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Effect of wheat flour substitution, maize variety and fermentation time on the characteristics of *Akara*, a deep oil fried dough product

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An investigation into the possibility of using local cereal resources (maize) to develop composite flour suitable for the production *of Akara* (a deep fried fermented dough) was undertaken. The experimental design was a 4 x 5 x 5 factorial experiment. Factor one was the maize variety (CMS 8806, CMS 8501, CMS 9015 and CMS 8704), factor two the substitution level (0, 10, 20, 30 and 40%) of wheat for maize flour and factor three was the fermentation times (0, 30, 60, 90 and 120 min). Dough nuts were produced from composite flour from wheat and maize flour. For the production of maize fine flour, wet milling of de-hulled, soaked grain was made followed by drying and sieving. Composite flours (32.4%) and other ingredients (13.5% sugar, 0.5% instant bakers' yeast and 0.3% iodised salt) were mixed with water, whipped for 10 min and cut into samples of 40 g which were manually shaped into balls. They were allowed to ferment and rise prior to deep frying. Flour samples were analyzed for their physico-chemical and functional properties. A mixed panel of women operating in dough nut production and some regular consumers was trained for sensory evaluation. The sensory attributes considered were colour, taste, texture and overall acceptability on a five point scale. Results showed that maize cultivars did not affect the quality of fine flours from wet milling. In composite flours, proteins, lipids and ash contents were significantly reduced as the level of maize flour increased. An inverse trend was observed with water absorption capacity. Dough swelling capacity and *Akara* density decreased with increase in maize substitution levels independently of the fermentation time and maize variety. Similarly, sensory scores decreased with increases in the substitution level independently of the maize cultivar used for composite flour preparation. However, *Akara* from composite flours had overall acceptability scores between 4.2 and 2.8 on a five-point scale. *Akara* prepared from CMS 8806 and CMS 8704 all of yellow color showed the highest sensory scores. From the results obtained, it could be suggested that composite flour from wheat and maize with up to 40% substitution level is acceptable for local commercial production of *Akara* with preference given to yellow maize.

Key words: Maize, flour, doughnut, characteristics.

INTRODUCTION

Traditional cereal foods play an important role in the diet of the people of Africa, particularly in cereal producing zones. Flour from various cereals is one of the main raw material used in the production of popular food products with high acceptability, good storage characteristics and affordable cost. One of such food product is *Akara*, a deep oil fried fermented dough, produced by women, using simple processing methods. It is a breakfast food

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largely consummed by children and adults in West and Central Africa, especially in Cameroon (Cerdan et al., 2004). Initially, dough for *Akara* was made from 100% imported wheat flour exposing production to price fluctuation due to importation and transportation costs. In an attempt to minimize production costs in rural areas, village women have developed composite flours by incorporating various amounts of rice or maize flour into wheat flour for *Akara* production. This has led to a lot of variability in taste, texture, size and appearance in the *Akara* from one producer to another and from one village to another. Studies conducted to develop composite flour suitable for bread production suggested that bread of acceptable characteristics could be obtained from composite flour with up to 40% substitution (Tiekoura, 1994; Keregero and Mtebe, 1994; Iwuoha et al., 1997). Bread with 40% or less sorghum composite flour had scores of relative acceptance above 70% as compared to the standard 100% wheat bread. From above 40% sorghum composite flour, bread produced received low acceptability scores of 6.9 on a nine-point scale (Carson et al., 2000). With maize flour, incorporation rate of up to 15% was shown to be acceptable suggesting that the type of cereal used affects the optimum acceptable level of flour incorporated. However, these results have had little application among bakers because the relative benefit from maize composite flour does not justify the extract expenses, time and production adjustments needed. Doughnut producers on the other hand are voluntarily adding various amounts of cereal flours in their dough to obtain besides *Akara*, different types of fried dough products *Cen-cen*, *Taara-pott-en, Wardi* and *Wayna* (Lopez and Muchnik, 1997).

The characterization and standardisation of the use of composite flour for doughnuts would strengthen and encourage its production. Based on availability, maize flour is probably the cheapest possible ingredient to be considered. However, the physico-chemical composition of maize grain from various cultivars varies considerably (FAO, 1993; IRA-NCRE, 1990) and this may affect the functionality of resulting maize flour. The method by which flour is produced (Watson, 1984; Munck, 1995) should equally be considered in developing composite flours. This study was designed to evaluate the effects of wheat flour substitution rate on composite flours from maize cultivars on the properties of *Akara*.

MATERIALS AND METHODS

Maize grain and wheat flour sources

Maize (*Zea mays* L.) grains used were obtained from the collection of Cameroon Maize Selection (CMS) of the maize breeding program of the Institute of Agricultural Research for Development (IRAD), Cameroon. Four leading cultivars were considered based on their high adoption by farmers. They included CMS 8501 and CMS 8704 both suitable for high rain fall or humid climate with long maturing cycle, high yielding potentials (5 to 7 ton/ha) and with white and yellow colors, respectively. The other two cultivars suitable to arid climate were CMS 8806 and CMS 9015 with yellow and white colors, respectively, with short maturing cycles and moderate yields of 4 to 5 ton/ha. All these varieties were grown under the same environmental conditions. Commercial baker's wheat flour (12% protein) purchased from the local market was used as a control.

Pre-treatment of maize grains and flour production

Flours from maize were produced in a wet milling process (Ndjouenkeu et al., 1989). De-hulled grains free of bran particles were soaked in clean tap water (1:3 w/v) for 4 h after which they were removed, partially sun dried on a mat for 2 h and milled in a hammer mill. The flour obtained was sun dried for 6 h and fractioned through a 400 µm sieve. Fine fraction of particle diameters less than 400 µ were used to formulate composite flours by thoroughly mixing in a baker mixer.

Experimental design

Composite flours in ratios of 90:10, 80:20, 70:30 and 60:40 w/w for wheat and maize flours, respectively, were reconstituted and used in the production of *Akara*. Whole wheat flour was used as control. A 4 x 5 x 5 factorial experiment was used with four maize varieties (CMS 8806, CMS 8501, CMS 9015 and CMS 8704), five substitution levels (0, 10, 20, 30 and 40% maize) and five fermentation times (0, 30, 60, 90 and 120 min).

Dough samples and doughnut production

Composite flours (32.4%) and other ingredients (13.5% sugar, 0.5% instant bakers' yeast and 0.3% iodised salt) were used for dough preparation. The ingredients were introduced in potable water (53.3 to 65.3%) according to the specific water absorption capacity (WAC) of composite flour, mixed for 3 to 5 min after which appropriate mass of flour was added and kneaded for 2 to 3 min. The dough was whipped for 10 min using a fork mixer (Bonnet, France) and cut into samples of 40 g which were manually shaped into balls. The balls were divided into two groups from which one group was fermented and tested for swelling capacity after 0, 30, 60, 90 and 120 min. The other group was fried in deep oil for 5 min after 90 min of incubation at room temperature (25 to 28°C).

Physico-chemical analysis

The dehulling and milling rates of maize grains were calculated as the ratio of the weight of dehulled grains and milled flour (400 µm) to that of whole and dehullled grains, respectively. Samples of 1000 grains were weighed, and whole wheat and composite flours analysed for moisture, proteins, lipids and ash contents as described by official methods of analysis (AOAC, 1999). Moisture content was determined as weight loss of 10 g sample after drying for 24 h at 102°C. Lipid content was calculated by weight loss after 16 h hexane extraction in a soxhlet apparatus. Protein content was determined by Kjeldahl digestion technique followed by spectrophotometric determination of resulting nitrogen. The ashing was done in a muffle furnace at 550°C for 24 h. Total carbohydrate was obtained by calculation (Egan et al., 1981).

Functional property analysis of flour and dough samples

Water absorption capacity was determined by the method of Phillips (Phillips et al., 1988). A sample of 1 g of the composite orwheat flour was mixed in 10 ml of distilled water and mechanically mixed for 30 min in a KS 10 agitator. The mixture was centrifuged

Table 1. Physico-chemical properties of maize and wheat flours (means ± sd)*.

Property	Flour sources				
	Wheat	CMS 8806	CMS 9015	CMS 8501	CMS 8704
Dehulling yield (%)		72.1±1.5[c]	70.8±2.0[a]	71.3±1.1[b]	72.7±1.5[c]
Flour yield (%)		57.3±1.2[b]	63.3±2.1[c]	57.1±1.1[b]	49.2±1.9[a]
1000 Grain weight (g)		188.4±0.9[a]	287.6±2.2[c]	305.8±3.1[d]	271.7±0.4[b]
Carbohydrates (%MS)	70.4±0.1[a]	78.5±0.3[b]	79.1±0.1[bc]	78.6±0.3[b]	78.4±0.2[b]
Moisture (%MS)	12.9±0.1[a]	13.9±0.0[c]	13.5± 0.4[b]	14.1± 0.1[c]	13.1±0.0[b]
Proteins (%MS)	12.0±0.1[b]	4.1±0.3[a]	4.6±1.0[a]	4.1±0.1[a]	4.7±0.4[a]
Lipids (%MS)	3.8±0.1[c]	2.5±0.2[a]	2.4±0.0[a]	2.7±0.1[a]	3.4±0.1[b]
Ash (%MS)	0.8±0.0[c]	0.7±0.0[b]	0.5±0.0[a]	0.3±0.0[a]	0.4±0.1[a]

Means in the same line with different letters are significantly ($p<0.05$) different.

at 4500 rpm for 30 min on a desktop centrifuge (Bioblock Scientific MLWT.62.1). The resulting sediment (M_2) was weighed and then dried at 105°C for 24 h and the dry weight (M_1) was determined. The WAC was then calculated as follows:

$$WAC (\%) = 100 \times (M_2-M_1)/M_1$$

Dough swelling capacity (DSC) was determined from the relative swelling (Delhaye et al., 1984) of 40 g dough sample gently filled to mark in a 10 cm graduated cylinder. After incubation at 30°C for the desire fermentation time, the DSC was estimated as the ratio of the height of each dough sample to that of wheat multiplied by 100.

Physical and sensory analysis

Physical parameters (weight and diameter) of fried doughnut were measured. Sensory evaluation was conducted using the quantitative descriptive analysis (Powers, 1984) by a 12 member mixed panel. Panelists were selected based on their past habit of consuming the conventional wheat *Akara.* They underwent training sessions on how to evaluate the organoleptic characteristics of *Makala* samples. Sensory attributes considred were flavor, color, taste, firmness and overall acceptability. The intensity of each attribute was scored on levels of likeness ranging from 1 (extreme dislike) to 5 (like extremely). Coded doughnut samples were presented to the panelists in disposable plates without any additional ingredient. Water was provided for rinsing the mouth between samples.

Statistical analysis

All measurements were carried out in triplicate and data obtained were treated with the statistical package SPSS (1993). The analysis of variance (ANOVA) was used to test the effects of the factors on the properties measured and the Duncan's multiple range test was used to separate treatment means whenever there were significant differences.

RESULTS

Flour physico-chemical characteristics

The physico-chemical composition of maize and wheat flours is presented in Table 1. The maize cultivars used were characterised by specific distinct 1000 grain weight, dehulling and milling rates. However, their fine flour fractions exhibited similar composition as far as protein, carbohydrate and moisture contents are concerned. The incorporation of various levels of these maize flours into wheat flour significantly affected the chemical properties of resulting composite flours (Figures 1 and 2).

Protein, lipids and ash contents significantly ($p<0.05$) decreased as the level of maize flour substitution increased independently of the cultivars used. The high lipid content of the grains of maize cultivar CMS 8704 led to composite flour with highest fat contents. Similar results where observed in *bro* (maize composite bread) made with blend of wheat and maize flours in the ratio of 60:40, respectively (Tiekoura, 1994).

Water absorption capacity

The maize cultivars used affected WAC of composite flours (Figure 3) with the yellow cultivars CMS 8806 showing the highest ($p<0.05$) values of WAC followed by CMS 8704. Wheat flour samples showed significantly lower ($p<0.05$) WAC values despite their higher protein content. WAC of composite flour increased significantly ($P<0.05$) with increase in the the quantities of wheat flour substituted. These results contradict past reports (Mbofung et al., 2002) indicating that most composite flours had lower WAC as compared to wheat flours. The quality of maize flour used may explain these differences in WAC. In the present case, the flour fraction used was made of very fine particles (<400 µ) obtained from wet milling. Similar results obtained earlier (Enwere, 1998) confirmed the fact that starch quality in terms of particle size equally plays an important role in the absorption of water.

Dough swelling capacity during fermentation

The maize cultivars used did not affect the swelling capacity of dough from composite flour which was 92 to 94%

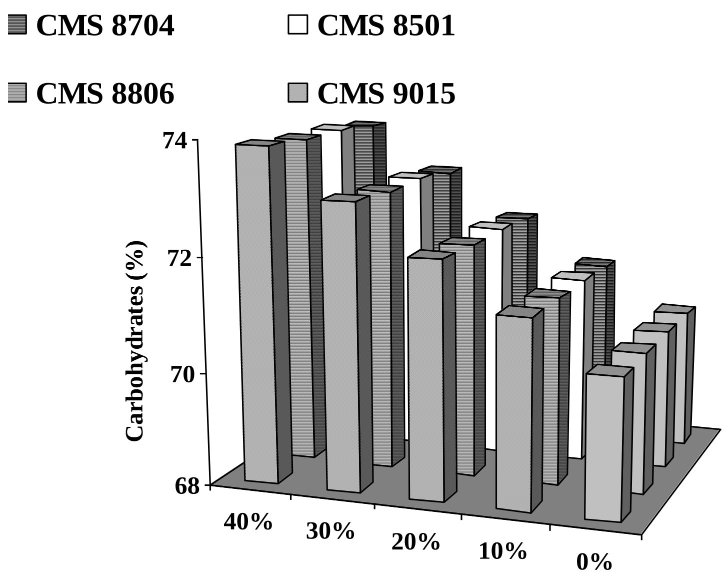

Figure 1. Variation in carbohydrate contents of composite flours as affected by the levels of substitution and maize varieties.

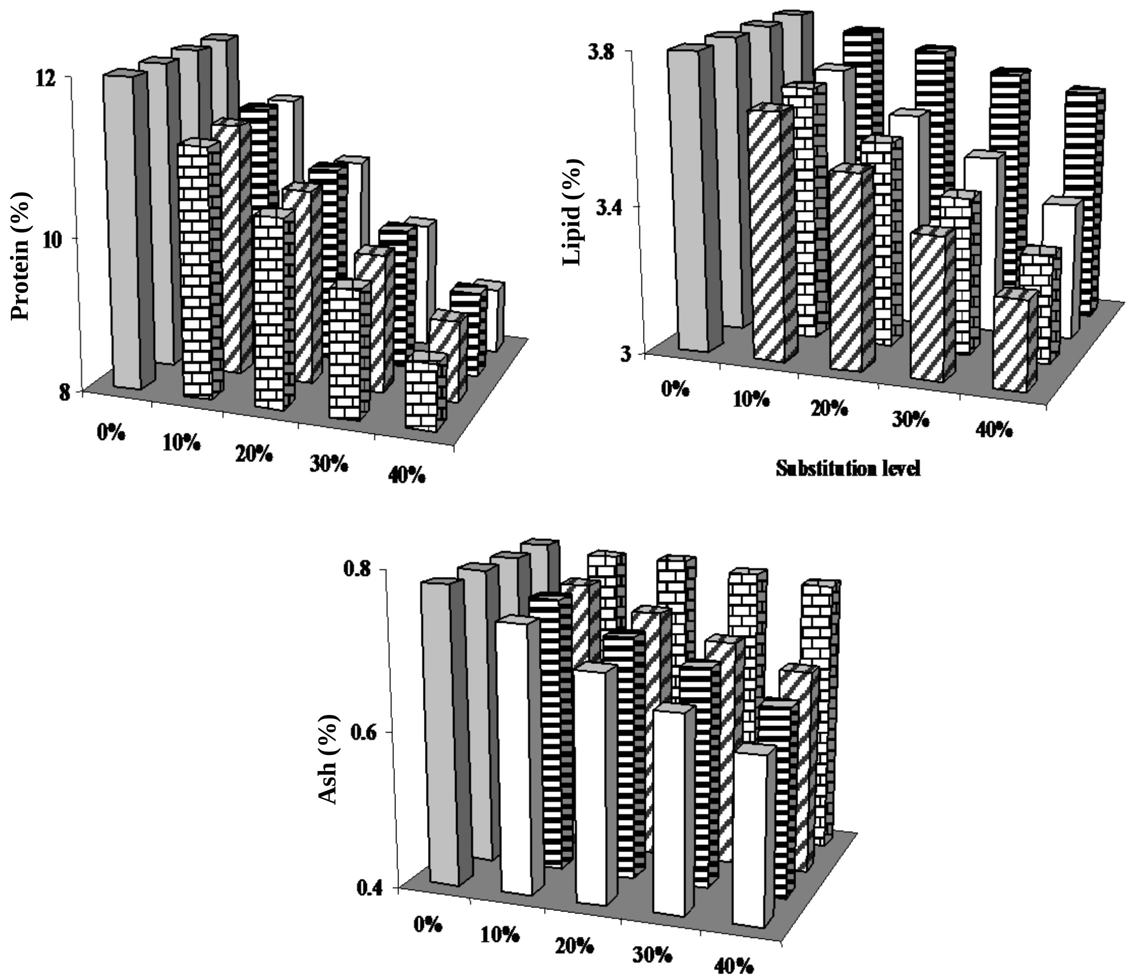

Figure 2. Variation in protein, lipid and ash contents of composite flours as affected by the level of substitution and maize varieties.

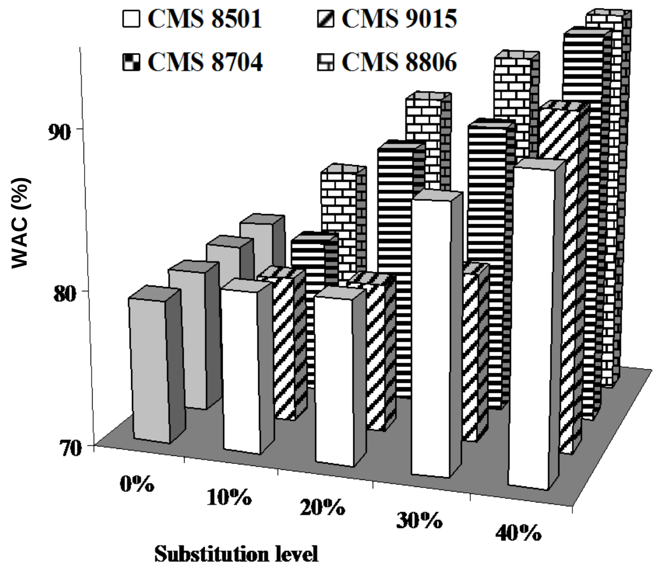

Figure 3. Water absorption capacity of wheat and composite flours as affected by the levels of substitution and maize varieties.

Table 2. Relative rising and weight losses of the dough as function of production parameters.

Dough parameter		Rising of the dough	Weight losses (g)
Substitution rate	0	1.00[a]	0.44[c]
	10	0.94[b]	0.44[c]
	20	0.91[c]	0.46[b]
	30	0.90[c]	0.48[a]
	40	0.88[e]	0.49[a]
Fermentation time in minutes	0	1.00[a]	0.0[e]
	30	0.98[b]	0.17[d]
	60	0.86[e]	0.43[c]
	90	0.88[d]	0.70[b]
	120	0.91[c]	1.02[a]

Means in the same column with different letters are significantly ($p<0.05$) different.

as compared to the control samples from wheat. The incorporation of various levels of maize flour into wheat flour and the fermentation time significantly influenced the rising of fermented dough. Dough swelling capacity (DSC) decreased with decreases in incubation time and increases in maize flour incorporation rates (Table 2). Dough rose to reach a peak after 90 min of fermentation followed by a decline. This was an indicator that dough fermentation time should not exceed 90 min, beyond which cracks appear in the dough ball, and thus facilitate the escape of all the gas trapped, resulting in a drop in its volume. For substitution levels ranging from 10 to 30%, the differences in terms of rising height between the control and the dough from composite flour did not exceed 10%. This was considered as an acceptable margin and therefore 30% substitution level was the possible highest level that would not hamper dough production. The lower gluten content of the composite flours as a result of higher substitution rate could explain the poor rising attributes of these flours. Dough fermentation is known to be affected by flour composition (Pyler, 1979; Delhaye et al., 1984) and this should be taken into account when designing dough products from composite flours. The dillution of the gluten network has affected the volume of gas produced and its retention, resulting in lower dough rising at high substitutions (He and Hoseney, 1991). An inverse trend was obtained in sorghum composite dough with the addition of vital wheat gluten to reinforce the gluten network and gas retention, resulting in higher volume (Cheong and Sun, 1998; Carson et al., 2000).

Table 3. Physical characteristics of fried doughnuts as a function of maize variety and substitution rates of wheat for maize flour.

Dough parameter		Weight of doughnuts prior to frying (g)	Diameters of doughnuts (cm)	Oil absorbed per 100 g (g)	Weight losses after frying (g)
Maize varieties	CMS 8806	39.51[a]	5.11[c]	7.46[e]	10.50[a]
	CMS 9015	39.48[a]	5.10[c]	7.17[f]	9.87[b]
	CMS 8501	39.48[a]	5.01[d]	7.46[e]	10.55[a]
	CMS 8704	39.49[a]	4.96[d]	8.23[c]	9.88[b]
Substitution levels (%)	0	39.31[b]	5.53[a]	6.12[f]	7.88[f]
	10	39.52[a]	5.39[b]	6.54[d]	9.39[d]
	20	39.53[a]	5.17[c]	7.65[d]	10.06[c]
	30	39.54[a]	4.92[d]	8.52[b]	11.28[b]
	40	39.56[a]	4.21[e]	9.07[a]	12.38[e]

Means in the same column with different letters are significantly ($p<0.05$) different.

Table 4. Sensory scores of A*kara* samples containing 0 to 40% maize flour.

Wheat flour substitution level	Origin of flours used for substitution	Sensory attributes of corresponding doughnut (*Makala*)				
		Colour	Texture	Taste	Flavour	Overall acceptance
0% Control	100% wheat	4.41	4.00	4.22	4.11	4.33
10%	CMS 8806	4.00	4.00	4.11	3.96	4.22
	CMS 8501	3.87	4.00	4.00	3.96	4.00
	CMS 8704	3.89	3.88	4.00	4.00	4.11
	CMS 9015	3.89	3.80	4.00	3.96	4.05
20%	CMS 8806	4.00	3.90	4.11	3.96	4.20
	CMS 8501	3.87	3.00	4.11	3.86	4.00
	CMS 8704	3.98	3.86	4.10	4.10	4.00
	CMS 9015	3.89	3.66	4.05	3.94	4.02
30%	CMS 8806	3.98	3.87	4.00	4.02	4.10
	CMS 8501	3.20	2.86	3.66	3.78	3.02
	CMS 8704	3.86	3.85	4.01	4.00	3.96
	CMS 9015	3.90	3,10	3.83	3.61	3.12
40%	CMS 8806	3.64	3.87	3.24	3.10	3.11
	CMS 8501	3.11	2.18	2.46	2.60	2.80
	CMS 8704	3.42	3.58	2.86	2.92	2.98
	CMS 9015	3.06	2.05	2.81	2.45	2.86

Akara physical and sensory attributes

The physical properties of *Akara* are presented in Table 3. Weights of dough nuts were similar irrespective of the maize variety used and levels of substitution. However, weight losses increased significantly in fried doughnut with increases in the fermentation time. Maize varietal effect was expressed on the size and oil retention capacity of finished dough nut. Doughnut from CMS 8704 was significantly higher in fat content, while the amounts of oil absorbed by the dough nut increased significantly with the rate of substitution. Dough nut diameters varied with the maize variety used in the substitution and decreased significantly with increased rate of substitution.

The composite doughnut sensory scores (Table 4) were significantly affected by the level of wheat flour substitution used for its production. Scores for texture and averall acceptance decreased with increases in the amounts of wheat flour substituted. Doughnut from yellow maize (CMS 8806 and CMS 8704) significantly received higher scores for color and flavor as compared to those from white maize (CMS 8501 and CMS 9015). *Akara* containing 10 and 20% maize flour received scores which were compared with the control independently of maize variety. As the level of maize flour incorporated increased, (30 and 40% level of substitution), the doughnuts had significant respectively ($p<0.05$) lower scores for all the attributes considered. Similar results were previously reported on 20 and 30% sorghum composite bread (Foda et al., 1987; Iwuoha et al., 1997) and 40% sorghum composite bread (Keregero and Mtebe, 1994). Lower scores for flavor and texture *of Akara* made from a blend of wheat and maize (ratio: 60:40) accounted for its least acceptance. *Akara* with best sensory properties was obtained from CMS 8806 and CMS 8704 maize cultivars all of yellow colour.

DISCUSSION

Cameroon improved maize varieties were used to produce composite flour, a major ingredient for *Makala* production. Fine flour from wet milling of maize grains was more suitable to blend with wheat flour as it improved in its functional properties. The influence of maize variety and maize processing method on composite flour was highlighted. Wet milling of maize grain produced fine flour of prarticle size much smaller than those from conventional milling of dry maize. The addition of these small particles of starch in wheat accounted for the improvements on water absorption capacities. With cassava flour, the reduction of the particule size (from 400 to 250 and 180 µm) had a positive effect on bread volume, meaning that particle size index affects the functional properties of composite flours. Although, the various maize cultivars showed specificities in their chemical composition, their wet milling resulted in fine flours of similar composition, thus suggesting the possibility of using any maize cultivars for composite flour production.

The level of wheat flour substituted affected more the functional properties of composite flours as compared to maize variety. Substitution of wheat for maize flour reduced the protein contents and particularly the gluten contents well known to affect gas production and consequently swelling of the dough. Previous results have shown that the major factors responsible for the bulk of water uptake were proteins contents, quality of starch and to a lesser extent, cellulose contents (Sefa-Dedeh et al., 2001; Martin and Fitzgerald, 2002). Substituting wheat for maize affected these factors resulting in doughnut of different sensory features. In sorghum, it was observed (Fliedel et al., 1989; Njintang et al., 2001) that flour of finer particle sizes would affect the particle size index giving a larger surface area in contact with water and thus increasing WAC which plays major roles in the food preparation processes. The range of application of most flours as food ingredients is dependent to a large extent on their ability to hydrate and thus imparting their desired functional property on the food system.

The sensory analysis done was useful is assessing the effect of maize variety and substitution level in the composite doughnut. It provided a basis for determining acceptance of composite dough nut by potential consumers. Sensory evaluation showed that all the various dough nuts produced were of acceptable quality as none was graded unfit for consumption and suggesting that blends of wheat and maize (ratio between 90:10 and 60:40) can serve for *Akara* production. Wet milling selected for maize flour production is a routine practice carried out daily by village women and can be achieved through the machinery locally available. This low cost of production of one ingredient will reduce the overall cost of production of doughnut and ensure more revenue to village women who are the main producers of doughnuts. The use of composite flour is of great importance to small scale producers with very little capital for rural women. Mixing is a simple process that can easily be adopted by women producing doughnuts. Comment from panelists showed that composite dough nuts were slow digesting and therefore could sustain farmers much longer on the field for long working hours. This argument was strongly in favor of the production of doughnuts from composite flour.

Conclusion

The maize cultivars developed were found suitable for the production of fine fraction in wet milling for composite flour. The differences in the cultivars did not affect the functional properties of composite flours, thus suggesting their possible use for large scale production. The acceptability of *Akara* decreased with increasing substitution rates from 10 to 40%. These results suggest that *Akara from* composite flour containing up to 40% maize can satisfy the consumers' demand in Sub-Saharan areas, especially in North Cameroon.

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