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Full Length Research Paper

Evaluation of suitability of commercially available maize grains for 'tuwo' production in Nigeria

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This study evaluated the physical characteristics of grains from five different maize varieties [that is, TZL Comp.3C2, TZL Comp.4C2, DMR-ESR-W, DMR-LSR-W and a market sample (Shagari variety)]. In addition, physicochemical properties of their flours, textural and sensory characteristics of *tuwo* (a maize-based non-fermented food dumpling) prepared from such flours were also evaluated. There were significant ($p < 0.05$) differences in the amylose content, kernel weight, length, width and depth of the maize varieties and their values ranged from 18.3-22.7%, 223.7-284.2 g/1000 kernels, 9.1-11.9 mm, 8.1 - 9.5mm and 3.6-4.8mm respectively. The damaged starch value of flours ranged from 11.3-13.9% while the pasting temperature, peak viscosity, breakdown viscosity, final viscosity, setback-1 and setback-2 ranged from 73.8-76.3°C, 108.1-150.1 RVU, 18.4 - 36.9 RVU, 147.4 - 212.3 RVU, 39.2 - 93.7 RVU and 20.8 - 68.8 RVU respectively; with significant differences at $p<0.05$. The lightness indexes (L*-values) of maize flour and *tuwo* ranged from 88.6-90.0 and 66.3-68.0 respectively while the colour intensity (chroma) of maize flour and *tuwo* also ranged from 14.7-15.3 and 8.8-9.4 respectively; with significant differences at $p<0.05$. There were significant ($p<0.05$) differences in the cohesiveness indexes (13.6-15.4%) and softness indexes (16.5-17.4 mm) of the food dumpling obtained from the maize varieties. Maize *tuwo* prepared from DMR-LSR-W was rated highest in terms of all the sensory factors [that is, colour, texture (hand-mouldability), aroma, taste and overall acceptability]. Both positive and negative correlations existed among some properties of kernel, flour and *tuwo* from different maize varieties.

Key words: Food dumpling, maize *tuwo*, commercial maize, suitability.

INTRODUCTION

Maize (*Zea mays* L.) is an important cereal crop in Africa with a wide variability in utilization which include human food uses, animal feed formulation, and as a basic raw material for industrial purposes (Mejia, 2005). Maize *tuwo,* one of the numerous maize-based food products from Africa, is particularly popular in Nigeria and across West Africa sub-region and is normally prepared from nonfermented maize flour to form a food dumpling or gel-like product through a combination of water, flour and thermal energy (Bolade et al., 2009). A food dumpling (e.g. maize *tuwo*) normally has such properties as being stiff after cooling, has yield value from a rheological assessment, can be moulded into shapes and has moisture content in the range of 64-80% (Muller, 1970). The ultimate consumption of maize *tuwo* is usually with any of the local vegetable soups (e.g. *kubewa, kuka, tafshe*, etc.) as a side dish with or without meat. This normally serves as a source of additional nutrients such as protein, minerals and vitamins. The quality indicators usually used for maize *tuwo* acceptability include mild creamy or white colour, ease of hand-mouldability, good swallowability, pleasant taste and acceptable overnight keeping quality (Aboubacar et al., 1999; Bolade et al., 2002).

Maize, the cereal crop from which maize *tuwo* is obtained, has been undergoing series of genetic engineering in Nigeria and some other countries in West and Central Africa for more than three decades with the principal objective of developing improved maize varieties (Manyong et al., 2000). The major areas in maize genetic engineering efforts include the development of high-yielding maize varieties (Manyong et al., 2000); establishment of grain yield stability (Pixley and Bjarnason, 2002); development of disease-resistant varieties (Bosque-Perez, 2000); development of maize varieties with enhanced mineral and vitamin content (Ortiz-Monasterio et al., 2007); development of drought-tolerant varieties (Campos et al., 2004); and the development of maize varieties with reduced anti-nutritional factors such as phytic acid (Raboy et al., 2001). In Nigeria, some of the maize varieties that have been obtained through genetic engineering and available for cultivation include DMR-ESR-W, DMR-LSR-W, DMR-LSR-Y, TZL Comp.3C2, TZL Comp.4C2, TZPB-SR (NARZO-30), TZSR-W-1 (NARZO-20), EV9043-SR, etc. (Iken and Amusa, 2004). These varieties have different yield potentials at different ecological zones of the country and therefore testing of new maize varieties across the country has become a necessary established practice in maize genetic engineering efforts.

Different researchers have worked with various maize varieties and it has been reported that these varieties usually differ in their chemical and physical characteristics (Vyn and Tollenaar, 1998), stress-enduring capacity (Vyn and Moes, 1988) and kernel breakage susceptibility (Bauer and Carter, 1986). Other variations that have been reported in maize varieties include differences in extrusion cooking behaviour (Robutti et al., 2002) while ogi quality from different maize varieties has also been observed to vary (Nago et al., 1998).

The effect of maize types on the physicochemical, thermal, morphological and rheological properties of maize starches has also been studied (Sandhu et al., 2004) while the influence of maize types on the textural properties of chapati (an Indian maize-based food product) has also been investigated (Sandhu and Singh, 2007).

Previous research works on maize *tuwo* had been on the effect of hydrothermal treatment of maize grains and flour particle fractions on the food product quality (Bolade et al., 2002; Bolade et al., 2009). Alika (1994) also investtigated the effect of non-commercial, experimental maize hybrids on the quality attributes of maize *tuwo* such as the stickiness and firmness of the food product. The author concluded that the additive genes, through cross-breeding using a 6-parent diallel cross, could lead to substantial positive effect on the stickiness and firmness of maize *tuwo*. However, there is the need to evaluate the commercially available maize varieties in Nigeria with a view to determining their suitability for *tuwo* production. The objective of this study therefore was to evaluate the selected maize varieties for kernel characteristics, physicochemical properties of flours, textural and sensory characteristics of a non-fermented maize-based food dumpling (*tuwo*) with a view to establishing the appropriate variety for end-use suitability of maize *tuwo* production.

MATERIALS AND METHODS

Materials

The maize varieties used for this study, based on commercial availability, were TZL Comp.3C2, TZL Comp.4C2, DMR-ESR-W, DMR-LSR-W, and a market sample (Shagari variety). Both TZL Comp.3C2 and TZL Comp.4C2 were obtained from the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria; while DMR-ESR-W and DMR-LSR-W were obtained from the Institute of Agricultural Research and Training (IAR and T), Moor Plantation, Ibadan, Nigeria. The market sample (Shagari variety) was obtained from Bodija local market, Ibadan, Nigeria.

Determination of physical characteristics of maize kernels

Kernel weight: This was evaluated by counting and weighing 50 maize grains and expressing the result as g/1000 kernels (McDonough et al., 2004).

Kernel volume: The method of Meikle et al. (1998) was used in determining the kernel volume. Twenty five maize grains were transferred into a measuring cylinder containing 20 ml of 95% ethanol and the volume measured by displacement method and expressing the result as cm^3/1000 kernels.

Bulk density: This was determined by filling a 100-ml measuring cylinder to the mark with maize grains followed by measuring of weight of the filled grains and the bulk density calculated and expressed as g/cm^3 (Kikuchi et al., 1982).

Kernel size: This was measured by randomly selecting three (3) kernels and measuring the three major axes, namely: length, width and depth with a Vernier Caliper (Adeyemi et al., 1987).

Determination of amylose content of maize grains

The amylose content of maize grains was determined using the method of Williams et al. (1970). Twenty milligrams (20 mg) of dried and ground sample were weighed into a 100-ml beaker followed by the addition of 10 ml of 0.5 N KOH solution. The mixture was subjected to magnetic stirring for 5 min, transferred into 100-ml volumetric flask and diluted to the mark with distilled water. Ten millilitres (10 ml) of the aliquot was pipetted into a 50-ml volumetric flask; 5 ml of 0.1 N HCl was added followed by the addition of 0.5 ml of iodine reagent. The whole mixture was finally diluted up to 50-ml mark with distilled water and then allowed to stand for 5 min. Thereafter, absorbance was measured at 625 nm with an atomic absorption spectrophotometer (model SP9, Pye Unicam, UK). The amylose content of the grain was determined using the derived standard formula:

Amylose content (%) = $[(85.24 \times A) - 13.19]$; where A = absorbance value.

Production of maize flour

Twenty kilograms of maize grains from each of the varieties were used for this study. Each batch was first tempered with water using a quantity of 3 - 4% (v/w) followed by decortication of the grains on a locally fabricated decorticator. This machine removed the germs and hulls of the grains. The decorticated grains (maize grits) were then ground into flour using a locally fabricated plate mill. The maize flour finally obtained was sieved using a sieve with 300 µm aperture and then kept in airtight polythene bags until needed.

Determination of damaged starch of maize flour

The damaged starch of flour from each of the maize varieties was determined according to the method of Farrand (1964). The test was based on starch susceptibility to α–amylase digestibility. Five grams of the experimental flour were digested for 1 h at 30±0.5°C with 46 ml α-amylase preparation. This mixture was rotated every

15 min. The extract obtained from the digestion was subjected to series of chemical treatments followed by ultimate titration against sodium thiosulphate solution from which an equivalent maltose figure was estimated. Damaged starch (%) was calculated as follows:

[(Maltose Figure – 3.5) × 6].

Determination of pasting properties of maize flour

The pasting properties of flour from each of the maize varieties were determined using a Rapid Visco-Analyzer, RVA-Series 4, with the aid of a Thermocline for windows, version 2.2 software (Newport Scientific, 1996). A sample of 4.0 g maize flour (14% moisture-basis) was transferred into a canister and approximately 25± 0.1 ml distilled water was added (correction factor was used to compensate for 14% moisture-basis). The slurry was heated to 50°C and stirred at 160 rpm for 10 s for thorough dispersion. The slurry was held at 50°C for up to 1 min followed by heating to 95°C over about 7.3 min and held at 95°C for 5 min, and finally cooled to 50°C over about 7.7 min. The pasting parameters such as the pasting temperature, peak viscosity, time to peak, breakdown, holding strength or trough, setback and final viscosity were automatically generated from the software attached to the RVA.

Production of maize *tuwo*

Maize *tuwo* was prepared from flour of each of the maize varieties using a method as described by Bolade et al. (2002). The overall ratio of flour to water used in maize *tuwo* preparation was 1:3.5 (w/v). Cold slurry of the flour was first prepared by mixing 20% of the desired quantity of flour (1 kg) with 25% of the desired quantity of water (3.5 l). This was followed by bringing 60% of the water into boiling and the cold slurry initially prepared was added to this boiling water coupled with vigorous stirring, using a wooden flat spoon, to form a pap-like consistency. The remaining quantity of the flour (80% of the desired total) was then added gradually to the boiling pap-like paste with continuous stirring so as to facilitate non-formation of lumps and to ensure a homogenous gel formation. The remaining quantity of water (15% of the desired total) was finally added to the formed gel, covered properly without stirring, and allowed to cook for about 5 - 7 min after which it was stirred vigorously to ensure smoothness of the gel. The final product so obtained is called maize *tuwo*.

Determination of colour characteristics of maize flour and tuwo

The colour of flour and *tuwo* prepared from each of the maize varieties was measured using a colour measuring instrument (ColorTec-PCM, model SN 3000421, USA) and the values expressed on the L*, a*, b* tristimulus scale. The instrument was initially standardized (L* = 90.29, a* = 1.37, b* = 0.06) using a white reference standard (white duplicating paper sheet, 80 g/m^2). The results from three replicates per sample were averaged. The colour intensity, expressed as chroma (C), was calculated from $(a^2 + b^2)^{1/2}$ while one of the following equations was used to calculate the hue angle: if $a > 0$ and $b > 0$, then $h^o = \tan^{-1}(b/a)$; if $a < 0$ and $b > 0$, then $h^o = [\tan^{-1}(b/a)] + 180^o$; if $a > 0$ and $b < 0$, then $h^o = [\tan^{-1}(b/a)] + 360°$ (McGuire, 1992).

Determination of cohesiveness index of maize *tuwo*

The cohesiveness index of maize *tuwo* prepared from each of the maize varieties was determined using the Universal Testing Machine (model M500-50KN, Testometric, England). Maize *tuwo* was placed inside a cylindrical plastic container (with a diameter of 50 mm and 96 mm in height), the internal surface of which was first oiled with edible vegetable oil to facilitate easy removal after solidification. The hot maize *tuwo* inside the cylindrical container was allowed to cool under ambient condition (30±2°C) and after about 4 h it was extruded from the container and the cylindrical *tuwo* mould subjected to compression test. The cylindrical *tuwo* mould was placed between two parallel flat stainless steel circular plates each having a diameter of 100 mm. The machine was set at a speed of 30 mm/min and allowed to compress the cylindrical *tuwo* mould until the food sample began to rupture. The cohesiveness index of the food dumpling (maize *tuwo*) was calculated as the strain at peak (%) which is the extent to which the cylindrical *tuwo* mould could be deformed before it ruptured.

Determination of softness index of maize *tuwo*

The softness indexes of maize *tuwo* prepared from each of the maize varieties were determined using Precision Cone Penetrometer (Benchtop model, Pioden Controls Ltd., UK). Freshly prepared hot maize *tuwo* was scooped inside a clean cylindrical tin container having only one end opened and a dimension of 6 cm (diameter) by 6 cm (height). After filling, the opened end was covered with an aluminium foil to prevent scale formation of *tuwo* and the container was thereafter allowed to cool under ambient condition (30±2°C). After cooling, *tuwo* inside the container was subjected to penetrometer evaluation by positioning its centre perpendicularly to the falling probe of the penetrometer. The probe was finally released to fall freely from a standard distance to penetrate into the product in the cylindrical tin container. The total depth of penetration of the probe was then read on the penetrometer scale and the reading, expressed in millimetre (mm), was taken as an index of the product softness.

Sensory evaluation

Maize *tuwo* prepared from each of the maize varieties were evaluated for their sensory qualities and general acceptability. A scoring test was used which was designed to determine which of the products was most preferred. A 40-member semi-trained taste panel was requested to carry out the rating of *tuwo* samples. The panelists were all familiar with the food product while they were also instructed on the use of sensory evaluation procedures. Each of the panelists was asked to rate the samples on the basis of colour, texture (mouldability), aroma, taste and overall acceptability using a nine-point hedonic scale (that is, 9 = like extremely; 5 = neither like nor dislike; 1 = dislike extremely) (Meilgaard et al., 1991).

Statistical analysis

All determinations reported in this study were carried out in triplicates. In each case, a mean value and standard deviation were calculated. Analysis of variance (ANOVA) was also performed and separation of the mean values was by Duncan's Multiple Range Test at $P < 0.05$. Correlation coefficients were also calculated using Statistical Package for Social Scientists (SPSS) software, version 10.0.

RESULTS AND DISCUSSION

Amylose and physical characteristics of maize grains from different varieties

The amylose content and physical characteristics of kernels from different maize varieties are presented in Table 1. The amylose content of Shagari variety (22.7%) was significantly ($p < 0.05$) higher than that of all the other varieties including the TZL Comp. 4C2 (18.3%) which was the lowest. The variation in the amylose content may be attributed to genetic factors. Jane et al. (1992) observed that the variation in the amylose content of starchy materials (e.g. cereals, roots, tubers, etc.) is attributable to genetic factors. The implication of this observation is that the different amylose/amylopectin ratios in the maize kernels are capable of influencing such starch properties as gelatinization, viscosity, retrogradation (Fredriksson et al., 1998) and textural quality of food (Lii et al., 1996). Higher amylose content and longer amylopectin chains have been implicated to contribute to hardness of food gels from maize (Mua and Jackson, 1997).

The kernel weight of TZL Comp. 3C2 (284.2 g/1000 kernels) was significantly ($p<0.05$) higher than that of all the other varieties including the DMR-ESR-W (223.7 g/1000 kernels) which was the lowest. The range of 223.7 to 284.2g/1000 kernels observed for these maize varieties was lower than a range of 230 to 415 g/1000 kernels earlier reported for other selected Nigerian maize varieties (Adeyemi et al., 1987) but slightly higher than a range of 217 to 248 g/1000 kernels reported for some Canadian maize varieties (Hilliard and Daynard, 1974). These observations may be attributed to genetic factors, climatic conditions and farming technologies (Pingali and Pandey, 2001). The kernel weight is generally observed to have a strong relation to grain yield (Adeyemi et al., 1987).

The kernel volume and bulk density of the maize varieties ranged from 197.3 to 241.3 cm^3/1000 kernels and 0.76 to 0.88 g/cm^3 respectively with significant ($p < 0.05$) differences. The kernel length, width, and depth of the maize varieties also ranged from 9.1 - 11.9 mm, 8.1 - 9.5 mm and 3.6 - 4.8 mm respectively with significant ($p < 0.05$) differences. The potential influence of these physical characteristics of maize grains on its general utilization is that the kernel weight, volume, width and depth were reported to be related to grain maturity and overall endosperm content thereby influencing starch, flour and grit yield (Adeyemi et al., 1987). Raju et al. (1992) also reported the superiority of the flat shaped (low kernel depth) maize grains in obtaining the desirable low fat and low fibre maize grits.

Influence of maize varieties on the damaged starch content of flour

The damaged starch values of flour from DMR-ESR-W (13.9%) was significantly ($p < 0.05$) higher than that of all the other varieties including the Shagari variety (11.3%) which was the lowest (Table 2). The variation in the damaged starch values of flours from different maize varieties indicates that different maize types could respond differently to the same milling operational procedures. This may be attributed to genetic make-up of endosperm of each maize variety as the bond strength, presumably, between the starch granules and the embedding protein matrix within the endosperm seems to differ, thus giving rise to varying resistances during milling. The degree of maize kernel hardness is another factor that may be responsible for damaged starch variation in the flours. Faridi (1990) observed that variation in the damaged starch value of cereal flour is dependent on the severity of the milling process and the hardness of the cereal kernel. Damaged starch plays an important technological role in food processing as damaged starch granules absorb more water than non-damaged starch and are more susceptible to enzymatic hydrolysis (Hoseney, 1994), thus influencing both end-use and rheological properties of flour dough (Lin and Czuchajowska, 1996).

Influence of maize varieties on the pasting properties of flour

The pasting properties of flours from different maize varieties are presented in Table 3. The pasting temperature of flour from TZL Comp. 4C2 (76.3°C) was significantly ($p < 0.05$) higher than that of all the other varieties including the Shagari variety (73.8°C) which was the lowest. Higher pasting or gelatinization temperature indicates that more energy is required to initiate starch gelatinization (Sandhu and Singh, 2007). The significance of this observation is that the market maize variety (Shagari) with the lowest pasting temperature will gelatinize faster than TZL Comp. 4C2 with the highest pasting temperature.

The peak viscosity of flours from the selected maize varieties ranged between 108.3 and 150.1 RVU with DMR-LSR-W and market sample (Shagari variety) having the lowest and the highest values respectively with significant differences at $p < 0.05$. The difference in the peak viscosity values is a reflection of different rates of water absorption by the flour as well as rate of starch granule swelling during heating (Ragaee and Abdel-Aal, 2006).

The breakdown value of DMR-LSR-W (36.9 RVU) was significantly ($p < 0.05$) higher than that of all the other varieties including the DMR-ESR-W (18.4 RVU) which was the lowest. A lower breakdown value indicates relative paste stability during cooking while a higher value indicates relative paste instability (Newport Scientific, 1996).

The final viscosity of maize flour from Shagari variety (212.3 RVU) was significantly ($p < 0.05$) higher than that of all the other varieties including the DMR-LSR-W (147.4 RVU) which was the lowest. The setback-1 (that is, difference between the final viscosity and trough) of

Table 1. Amylose content and physical characteristics of kernels from different maize varieties[1].

Maize variety	Amylose content (%)	Physical characteristics					
		Kernel weight (g/1000 kernels)	Kernel volume (cm^3/1000 kernels)	Bulk density (g/cm^3)	Kernel size (mm)		
					Length	Width	Depth
TZL Comp. 3C2	19.7^{b}	284.2^{a}	221.3^{b}	0.77^{b}	9.1^{c}	8.4^{b}	4.6^{a}
TZL Comp. 4C2	18.3^{c}	264.7^{b}	205.3^{c}	0.76^{b}	10.3^{b}	9.5^{a}	4.8^{a}
DMR-ESR-W	18.9^{c}	223.7^{d}	197.3^{cd}	0.86^{a}	10.1^{b}	9.1^{a}	4.4^{a}
DMR-LSR-W	20.1^{b}	244.6^{c}	210.2^{c}	0.85^{a}	11.2^{b}	8.5^{b}	4.7^{a}
Market sample (Shagari variety)	22.7^{a}	268.2^{b}	241.3^{a}	0.88^{a}	11.9^{a}	8.1^{b}	3.6^{b}
Range	18.3 - 22.7	223.7 - 284.2	197.3 - 241.3	0.76 - 0.88	9.1 - 11.9	8.1 - 9.5	3.6 - 4.8

[1]Results are mean values of triplicate determination. Mean values followed by different superscripts in each column are significantly different at $p < 0.05$.

Table 2. Damaged starch value of flour from different maize varieties.

Flour source	Damaged starch value (%)[1]
TZL Comp. 3C2	13.4^{a}
TZL Comp. 4C2	12.6^{b}
DMR-ESR-W	13.9^{a}
DMR-LSR-W	12.2^{b}
Market sample (Shagari variety)	11.3^{c}
Range	11.3 - 13.9

[1]Results are mean values of triplicate determination. Mean values followed by different superscripts in each column are significantly different at $p < 0.05$.

Table 3. Pasting properties of flours from different maize varieties.

Flour source	Pasting factor[1]							
	Pasting temperature (°C)	Peak viscosity (RVU)[2]	Trough (RVU)	Breakdown value (RVU)	Final viscosity (RVU)	Setback-1 (Difference between final viscosity and trough; RVU)	Time to reach peak viscosity (min)	Setback-2 (Difference between final and peak viscosity; RVU)
TZL Comp. 3C2	75^{b}	142.4^{b}	116.8^{b}	25.6^{c}	204.3^{b}	87.5^{b}	9.0^{a}	61.9^{b}
TZL Comp. 4C2	76.3^{a}	124.5^{c}	99.6^{d}	24.9^{c}	193.3^{c}	93.7^{a}	9.0^{a}	68.8^{a}
DMR –ESR – W	74.1^{c}	127.1^{c}	108.7^{c}	18.4^{d}	147.9^{d}	39.2^{d}	9.0^{a}	20.8^{d}

Table 3. Contd.

DMR –LSR –W	74.6^{b}	108.3^{d}	71.4^{e}	36.9^{b}	147.4^{d}	76.0^{c}	9.0^{a}	39.1^{c}
Market sample (Shagari variety)	73.8^{c}	150.1^{a}	123.8^{a}	26.3^{a}	212.3^{a}	88.5^{b}	8.6^{b}	62.2^{b}
Range	73.8 - 76.3	108.3 - 150.1	71.4 - 123.8	18.4 - 36.9	147.4 - 212.3	39.2 - 93.7	8.6 - 9.0	20.8 - 68.8

[1]Results are mean values of triplicate determinations. Mean values followed by different superscripts in each column are significantly different at $p < 0.05$.
[2]RVU = Rapid Visco Unit.

Table 4. Colour indices of flour and *tuwo* from different maize varieties[1].

Sample source	Flour					*Tuwo*				
	L*	a*	b*	Chroma, C	Hue angle, h°	L*	a*	b*	Chroma, C	Hue angle, h°
TZL Comp. 3C2	89.2^{a}	-0.09^{ab}	15.1^{a}	15.3^{a}	90.3^{a}	66.3^{b}	-1.6^{b}	8.7^{b}	8.8^{b}	100.3^{c}
TZL Comp. 4C2	88.6^{b}	-0.12^{b}	14.8^{a}	14.8^{b}	90.5^{a}	66.7^{b}	-1.9^{a}	9.1^{a}	9.4^{a}	101.8^{ab}
DMR-ESR-W	90.0^{a}	-0.07^{a}	15.0^{a}	15^{a}	90.3^{a}	68^{a}	-1.7^{ab}	8.9^{a}	9.1^{a}	100.6^{c}
DMR-LSR-W	90.0^{a}	-0.08^{a}	14.7^{ab}	14.7^{b}	90.3^{a}	67.7^{a}	-1.9^{a}	8.9^{a}	9.1^{a}	102.1^{a}
Market sample (Shagari variety)	89.0^{a}	-0.11^{b}	15.0^{a}	15^{a}	90.4^{a}	67.5^{a}	-1.9^{a}	9.1^{a}	9.3^{a}	101.7^{b}

[1]Results are mean values of triplicate determinations. Mean values followed by different superscripts in each column are significantly different at $p < 0.05$.

maize flour from TZL Comp.4C2 (93.7 RVU) was significantly ($p < 0.05$) higher than that of all the other varieties including the DMR-ESR-W (39.2 RVU) which was the lowest. The setback-1 has been observed to be closely related to a measure of the extent of retrogradation or re-ordering process of the starch molecules particularly during cooling (Sandhu and Singh, 2007). Similarly, the setback-2 (that is, difference between the final and peak viscosity) of maize flour from TZL Comp.4C2 (68.8 RVU) was significantly ($p < 0.05$) higher than that of all the other varieties including the DMR-ESR-W (20.8 RVU) which was the lowest. The setback-2 has also been observed to influence the textural characteristics of food gels or dumplings obtained from such flour or starch (Newport Scientific, 1996; Otegbayo et al., 2006). Therefore, the TZL Comp. 4C2 and market sample (Shagari variety) with relative high setback-1 values would, most probably, produce maize *tuwo* with a higher retrogradation tendency than other maize varieties (Ragaee and Abdel-Aal, 2006). The DMR-ESR-W and DMR-LSR-W with lower setback-2 would, most probably, produce maize *tuwo* with higher cohesiveness index than other varieties as a food gel or dumpling with low setback-2 value has been implicated to produce good cohesiveness (Bolade and Buraimoh, 2006; Otegbayo et al., 2006).

Colour characteristics of flour and *tuwo* from different maize varieties

The colour indices of flour and *tuwo* samples from different maize varieties are presented in Table 4. The colour lightness (L*-value) of flour from DMR-ESR-W (90.0) was significantly ($p < 0.05$) higher than that of all the other varieties including the TZL Comp.4C2 (88.6) which was the lowest. The L*-value for maize *tuwo* also ranged from 66.3 to 68.0 with TZL Comp. 3C2 and DMR-ESR-W having the lowest and highest value respectively with significant ($p < 0.05$) differences. The implication of these observations is that different maize varieties have high tendency of giving flours and maize *tuwo* varying lightness indices; which may be attributed to inherent genetic attributes of each maize type.

The colour intensity (chroma) of flour from TZL Comp.3C2 (15.3) was significantly ($p < 0.05$) higher than that of all the other varieties including the DMR-LSR-W (14.7) which was the lowest. Similarly, the chroma of *tuwo* samples ranged from 8.8 to 9.4 with TZL Comp.3C2 and TZL Comp.4C2 giving the lowest and highest values respectively with significant differences at $p < 0.05$. These observations with colour characteristics of flour and *tuwo* from different maize varieties indicate that the conversion of maize

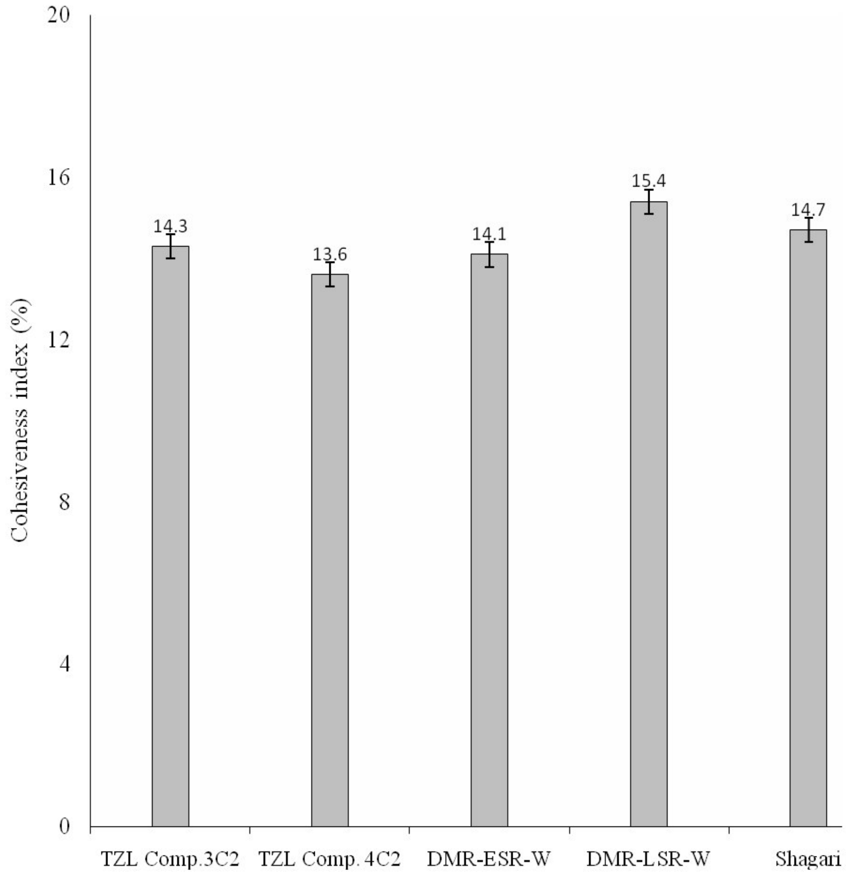

Figure 1. Cohesiveness index of *tuwo* from different maize varieties.

flour to *tuwo* usually leads to a reduction in the lightness index (L*-value) and colour intensity (chroma); which may be attributed to a combination of water, flour and thermal energy involved in the process of maize *tuwo* production. This process therefore might have led to physical interaction and chemical transformation of some components (Saldana and Brown, 1984) thereby causing a lowering of colour index values.

The hue angle (h°) of the flour samples from different maize varieties also ranged from 90.3 to 90.5° while that of *tuwo* samples ranged from 100.3 to 102.1°. The hue angle shifting from 0 to 90° connotes a colour change from red to yellow while a shift from 90 to 180° connotes a colour change from yellow to green (Francis and Clydesdale, 1975). However, the hue angle (h°) seems not to be a useful indicator for describing the colour changes in white maize grain processing in spite of being described as the coordinate that best reflects the visual colour in fruit ripening (Ferrer et al., 2005), as red-yellow-green colour indices are seldom applicable in *tuwo* preparation. Colour is one of the important quality indicators influencing consumer acceptability of maize *tuwo* while mild creamy or white colour is most preferred.

Effect of maize variety on the cohesiveness index of *tuwo*

The cohesiveness index of maize *tuwo* prepared from DMR-LSR-W (15.4%) was significantly ($p < 0.05$) higher than that of all the other varieties including the TZL Comp. 4C2 (13.6%) which was the lowest (Figure 1). The difference in the cohesiveness indexes of maize *tuwo* samples may be attributed to different degrees of interactions of flour components (that is, protein, fibre, oil and non-starch polysaccharides) with solubilised amylose and amylopectin components of starch granules during heating thereby affecting the rheological properties of the food dumpling (Hardacre and Clark, 2006). Cohesiveness of a food material has been described as the rate at which the material disintegrates under a compressive force (Pomeranz and Meloan, 1987). The smaller the deformation under a given load, the lower the cohesiveness and the greater the “snappability” of the product (Szczesniak, 1966). Therefore, a higher value of cohesiveness index indicates that the sample exhibited higher percent height displacement or deformation under compression before eventual rupturing particularly at

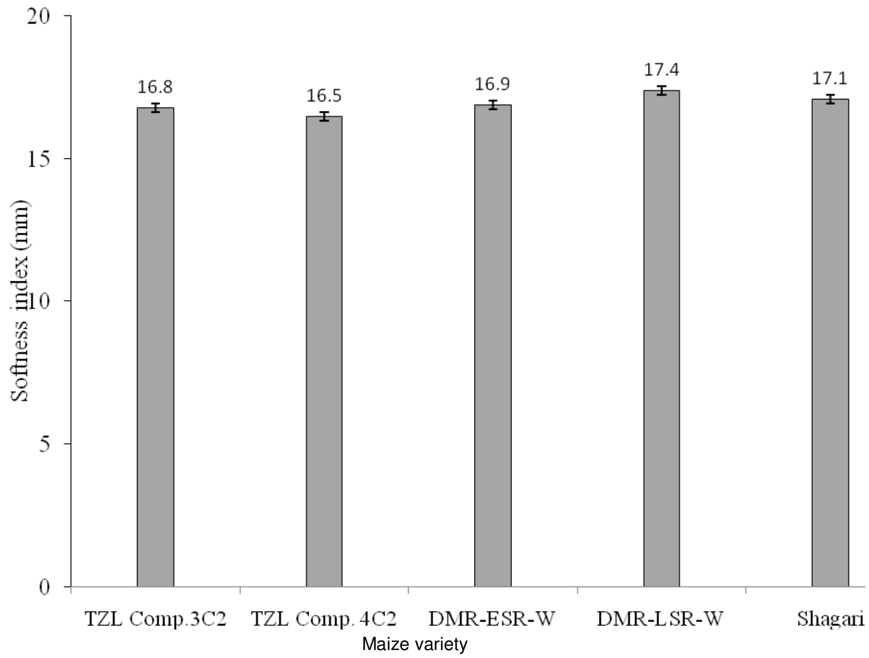

Figure 2. Softness index of *tuwo* from different maize varieties.

maximum compressive force. The cohesiveness of food dumpling like maize *tuwo* is an important quality attribute that usually influences consumer acceptability of the food product (Aboubacar et al., 1999; Ndjeunga and Nelson, 2005). Moulding of food bolus with fingers and palm is one of the preliminary actions that usually precede maize *tuwo* consumption and good hand-mouldability is therefore a factor that influences the overall enjoyment of the food. An enhanced cohesiveness index of maize *tuwo* will predispose the food product towards good hand-mouldability and hence, increased psychological satisfaction during consumption. Maize *tuwo* from DMR-LSR-W and market sample (Shagari variety) with relative high cohesiveness indexes are highly predisposed towards having good hand-mouldability than *tuwo* from other maize varieties.

Effect of maize variety on the softness index of *tuwo*

The softness index of maize *tuwo* prepared from DMR-LSR-W (17.4 mm) was significantly ($p < 0.05$) higher than that of all the other varieties including the TZL Comp. 4C2 (16.5 mm) which was the lowest (Figure 2). The variation as observed in the softness indexes may be attributed to the degree of inherent associative forces within the starch molecules in the food product which may be caused by genetic factors (e.g. amylose/amylopectin ratio) and level of chemical transformation during *tuwo* preparation. Mua and Jackson (1997) observed that higher amylose content and longer amylopectin chains could contribute to the hardness of a food gel or dumpling from maize, thus affecting its softness index. Moorthy et al. (1996) also observed that the flour preparation methods could affect the inherent associative forces within the starch molecules of the flour and by implication that of food product prepared from such flour. Softness index of maize *tuwo* can be used to simulate the force required to compress the food product between the tongue and palate which is normally a preliminary action usually carried out in the mouth during consumption. This can therefore lead to whether the food product will eventually be chewed or swallowed. Maize *tuwo*, like many other traditional food gels or dumplings, is consumed by swallowing rather than being masticated or chewed and it is the prevailing textural characteristics of the product, at the point of consumption, that usually determine whether such food is swallowable or chewable (Prinz and Lucas, 1995; Szczesniak, 2002). Even in certain areas (e.g. Hausa-speaking communities of northern Nigeria) where food chewability, rather than swallowability, is a common food eating habit, it is important to note that it is the peculiarity of the available traditional foods (e.g. cereal-based foods) in the environment coupled with the textural quality of such foods that make the people to cultivate the food-chewing habit. Consequently, this food-chewing habit has now metamorphosed into a food-related cultural practice. Therefore, lower softness index can predispose the food product towards being masticated or chewed while relative high softness index encourages swallowability. Hence, maize *tuwo* from DMR-LSR-W and market sample (Shagari variety) with relative high softness indexes are highly predisposed towards having better

Table 5. Sensory quality rating of *tuwo* from different maize varieties.

Tuwo source	Sensory factor[1]				
	Colour	Texture (hand-mouldability)	Aroma	Taste	Overall acceptability
TZL Comp. 3C2	7.5^{b}	6.2^{b}	5.5^{c}	7.4^{b}	6.4^{c}
TZL Comp. 4C2	6.3^{c}	6.9^{b}	6.9^{ab}	6.1^{c}	6.9^{c}
DMR-ESR-W	7.5^{b}	7.4^{a}	6.1^{b}	6.9^{bc}	8.2^{ab}
DMR-LSR-W	8.2^{a}	7.9^{a}	7.8^{a}	8.1^{a}	8.7^{a}
Market sample (Shagari variety)	6.8^{c}	6.8^{b}	7.2^{a}	7.4^{b}	7.9^{b}

[1]Results are mean values of panelists' rating. Mean values followed by different superscripts in each column are significantly different at $p < 0.05$.

swallowability than *tuwo* from other maize varieties.

Sensory quality rating of tuwo from different maize varieties

The sensory quality rating of maize *tuwo* from different maize varieties is presented in Table 5. Maize *tuwo* prepared from DMR-LSR-W was rated highest in terms of colour, texture (hand-mouldability), aroma, taste and overall acceptability; though not significantly different at $p < 0.05$ from DMR-ESR-W in terms of texture (hand-mouldability) and overall acceptability as well as from the market sample (Shagari variety) in terms of aroma. Therefore, due to the relative high sensory quality rating of maize *tuwo* from DMR-LSR-W coupled with its relative high cohesiveness index (15.4%) which could predispose it towards good hand-mouldability during consumption as well as an exhibition of relatively high softness index (17.4 mm) that could predispose it towards being swallowed rather than being chewed or masticated; DMR-LSR-W was eventually identified as the most appropriate variety for maize *tuwo* production.

Pearson correlation coefficient among some quality characteristics of maize grains, flour and *tuwo* from different varieties

Several significant correlations were observed among some quality characteristics of maize grains, flour and *tuwo* from different maize varieties (Table 6). Amylose was positively correlated with softness index (r = 0.54), aroma (r = 0.56) and overall acceptability (r = 0.72); but negatively correlated with damaged starch (r = -0.50). Some properties of the maize flour were observed to exhibit some degrees of correlation. The damaged starch was negatively correlated with the sensory quality factors such as texture (r = -0.69), aroma (r = -0.55) and overall acceptability (r = -0.59). The peak viscosity was positively correlated with final viscosity (r = 0.82) while it was negatively correlated with the sensory quality factors such as texture (r = -0.81) and overall acceptability (r = -0.56). The breakdown viscosity was positively correlated with cohesiveness index (r = 0.79), softness index (r = 0.70), aroma (r = 0.70) and taste (r = 0.68). The final viscosity was positively correlated with setback, version II (r = 0.89) but negatively correlated with colour (r = -0.66), texture (r = -0.87) and overall acceptability (r = -0.72). The setback, version II was also observed to negatively correlate with colour (r = -0.65), texture (r = -0.69) and overall acceptability (r = -0.66). The cohesiveness index was positively correlated with softness index (r = 0.98) while the cohesiveness and softness indexes were observed to be positively correlated with all the sensory quality factors of maize *tuwo* including colour (r = 0.75 and 0.77 respectively), texture (r = 0.50 and 0.64 respectively), aroma (r = 0.57 and 0.59 respectively), taste (r = 0.96 and 0.92 respectively) and overall acceptability (r = 0.68 and 0.80 respectively).

Therefore, the various correlations observed among the kernel property, flour characteristics and rheological properties of *tuwo* obtained from different maize varieties are fundamental pointers to a strong interrelationship among the factors as well as providing valuable information on the degree of influence of one factor on another. However, Szczesniak (2002) observed that correlations between instrumental assessment and sensory evaluation of food products may not always be very good and sometimes may be product-dependent.

Conclusion

The conclusion that can be made from this study is that the maize varieties used exhibited different physical characteristics in their kernels, varying physicochemical properties in their flours, different rheological properties (that is, cohesiveness and softness indexes) of maize *tuwo* prepared from the flours as well as different assessment levels in their organoleptic properties. The maize variety, DMR-LSR-W, was ultimately identified as the most appropriate for maize *tuwo* preparation for its highest cohesiveness and softness indexes coupled with its highest sensory quality rating though not significantly different at $p < 0.05$ from DMR-ESR-W. Therefore, for a

Table 6. Pearson correlation coefficient (r) among various properties of kernel, flour and *tuwo* from different maize varieties.

No.	Parameters	1	2	3	4	5	6	7	8	9	10	11	12	13
	Kernel properties													
1	Amylose	1.00												
	Flour properties													
2	Damaged starch	-0.50	1.00											
3	Peak viscosity	0.14	0.48	1.00										
4	Breakdown	0.04	0.13	-0.48	1.00									
5	Final viscosity	-0.14	0.49	0.82	-0.15	1.00								
6	Setback, version II	-0.32	0.37	0.46	0.15	0.89*	1.00							
	***Tuwo* properties**													
7	Cohesiveness index	0.44	0.15	-0.27	0.79	-0.31	-0.27	1.00						
8	Softness index	0.54	-0.01	-0.34	0.70	-0.46	-0.44	0.98**	1.00					
9	Colour	0.02	0.26	-0.46	0.48	-0.66	-0.65	0.75	0.77	1.00				
10	Texture	0.45	-0.69	-0.81	0.41	-0.87	-0.69	0.50	0.64	0.50	1.00			
11	Aroma	0.56	-0.55	-0.47	0.70	-0.24	0.02	0.57	0.59	0.07	0.68	1.00		
12	Taste	0.29	0.39	-0.13	0.68	-0.25	-0.28	0.96*	0.92*	0.83	0.32	0.30	1.00	
13	Overall acceptability	0.72	-0.59	-0.56	0.42	-0.72	-0.66	0.68	0.80	0.52	0.93*	0.73	0.51	1.00

*Correlation is significant at P < 0.05; **Correlation is significant at P < 0.01.

maize variety to be appropriate for *tuwo* production, it must possess such requirements as moderate amylose content (18.9 - 20.1%), kernel weight (224 - 245 g/1000 kernels), kernel length and width (10.1 - 11.2 and 8.5 - 9.1 mm respectively) and damaged starch value of maize flour (12.2 - 13.9%). Other requirements include peak and final viscosities of maize flour (108.5 - 127.1 and less than 148 RVU respectively) and low setback-2 value (less than 39.1 RVU).

REFERENCES

Aboubacar A, Kirleis AW, Oumarou M (1999). Important sensory attributes affecting consumer acceptance of sorghum porridge in West Africa as related to quality tests. J Cereal Sci., 30: 217–225.

Adeyemi IA, Commey SN, Fakorede MAB, Fajemisin JM (1987). Physical characteristics and starch pasting viscosity of twenty Nigerian maize varieties. Niger. J. Agron., 2: 65-69.

Alika JE (1994). Combining ability for quality of maize flour in a 6-parent diallel cross. Afri. Crop Sci. J., 2: 49-53.

Bauer PJ, Carter PR (1986). Effect of seeding date, plant density, moisture availability, and soil nitrogen fertility on maize kernel breakage susceptibility. Crop Sci., 26: 1220-1226.

Bolade MK, Buraimoh MS (2006). Textural and sensory quality enhancement of sorghum tuwo. Int. J. Food Sci. Technol. 41(S2): 115-123.

Bolade MK, Usman MA, Rasheed AA, Benson EL, Salifou I (2002). Influence of hydrothermal treatment of maize grains on the quality and acceptability of *tuwon masara* (traditional maize gel). Food Chem., 79: 479-483.

Bolade MK, Adeyemi IA, Ogunsua AO (2009). Influence of particle size fractions on the physicochemical properties of maize flour and textural characteristics of a maize-based nonfermented food gel. Int. J. Food Sci. Technol., 44: 646-655.

Bosque-Perez NA (2000). Eight decades of maize streak virus research. Virus Res., 71: 107-121.

Campos H, Cooper M, Habben JE, Edmeades GO, Schussler JR (2004). Improving drought tolerance in maize: A view from industry. Field Crop Res., 90: 19-34.

Faridi H (1990). Application of rheology in the cookie and cracker industry. In: Faridi H, Faubion JM (eds) Dough rheology and baked product texture, New York, USA, Van Nostrand Reinhold. pp. 363-384.

Farrand EA (1964). Flour properties in relation to the modern bread processes in the United Kingdom, with special reference to alpha-amylase and starch damage. Cereal Chem., 41: 98-111.

Ferrer A, Remon S, Negueruela AI, Oria R (2005). Changes during the ripening of the very late season Spanish Peach cultivar Calanda: Feasibility of using CIELAB coordinates as maturity indices. Sci. Hortic., 105: 435-446.

Francis FJ, Clydesdale FM (1975). Food Colorimetry: Theory andApplications. AVI Publisher, Westport, U.S.A. pp. 51-62.

Fredriksson H, Silverio J, Andersson R, Eliasson AC, Aman P (1998). The influence of amylose and amylopectin characteristics of gelatinization and retrogradation properties of different starches. Carbohyd. Polym., 35: 119-134.

Hardacre AK, Clark SM (2006). The effect of hybrid and growing environment on the rheological properties of starch and flour from maize (Zea mays L.) grain dried at fourtemperatures. Int. J. Food Sci. Technol., 41(S2): 144 - 150.

Hilliard JH, Daynard TT (1974). Starch content, test weight and other quality parameters of corn production in different areas of Ontario. Crop Sci., 14: 546-548.

Hoseney RC (1994). Dry milling of cereals. In: Hoseney RC (ed) Principles of cereal science and technology, St. Paul, MN, USA, American Association of Cereal Chemists, pp. 125-145.

Iken JE, Amusa NA (2004). Maize research and production in Nigeria. Afri. J. Biotechnol., 3(6): 302-307.

Jane J, Xu A, Radosavljevic M, Seib PA (1992). Location of amylose in normal starch granules. I. Susceptibility of amylose and amylopectin to cross-linking reagents. Cereal Chem., 69: 405 – 409.

Kikuchi K, Takatsuji I, Tokuda M, Miyake K (1982). Properties and uses of horny and floury endosperms of corn. J. Food Sci., 47: 1687-1692.

Lii CY, Tsai ML, Tseng KH (1996). Effect of amylose content on the rheological property of rice starch. Cereal Chem., 73: 415 – 420.

Lin PY, Czuchajowska Z (1996). Starch damage in soft wheats of the Pacific Northwest. Cereal Chem., 73: 551-555.

Manyong VM, Kling JG, Makinde KO, Ajala SO, Menkir A (2000). Impact of IITA-improved germplasm on maize production in West and Central Africa. [Internet document]. URL http://www.cgiar.org/impact/research/maize. Accessed on 10th July, 2007.

McDonough CM, Floyd CD, Waniska RD, Rooney LW (2004). Effect of accelerated aging on maize, sorghum, and sorghum meal. J. Cereal Sci. 39: 351–361.

McGuire RG (1992). Reporting of objective color measurement. Hort. Sci., 27: 1254 – 1255.

Meikle WG, Adda C, Azoma K, Borgemeister C, Degbey P, Djomamou B, Markham RH (1998). The effects of maize variety on the density of Prostephanus truncatus (Coleoptera: Bostrichidae) and Sitophilus Zeamais (Coleoptera: Curculionidae) in post-harvest stores in Benin Republic. J Stored Product Res., 34: 45-58.

Meilgaard MC, Carr TB, Civille GV (1991). Sensory Evaluation Technique, 2nd edn. CRC Press, Boca Raton, FL. pp. 65-85.

Mejia D (2005). Maize: Postharvest Operations. In D. Mejia, and E. Parrucci, FAO Post-harvest Compendium. [Internet document]. URL http://www.fao.org/inpho/. Accessed on 10th January, 2007.

Moorthy SN, Rickard J, Blanshard JMV (1996). Influence of gelatinization characteristics of cassava starch and flour on the textural properties of some food products. In: Dufour D, O'Brien GM, Best R (eds) Cassava flour and starch: progress in research and development, Colombia CIAT. pp. 150-155.

Mua JP, Jackson DS (1997). Relationships between functional attributes and molecular structures of amylose and amylopectin fractions of corn starch. J. Agric. Food Chem., 45: 3848–3854.

Muller HG (1970). Traditional cereal processing in Nigeria and Ghana. Ghana J. Agric. Sci. 3: 187-195.

Nago CM, Tetegan E, Matencio F, Mestres C (1998). Effects of maize type and fermentation conditions on the quality of Beninese traditional ogi, a fermented maize slurry. J. Cereal Sci., 28: 215-222.

Ndjeunga J, Nelson CH (2005). Towards understanding household preference for consumption characteristics of millet varieties: a case study from western Niger. Agric. Econ. 32: 151-165.

Newport Scientific (1996). Operational Manual for the Series 4 Rapid Visco Analyser. Newport Scientific Pty, Ltd., Sydney, Australia. pp. 5-12.

Ortiz-Monasterio JI, Palacio-Rojas N, Meng E, Pixley K, Trethowan R, Pena RJ (2007). Enhancing the mineral and vitamin content of wheat and maize through plant breeding. J. Cereal Sci. 46: 293-307.

Otegbayo B, Aina J, Asiedu R, Bokanga M (2006). Pasting characteristics of fresh yams (*Dioscorea* spp.) as indicators of textural quality in a major food product – pounded yam. Food Chem. 99: 663–669.

Pingali PL, Pandey S (2001). Meeting world maize needs: technological opportunities and priorities for the public sector. In: Pingali PL (ed) CIMMYT 1999-2000 World Maize Facts and Trends, Mexico, CIMMYT, pp. 1-3.

Pixley KV, Bjarnason MS (2002). Stability of grain yield, endosperm modification, and protein quality of hybrid and open-pollinated Quality Protein Maize (QPM) cultivars. Crop Sci., 42: 1882-1890.

Pomeranz Y, Meloan CE (1987). Food Analysis: Theory and Practice. 2nd edn. Van Nostrand Reinhold, New York. pp. 64-101.

Prinz JF, Lucas PW (1995). Swallow thresholds in human mastication. Arch. Oral Biol. 40: 401- 403.

Raboy V, Young KA, Dorsch JA, Cock A (2001). Genetics and breeding of seed phosphorus and phytic acid. J. Plant Physiol., 158: 489-497.

Ragaee S, Abdel-Aal, EM (2006). Pasting properties of starch and protein in selected cereals and quality of their food products. Food Chem. 95: 9-18.

Raju GN, Bhashyam MK, Narasimha HV, Murthy SS, Srinivas T (1992). Grain morphology and structure in relation to milled product quality in maize (Zea mays L.). Int. J. Food Sci. Technol., 27: 213-220.

Robutti J, Borras F, Gonzalez R, Torres R, DeGreef D (2002). Endosperm properties and extrusion cooking behavior of maize cultivars. Lebensm. Wiss. Technol., 35: 663-669.

Saldana G, Brown HE (1984). Nutritional composition of corn and flour tortillas. J. Food Sci., 49: 1202-1203.

Sandhu KS, Singh N (2007). Some properties of corn starches II: Physicochemical, gelatinization, retrogradation, pasting and gel textural properties. Food Chem., 101: 1499–1507.

Sandhu KS, Singh N, Kaur M (2004). Characteristics of the different corn types 456 and their grain fractions: physicochemical, thermal, morphological and rheological properties of starches. J. Food Eng., 64: 119–127.

Szczesniak AS (1966). Texture measurements. Food Technol., 20: 52-58.

Szczesniak AS (2002). Texture is a sensory property. Food Qual. Pref. ,13: 215-225.

Vyn TJ, Moes J (1988). Breakage susceptibility of corn kernels in relation to crop management under long growing season conditions. Agron. J. 80: 915-920.

Vyn TJ, Tollenaar M (1998). Changes in chemical and physical quality parameters of maize grain during three decades of yield improvement. Field Crop Res., 59: 135-140.

Williams PC, Kuzina FD, Hlynka I (1970). A rapid colorimetric method for estimating the amylose content of starches and flours. Cereal Chem., 47: 411- 421.