced better reconstitution indices, water holding capacities, bulk densities and gross energy after fermentation (Onilude et al., 1999). The aim of the present study was therefore to analyze some functional properties of maize meal, soy flour and maize meal/soy-flour blends, potentially important for sour maize bread-making and possibly, other applications in confectioneries.

MATERIALS AND METHODS

Collection and processing of samples

A commercial flour variety of white maize (*Zea mays*) and soybean seeds (*Glycine max*) were obtained from a local market in Ibadan, South-western Nigeria. A quality protein maize grain variety Obatanpa QPM was collected from International Institute for Tropical Agriculture (IITA), Ibadan, Nigeria. Soybean seeds were processed into cooked soy flour to remove all anti-nutritional factors as shown in Figure 1. Maize samples were milled into meals (Figure 2). Maize meal with particle size < 0.2 mm was used because it is particularly valuable as an ingredient for maize bread as well as meal mixes, maize muffins and some extruded maize snack products compared to maize flour with less than 0.2 mm particle size (Okoruwa, 1995). A knife mill (Fritsch Industriestr. 8 0-55743, Idar-oberstein, Germany) was used for milling all samples. Sieves with 0.2 mm and 0.6 mm pore sizes were used for sieving into fine flour for soybean and meal for maize, respectively. Maize meal from the commercial maize variety and soybean flour were then mixed in the ratios 9: 1 and 8:2 for flour/meal blends.

Chemical analyses and determination of nutrient compositions

pH: The pH of the meal/flour samples was determined as described by Egan et al. (1981) for flours. 10 g of each sample was suspended in 90 ml sterile distilled water and homogenized. The mixtures were allowed to stand for 30 min before being filtered. The pH values of the filtrates were then determined by a combined glass electrode probe and a pH meter (Mettler-Toledo, Essex M3509 Type 340). Three readings were taken per sample.

Proximate composition: Proximate composition of the resulting maize meals, soybean flour and their blends were determined by the methods of Association of Official and Agricultural Chemists (A.O.A.C, 1990) on dry matter basis. Ash, crude protein (N x 6.25), fat (ether extract) and fibre were evaluated. All measurements were made in triplicate. Total carbohydrate was calculated by difference.

Vitamin and mineral composition: The amounts of vitamins A, B_1 (Thiamin), B_2 (Riboflavin), B_3 (Niacin), C (Ascorbic acid) and E (Tocopherol) as well as calcium, iron, phosphorus and potassium in flours, meals and blends were measured absorptiometrically by the atomic absorption spectrophotometer (AAS) after treatments using the procedures of Egan et al. (1981).

Determination of functional properties

The functional properties of the maize meal, soybean flour and mixtures of maize meal and soybean flour were determined by standard procedures as follows:

Visco-elastic properties: Viscosity properties were determined with the rapid visco-analyser (RVA), a heating and cooling viscometer configured especially for testing starch-based and other products requiring precise control of temperature and shear. It provides a rapid, simple test incorporating precise temperature and speed control, as well as the use of a paddle sensor to ensure maintenance of homogeneity as appropriate for starch-based samples. The RVA contained its own microprocessor, which is used to carry out internal control and monitoring functions. It is also able to communicate with a PC through a RS 232 serial port. The series 3 RVA used in this work runs with the Thermocline for windows software. The windows program running on a PC is used to accept configuration information and test profiles from the operator and pass these to the RVA's own microprocessor. 3 g of each sample were weighed into weighing vessels prior to transfer into the disposable test canister. 25 ml water was dispensed into a new test canister. The samples were then transferred onto the water surface in the canister, after which the paddle was placed into the canister. The blade was then vigorously jogged up and down through the sample ten times or more until no flour lumps remained on the water surface or on the paddle. The paddle was placed into the canister and both were inserted firmly into the paddle coupling so that the paddle is properly centered. The measurement cycle was initiated by depressing the motor tower of the instrument. The test was then allowed to proceed and terminate automatically. The properties of the samples were characterized using the parameters recorded on the viscosity trace that is; peak viscosity, peak time, pasting temperature, peak temperature, and final viscosity. Viscosity was recorded in RVU.

Bulk densities of the flours/meals: Bulk density was determined by the method of Narayana and Narasinga-Rao (1984). An empty calibrated centrifuge was weighed. The tube was then filled with a sample to 5 ml by constant tapping until there was no further change in volume. The weight of the tube and its contents was taken and recorded. The weight of the sample alone was then determined by difference. Bulk density was calculated from the values obtained as follows:

Bulk density (g/ml) = Weight of sample / Volume occupied

Dispersibility of flours/meals or flour blends: Dispersibility in water which indicates their ability to reconstitute was determined by the method of Kulkarni et al. (1991). 10 g of each flour sample were weighed into a 100 ml-measuring cylinder. Distilled water was added up to 100 ml volume. The sample was vigorously stirred and allowed to settle for 3 h. The volume of settled particles was recorded and subtracted from 100 to give a difference that is taken as percentage dispersibility.

Swelling power of flours/meals: Swelling power was determined by the procedure of Takashi and Seib (1988) for each sample at 80, 90 and 100℃. An amount of 1 g of sample was mixed into 50 ml distilled water contained in a centrifuge tube. The slurry was mechanically stirred with a stainless steel paddle at a rate just sufficient to keep the flour completely suspended. The tube with the slurry was gently lowered into a thermostatic water bath and held at 70℃ for 15 min with slow but continuous stirring to prevent clumping. The centrifuge tube was then removed, wiped dry and weighed with its contents. The tube containing the paste was centrifuged at 3000 x g for 10 min using SPECTRA, U.K. (Merlin 503) centrifuge. The supernatant was decanted after centrifugation and the weight of the sediment taken. Thereafter the moisture content of the sedimented gel was determined to get the dry matter content of the gel. Swelling power was then calculated as:

Weight of wet mass of sediment / Weight of dry matter in the gel

Water absorption capacity (WAC): WAC which gives an indication of the amount of water available for gelatinization was determined according to Solsulski (1962). 2.5 g of each sample were added to 30 ml distilled water in a weighed 50 ml centrifuge tube. The tube was agitated by vortex for about 5 min before being centrifuged at 4000 x g for 20 min. The mixture was decanted and the clear supernatant discarded. Adhering drops of water were carefully siphoned as much as quantitatively possible and the tube was reweighed. WAC was expressed as the weight of water bound by 100 g dry flour.

Baking studies

Ingredients: All the flour/meal samples were used in baking sour maize bread. The amounts of other ingredients per 100 g of flour were: baking fat 10 g, sugar 30 g, salt 0.5 g, ascorbic acid 0.1 g, starter culture 1 ml (containing 10^6 to 10^7 cells per ml) and water 120 ml. A mixed starter culture of *Lactobacillus plantarum* and *Saccharomyces cerevisiae* was used as inoculum for the baking trials in this study (Edema, 2004). All ingredients were weighed in a bowl and mixed (Philips hand mixer Type HR 1453) for 10 min at high speed. The mixture was allowed to stand for 1 to 4 h at room temperature for batter development. This was followed by gentle mixing for 5 min after which the batter was scaled (batter weight = 150 g) into greased baking pans. Modifications of the methods of

Table 1. Proximate compositions and pH of flour/meal samples.

Parameters (%)	CSM	QPM	CSS	MSA	MSB
Moisture content	7.15_b	$6.90_{a,b}$	6.11_a	7.66_b	7.42_b
Fat content	4.09_a	4.80_a	14.03_c	8.66_b	9.14_b
Crude protein	8.96_a	11.76_b	36.00_e	20.73_c	22.76_d
Crude fibre	1.48_c	1.09_b	0.21_a	0.34_a	0.22_a
Ash content	$1.33_{a,b}$	1.02_a	2.95_b	2.85_b	2.88_b
Carbohydrate	77.06_c	74.43_c	40.67_a	59.76_b	57.58_b
pH	6.03_a	6.09_a	6.85_a	6.38_a	6.44_a

CSM: Flour from commercially sold floury maize.
QPM: Flour from quality protein maize from IITA.
CSS: Flour from commercially sold soybeans.
MSA: Maize-soy flour blend 1(90% maize flour + 10% soybean flour).
MSB: Maize-soy flour blend 2 (80% maize flour + 20% soybean flour).
Values followed by different subscripts are significantly different by Duncan's Multiple Range Test across columns ($p \leq 0.05$).

Eggleston et al. (1992), Omoaka and Bokanga (1994) and Sanni et al. (1998) were used in the mixing and baking steps. Loaves were baked at 160 to 180°C for 35 min in a Moulinex OPTICHEF Oven Model BH5 with timer. After baking, the loaves were left for about 10 min in the oven. They were then quickly removed from the pans, arranged in trays and returned to the oven for 1 to 2 h or until required for analysis. Analyses were carried out after the baked loaves had attained room temperature or internal crumb temperature was about 35±2°C.

Determination of bread properties: The weights, heights and volumes of bread samples were determined by standard methods (Lonner and Preve-Akesson, 1989; Sanni, Onilude and Fatungase, 1998). Bread crumb/crust structure and colour were judged. The regularity of the porosity of the bread crumb was also judged. Hydration capacity of the bread samples was determined on dry matter basis and calculated using the following formula:

Hydration capacity (%) = uptake of water (g) x 100 / Crumb dry matter content (g)

Sensory evaluation was carried out on the bread samples within 24 h of baking. The samples were evaluated by 10 semi-trained panelists comprising staff and students of the University community on a 9-point hedonic scale of 9 (like extremely) to 1 (dislike extremely) for appearance, texture, taste and overall preference (Meilgaard et al., 1988).

Analysis of Data

Data generated from the study were analyzed by one-way analysis of variance (ANOVA) at 5% level of significance and bivariate correlations using SPSS10.0 for windows software.

RESULTS

Physical and chemical properties of samples

The pH and proximate composition of the flour/meal samples analyzed in this work are presented in Table 1. pH values were between 6.03 for maize meal (CSM) and 6.85 for soybean flour (CSS). The differences in the pH values obtained were not significant at the 5% level. Moisture contents ranged from 6.11% for soybean flour (CSS) to 7.66% for maize meal-soybean flour blend ratio 9:1 (MSA). Meal from commercially sold maize of the floury type (CSM) had the lowest fat and protein contents of 4.09 and 8.96%, respectively, while having the highest crude fibre value of 1.48%. Statistical analysis revealed that there were no significant differences in proximate compositions of maize meal-soybean flour blends ratios 9:1 (MSA) and 8:2 (MSB) except in their protein contents. Quality protein maize (QPM) obtained from IITA, Ibadan for comparative purpose was significantly different from the commercially sold floury maize mainly in protein and crude fibre only. Ash contents varied from 1.02% for quality protein maize (QPM) to 2.95% for soybean flour (CSS). All samples were significantly different in their proximate parameters except moisture content values. Significant bi-variate correlations were observed in proximate compositions at the 1% level (2-tailed) except for moisture content values. Table 2 shows the vitamin and mineral contents of the flour/meal samples. Sample CSM generally had the lowest contents of both vitamins and minerals compared with the other flours. All samples recorded reasonably high quantities of iron although the differences in amounts were not significant.

Functional properties

Visco-elastic properties of flours are shown in Table 3. CSS recorded a negative viscosity value of –6.53 rvu while CSM had the highest viscosity value of 73.84 rvu. The maize meal-soy flour blends (MSA and MSB) were not significantly different from each other in visco-elastic

Table 2. Vitamin and mineral contents of flour/meal samples.

Component	CSM	QPM	CSS	MSA	MSB
Calcium	11.47_a	12.37_b	13.33_d	12.50_{bc}	13.10_d
Phosphorus	0.25_a	0.26_a	0.33_b	0.25_a	0.26_a
Potassium	0.02_a	0.02_a	0.04_b	0.04_{ab}	0.04_b
Iron	2.70_a	2.83_a	2.63_a	2.83a	2.93_a
Vitamin A	0.06_a	0.13_b	0.46_d	0.12_b	0.23_c
Thiamin	0.35_a	0.39_{ab}	0.60_c	0.44_b	0.64_c
Riboflavin	0.13_a	0.15_{ab}	0.21_c	0.16_b	0.17_b
Ascorbic acid	4.27_a	4.07_a	5.13_b	4.40_a	4.55_a
Niacin	2.43_b	2.69_b	1.78_a	1.81_a	1.87_a
Vitamin E	0.16_a	0.19_b	0.26_c	0.20_b	0.22_b

CSM: Flour from commercially sold floury maize
QPM: Flour from quality protein maize from IITA
CSS: Flour from commercially sold soybeans
MSA: Maize-soy flour blend 1(90% maize flour + 10% soybean flour)
MSB: Maize-soy flour blend 2(80% maize flour + 20% soybean flour)
Values are in mg/100g sample except for vitamin A in µg.
Values followed by different subscripts are significantly different by Duncan's Multiple Range Test across columns ($p \leq 0.05$)

Table 3. Visco-elastic properties of flour/meal samples.

Property (rvu)	CSM	QPM	CSS	MSA	MSB
Peak1	39.30_d	32.41_c	6.22_a	31.16_c	27.71_b
Trough1	34.89_c	31.70_c	-7.39_a	26.19_b	23.82_b
Breakdown	3.36_a	5.35_b	13.61_c	5.31_b	5.41_b
Final viscosity	73.84_d	65.73_c	-6.53_a	56.69_b	55.65_b
Setback	39.50_d	31.43_c	0.86_a	31.39_c	29.95_b
Peak time	4.53_b	4.59_b	0.03_a	4.28_b	4.49_b
Pasting temperature	75.31_b	76.43_c	0.00_a	76.70_c	77.12_c

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or other functional properties (Table 4) except in amylose contents. QPM and CSM were significantly different from each other in their pasting temperatures as MSA and MSB were not significantly different for the same property. QPM and CSM were however not significantly different in bulk densities or swelling power at 70, 90 and 100°C. Significant positive correlations existed among the functional properties of the flours at the 1% level (2-tailed).

Bread properties

The properties of the bread samples baked using the flours/meal blends are presented in Table 5. Bread samples had weights ranging between 122.87 g (CSM) and 124.23 g (CSS). The highest values for height and volume were recorded for bread from MSA flour/meal blend while soybean flour had the highest hydration capacity value. Crumbs of breads from soybean flour and blends containing soybean flour had regular porosity and moderate elasticity while all bread samples had small cracks on their crusts.

Among the bread properties, positive correlation existed only between bread height and volume at the 5% level (2-tailed). The mean sensory scores of the bread samples are shown in Table 6. Breads baked with soybean flour/maize meal blends were rated higher than the others being the preferred samples and not significantly different from each other in taste and overall

Table 4. Some functional properties of flour/meal samples.

Property	CSM	QPM	CSS	MSA	MSB
Amylose Content (%)	9.47_d	9.04_b	1.39_a	9.11_c	8.99_b
Water absorption Capacity (%)	194.65_d	174.27_c	168.28_a	173.24_b	172.98_b
Dispersibility (%)	34.93_c	34.07_b	32.70_a	33.10_a	32.93_a
Bulk density (g/ml)	0.47_b	0.46_b	0.38_a	0.55_c	0.55_c
Swelling power at 70°C	15.76_c	15.85_c	5.89_a	14.84_b	14.75_b
Swelling power at 80°C	19.44_c	19.76_c	6.72_a	14.24_b	14.22_b
Swelling power at 90°C	20.36_c	20.63_c	8.37_a	19.10_b	19.05_b
Swelling power at 100°C	24.68_c	24.76_c	9.40_a	22.18_b	22.15_b

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CSS: Flour from commercially sold soybeans
MSA: Maize-soy flour blend 1(90% maize flour + 10% soybean flour)
MSB: Maize-soy flour blend 2 (80% maize flour + 20% soybean flour)
Values followed by different subscripts are significantly different by Duncan's Multiple Range Test across columns ($p \leq 0.05$)

Table 5. Properties of sour maize bread samples from different meal/flour blends.

Parameter	CSM	QPM	CSS	MSA	MSB
Weight (g)	122.87_{ab}	122.07_a	124.23_c	123.90_{bc}	123.93_{bc}
Height (cm)	3.57_a	3.40_a	3.53_a	3.96_b	3.63_a
Volume (ml)	114.23_a	115.30_b	114.50_{ab}	116.93_c	116.53_c
Crumb dry matter (%)	69.60_a	69.27_a	69.37_a	69.27_a	69.07_a
Crumb Hydration (%)	880.37_c	884.67_c	863.97_a	870.33_b	895.93_d
Porosity of crumb	Irregular	Irregular	Regular	Regular	Regular
Crumb color	Cream	Cream	Dark brown	Light brown	Brown
Elasticity of crumb	Weak	Weak	Weak	Moderate	Moderate
Crust color	Light brown	Light brown	Dark brown	Brown	Brown
Crack formation	Small cracks	Small cracks	Small cracks	Small cracks	Small cracks

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acceptability. MSA blend containing 10% soybean was the preferred bread sample in appearance and texture while bread from 100% soybean flour was the least acceptable for all sensory parameters scored. Positive, significant correlations were observed at the 0.01 level (2-tailed) among all sensory properties scored.

DISCUSSION

The functional properties of maize meals (CSM and QPM), soy flour (used in fortifying the maize meal for bread production) CSS and maize meal-soy flour blends (MSA and MSB) were studied. QPM was used in this work basically for comparative purposes with the commercially sold maize CSM with a view to possible large-scale application if observed to be significantly better than the commercially sold maize (Villegas et al., 1990; Martinez et al., 1996; Martinez et al., 1996). This is because maize and other cereal crops are deficient in two essential amino acids lysine and tryptophan. Quality protein maize (QPM) varieties are known to improve protein quality in maize based diets as they have almost

Table 6. Mean sensory scores for bread samples produced from different flours, meals and blends.

Bread sample	Appearance	Texture	Taste	Overall acceptability
CSM	5.2_b	5.1_{bc}	4.2_b	3.7_b
QPM	5.4_b	5.0_b	4.3_b	4.2_b
CSS	3.4_a	2.2_a	2.0_a	2.8_a
MSA	6.8_c	6.9_d	5.9_c	6.1_c
MSB	6.0_{bc}	5.8_c	5.7_c	5.8_c

* To determine scores on a 9-point hedonic scale, values are brought to the nearest whole number.
CSM: Flour from commercially sold floury maize.
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Values followed by different subscripts are significantly different by Duncan's Multiple Range Test across columns ($p \leq 0.05$).

double the percentages of lysine and tryptophan compared to normal maize (Okoruwa, 1995). Compared with normal maize however, production of QPM varieties has some disadvantages. QPM varieties have softer, floury endosperms, making them slightly lower yielding and more susceptible to storage insects because the major storage protein in maize, zein, is also greatly reduced in QPM varieties. However the breeding program at IITA has successfully developed high-yielding, flintier QPM varieties, which unfortunately, are still susceptible to weevils in storage. Proteins from legumes also have higher concentrations of these amino acids, but are frequently deficient in methionine and cystine. Maize has adequate levels of these two amino acids. Consumption of maize with a legume is therefore an effective means of improving protein quality in the diet; hence the use of maize meal-soy flour blends in this work.

The functional (quality) properties studied were physico-chemical including water absorption capacity, dispersibility, bulk density, swelling power, protein, fat, ash, crude fibre, vitamin, mineral and amylose content as well as rheological (pasting viscosities as measured by the rapid visco analyzer (RVA). As expected, the protein contents of maize meal-soy flour blends increased with increase in percentage of soy flour added. For soy flour and blends containing it, ash content increased with protein content. Bulk density values obtained were generally lower (between 0.38 for CSS and 0.55 for MSA) than those obtained by Amarjeet et al. (1993) for durum wheat blends (0.80 to 0.82). Swelling power at the different temperatures tested were comparable with values obtained by Eggleston et al. (1993). Water absorption capacity (WAC) values obtained were higher than farinograph water absorption observed by Chauhan et al. (1992), Amarjeet et al. (1993), Amarjeet et al. (1995) and Eggleston (1993) for quinoa-wheat blends, wheat, soy and durum wheat blends and cassava flours, respectively. CSS had the lowest WAC of 168.28. This was contrary to the observation of Amarjeet et al. (1995) who reported increased water absorption with increased soy flour fortification. Peak time was also higher for flour samples in this work (between 4.28 and 4.59 except for CSS with 0.03) when compared with the values of 2.17 to 3.00 obtained by Amarjeet et al. (1995). Pasting temperatures were only slightly higher ranging from 75.30 to 77.12 (except for CSS with 0.00) compared with 64 to 69 obtained by Eggleston et al. (1993) for cassava flours. Nutrient compositions (proximate, vitamin and minerals) for maize meal and soybean flour were relatively comparable to values obtained by previous workers for these food materials (IITA, 1990; Bureng and Olatunji, 1992; Okoruwa, 1995). Maize is the richest of the cereals in fat with the exception of oats, but it has lower ash content than the other cereals. The processing of maize into meal rather than flour contributed to the improved calcium content of the meal. Contrary to what obtains in maize flour, the meal was rich in phosphorus and iron contents (Okoruwa, 1995). Like other cereals, maize does not contain important quantities of ascorbic acid. The effect of different flours/flour blends on the properties of the fermenting matrix was investigated using a mixed starter culture of *L. plantarum* and *S. cerevisiae*. A mixed culture was used because previous research by some of the authors revealed that a mixed culture is preferable to a single culture as starter for sour maize bread (Edema, 2004). *S. cerevisiae* is important for good batter leavening and bread viscosity while *L. plantarum* carries out the souring activity. Lactic acid bacteria have been known to take part in bread fermentations such as in the production of the Swedish rye sour dough (Lonner and Preve-Akesson, 1989) and the Indian *Idli* (Mukherjee et al., 1965). The lactics are also able to inhibit food spoilage by other microorganisms through the production of inhibitors such as diacetyl, hydrogen peroxide and bacteriocins. Moreover, the symbiotic association between lactic acid bacteria and yeasts is common in many food fermentations with the lactic acid bacteria providing the acid environment for yeast growth, while the yeasts provide vitamins and other growth factors for the lactic acid bacteria (Bushell and Slater, 1981; Odunfa and Adeyele, 1985; Wood and Hudge, 1985).

The type of flour/meal or blend used for sour maize bread making affected the nutritional value as well as physico-chemical properties of the breads produced in this study. The soy flour present in the flour blends used could also have contributed to the loaf volume as reported by Amarjeet et al. (1995), who observed increased loaf volume with increased level of fortification of Punjah wheat varieties with soy flour. The observed regularity of the vacuoles in the crumb is not unrelated to volume as observed by Eggleston et al. (1992). These workers reported an increase in loaf volume by up to 29% over the control bread and a very uniform distribution of gas cells which left the bread texture very soft and spongy, when 10 g of margarine was used in baking cassava bread.

The present study evaluated different maize meals and maize-soybean blends for their properties and their effects on the properties sour maize bread samples produced from them. In order to produce a nutritionally balanced and organoleptically acceptable bread product from maize, the addition of not more than 10% protein supplement in the form of soybean flour or other legumes with amino acid profile comparable to that of soybeans, is recommended. Sour maize bread is a new bread specialty being developed with advantages such as improved shelf stability and safety using an adaptation of the sour dough technique. Further studies in these areas include selection of improved varieties of maize and protein supplements such as cowpea and grain amaranth as well as optimization of processing conditions for the production of sour maize bread.

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