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Full Length Research Paper

Effect of flour production methods on the yield, physicochemical properties of maize flour and rheological characteristics of a maize-based non-fermented food dumpling

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The study was aimed at investigating the influence of flour production methods (grit soaking method [GSM], grit non-soaking method [GNM] and pestle and mortar dehulling method [PMDM]) on the yield, physicochemical properties of maize flour and rheological characteristics of a maize-based non-fermented food dumpling. The flour yield from the production methods ranged between 56.6 and 62.3% with GSM and GNM giving the lowest and highest values respectively. There were variations in the mean particle size (203.3 - 220.5 µm) and damaged starch content (12.2 - 14.5%) of flours obtained from the three production methods. The flours from the production methods also exhibited variations in the pasting temperature (73.2-74.6°C), peak viscosity (84.2 - 110.6 RVU) and final viscosity (111.4 - 147.4 RVU). The lightness indices (L*-values) of the flours (88.8 - 90.0) and maize 'tuwo' (66.9 - 67.7) were affected by the flour production methods while the chroma (C-values) of the flours (14.6 - 14.9) and maize 'tuwo' (8.9 - 9.1) were also affected though not significantly different ($p<0.05$). The cohesiveness index (15.1 - 15.9%) and softness index (17.2-17.8 mm) of maize 'tuwo' prepared from the flours also exhibited variations.

Key words: Dumpling, flour, maize, tuwo, rheological characteristics.

INTRODUCTION

Maize (*Zea mays* L.) is an important cereal grain in the world and it has a diverse form of utilization including human food uses, animal feed formulation and as a basic raw material for industrial purposes (Courtois et al., 1991). In Africa, a greater proportion of maize grains being produced is used as human food whereas industrial processing of the bulk of maize grains are carried out in the developed countries (Anon, 1997). However, there has been a tremendous increase in maize grain utilization for animal feed formulations in the developing countries in recent times due to a rapid increase in poultry consumption (Okoruwa, 1997). Maize is consumed in diverse forms in different parts of Africa, from boiled or roasted maize cobs to dry-milling of grains to obtain flour or wet-milling to obtain starch (Rooney and Serna-Saldivar, 1987). Many traditional African food products that can be obtained from maize include ogi, eko or agidi, maize tuwo or tuwon masara, bantu, aliha, abari, kenkey, injera, guguru, kokoro, elekute, egbo, chenga, etc. (Okoruwa, 1997). Dry-milling is an age-long processing procedure for cereal grains and its primary objective is to separate the kernel into its anatomical parts (that is endosperm, bran, and germ) which is essentially a physical change in the cereal grains (Johnson, 1991). Different classes of end-products of dry-milling of cereal grains include flaking, coarse, medium or fine grits; coarse or fine meal; flour and germ (Kent and Evers, 1994).

The production of flour from maize grains via dry-milling, particularly in Africa, is usually accomplished through diverse production methods. One method involves grinding the whole maize grains using motor-driven grinder to obtain whole maize flour (Nago et al., 1997) or the maize grains may first be dehulled using pestle and mortar after which the dehulled grains are ground or milled into flour (Mestres et al., 2003). The maize flour from this form of production method is usually rich in lipids, which are present in the germ, thereby leading to a rapid development of rancidity in the flour (Andah, 1976; Nago et al., 1997). Another method of maize flour production involves initial dehulling and degerming of the maize grains using a decorticating equipment to obtain the maize grits. It is these grits that are finally milled into flour (Mestres et al., 2003).

Maize flour, one of the end-products of dry-milling of maize grains, and the food products derivable from the flour have been observed of able to exhibit variations in their physical, chemical and/or rheological properties due to such factors as maize varieties (Mestres et al., 1991; Pan et al., 1996; Yuan and Flores, 1996; Nago et al., 1997; Sandhu et al., 2007), milling methods (Nghi and Narasimha, 1994; Martinez-Flores et al., 1998), particle size differential of flour (Bolade et al., 2009) and differences in the drying temperatures of maize grains (Hardacre and Clark, 2006). However, there are limited research works on the effect of flour production methods, with variation in the unit operations, on the flour properties and textural characteristics of food products prepared from such flour. Housson and Ayernor (2002) studied the physicochemical properties of whole maize flour and dehulled-degermed maize flour so as to predict the functional properties of products derivable from such flours. Mestres et al. (2009) also investigated the influence of maize flour, produced through the use of disc and hammer mills, on the quality attributes of thick pastes commonly consumed in Benin, a West African country.

The objective of this study therefore was to investigate the influence of flour production methods on the yield, physicochemical properties of maize flour and rheological characteristics of a non-fermented maize dumpling (maize tuwo) commonly consumed within Hausa-speaking communities of West Africa sub-region.

MATERIALS AND METHODS

Materials

The maize variety used for the study was DMR-LSR-W, which is white maize and was obtained from the Institute of Agricultural Research and Training (IAR & T), Moor Plantation, Ibadan, Nigeria. The maize grains were two months old after harvest.

Production of maize flour

Three different methods were used to produce maize flour, namely: Grit Non-soaking Method (GNM), Grit Soaking Method (GSM) and Pestle and Mortar Dehulling Method (PMDM). Fifteen kilograms of maize grains were used for each method to produce the flour.

Grit non-soaking method (GNM): This involves initial cleaning of the maize grains manually by removing the stones, damaged kernels and other extraneous materials. The cleaned grains were then tempered by sprinkling 5% water (v/w) on the grains coupled with thorough mixing. This was followed by decortication of the grains on a Grantex decorticating machine, which removed the brans and the germ to obtain the grits. The grits were finally milled using a disc attrition mill (Agrico Model 2A, New Delhi, India) to obtain the flour followed by sieving using a sieve with 300 µm aperture and then kept in airtight polythene bags until needed.

Grit soaking method (GSM): The maize grains were subjected to similar unit operations as that of grit non-soaking method (GNM). However, the grits obtained were soaked in cold water (submerged) for 3 h after which they were drained and oven-dried at 55°C for 16 h. The dried grits were finally milled and sieved in a similar manner as that of grit non-soaking method (GNM).

Pestle and mortar dehulling method (PMDM): The manually cleaned maize grains were tempered (5% water addition, v/w) followed by manual dehulling using wooden pestle and mortar through pounding. The pounded grains were manually winnowed to remove the adhering brans and other light-weight materials. The grits eventually obtained were finally milled and sieved in a similar manner as that of grit non-soaking method (GNM).

Evaluation of mass balance in maize flour production

The mass balance in maize flour production was based on the basic principles of conservation of mass (Earle, 1983). Mathematically, this can be expressed as follows:

$$Wmg = Wsf + Whg + Wss + Wot + Wlm$$

Where;
Wmg = weight of maize grains used
Wsf = weight of sieved maize flour
Whg = weight of hulls and germ removed
Wss = weight of soluble solids in the soaking water
Wot = weight of over-tails from flour sieving operation
Wlm = weight of other lost materials incurred during flour production.

Weight of hulls and germ removed was estimated as the difference between weight of maize grains used and weight of maize grits obtained after decortication. Weight of soluble solids in the soaking water was evaluated by weighing 10 ml of the soaking water in a glass Petri dish followed by drying in an oven at 105°C for 3 h. The weight of remaining solids in the Petri dish was used to estimate the total soluble solids in the soaking water. Weight of over-tails from flour sieving operation was estimated as the difference between weight of unsieved flour and weight of sieved flour. Weight of other lost materials incurred during flour production represents losses that could not be accounted for during processing.

Determination of mean particle size of maize flour

The particle size distribution of maize flour (250 g) from each production method was carried out using a sieve analysis technique with the aid of Endecotts Test Sieve Shaker (model 1 MK11-11381, London, UK). Sieves of different apertures (that is 425, 300, 150 and 75µm) and pan were used by placing them in the shaker for 10 min. The flour retained on each sieve was weighed and the mean particle size (MPS) of the flour determined using the method of Arambula et al. (1998) as follows:

$$\text{Mean particle size (MPS)} = (W_1d_1+W_2d_2+.....+W_5d_5)/R$$

Where;

W_{1-5} = weight of flour through each sieve
d_{1-5} = diameter of mesh for each sieve

R = total recovery.

Determination of damaged starch of maize flour

The damaged starch of maize flour from each production method was determined according to the method of Farrand (1964). The test was based on starch susceptibility to α–amylase digestibility. 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 maize flour from each production method were determined using a Rapid Visco-Analyzer, RVA-Series 4 (Anon, 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 parameters calculated from the pasting curve include the pasting temperature, peak viscosity, time to peak, breakdown, holding strength or trough, setback, and final viscosity.

Production of maize 'tuwo'

Maize 'tuwo' was prepared from flour of each production method 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 (1.5 kg) with 25% of the desired quantity of water (5.25 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 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 obtained through each production method 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); where L* represents the colour lightness while a* and b* represent the degree of redness/greenness and yellowness/blueness respectively. 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 $h^o = [\tan^{-1}(b/a)] + 360^o$ (McGuire, 1992).

Determination of cohesiveness index of maize tuwo

The cohesiveness index of maize tuwo prepared from flour obtained through each production method was determined using the Universal Testing Machine (model M500-50KN, Testometric, England). Maize tuwo was initially prepared inside a cylindrical plastic container (with a diameter of 50 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 20 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 index of maize tuwo prepared from flour obtained through each production method was 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.

Statistical analyses

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 $p<0.05$ using Statistical Package for Social Scientists (SPSS) software, version 10.0; on a personal computer.

RESULTS AND DISCUSSION

Mass balance in maize flour production from different methods

The mass balance in the production of maize flour from three different methods is presented in Table 1. The proportion of materials added, recovered or removed during tempering and decortication steps were the same for both grit soaking method (GSM) and grit non-soaking method (GNM). The quantity of water used for tempering

Table 1. Mass balance in the production of maize flour from three different methods.

Operation	Component in the mass balance	Proportion (%)[1]		
		Grit soaking Method (GSM)	Grit non-soaking method (GNM)	Pestle and mortar dehulling method (PMDM)
Starting material	Maize grains (9.8 ± 0.5%, moisture content)	100	100	100
Tempering	Average quantity of water used for tempering the grains prior to decortication.	5.0^a (v/w)	5.0^a (v/w)	5.0^a (v/w)
Decortication[2]	i) Average quantity of maize grits recovered after decortication.	69.6 ± 1.4^a	69.6 ± 1.4^a	NA[4]
	ii) Average quantity of hulls, germs and grain brokens removed.	30.4 ± 1.2^a	30.4 ± 1.2^a	NA
Pestle and mortar Dehulling	i) Average quantity of maize grits recovered after manual dehulling.	NA	NA	71.2 ± 1.8
	ii) Average quantity of hulls, germs and grain brokens removed.	NA	NA	28.8 ± 1.1
Soaking	Average quantity of soluble solids in grit-soaking water	1.6 ± 0.1	NA	NA
Oven-drying	i) Average quantity of maize grits (10.1±0.3%, moisture content) recovered after oven-drying.	64.1 ±1.3	NA	NA
	ii) Average loss during oven-drying operation.	3.9 ±0.4	NA	NA
Milling[3]	i) Average quantity of unsieved flour after milling.	60.5 ± 0.9^c	65.8 ± 1.1^b	67.3 ± 0.7^a
	ii) Average loss during milling.	3.6 ± 0.6^a	3.8 ± 0.4^a	3.9 ± 0.6^a
Sieving (< 300 µm)	i) Average quantity of sieved flour recovered.	56.6 ± 1.4^b	62.3 ± 1.3^a	59.7 ± 1.1^a
	ii) Average quantity of over-tails.	3.9 ± 0.5^b	3.5 ± 0.4^b	7.6 ± 0.3^a

[1]Average values within the same row having the same letter are not significantly different at $p < 0.05$; [2]Temperature of maize grits during decortication= 45 – 50°C; [3]Temperature of flour during milling operation: 1st run (max.) = 58°C, 2nd run (max.) = 64°C; [4]NA = Not applicable.

was 5% (v/w) for all the methods while the average quantity of maize grits recovered after decortication was 69.6% for GSM and GNM respectively. The hulls, germs and grain brokens removed during decortication step accounted for 30.4% for GSM and GNM respectively. However, for pestle and mortar dehulling method (PMDM), the quantity of maize grits recovered after manual dehulling was 71.2%; higher than that of GSM and GNM respectively. The reason for this observation may be attributed to a possible ineffective manual dehulling operation which might have left substantial quantity of bran and germ unremoved.

The average quantity of soluble solid that leached out during grit soaking, quantity of maize

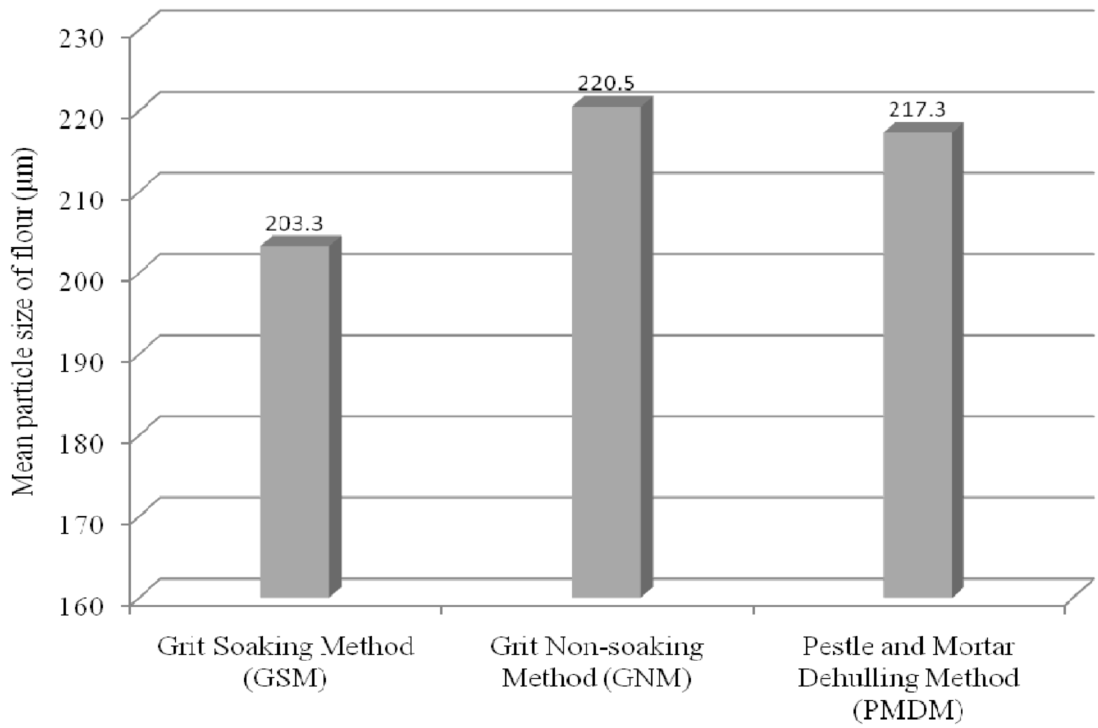

Figure 1. Effect of flour production method on the mean particle size of maize flour.

grits recovered after oven-drying and the loss incurred during oven-drying were 1.6, 64.1 and 3.9% respectively specifically for the GSM. The quantity of unsieved flour obtained after milling from the production methods ranged between 60.5 and 67.3% with GSM and PMDM giving the lowest and highest values respectively. The significant difference ($p < 0.05$) in the flour output is attributable to variation in the grit input prior to milling. The loss incurred during milling ranged between 3.6 and 3.9% for all the production methods with no significant difference ($p<0.05$).

The ultimate quantity of sieved flour (< 300 µm) obtained from the production methods ranged between 56.6 and 62.3% with GSM and GNM giving the lowest and highest values respectively with a significant difference ($p < 0.05$). The proportion of over-tails recovered from all the production methods also ranged between 5.5 and 7.6% with GNM and PMDM giving the lowest and highest values respectively with a significant difference ($p < 0.05$). The observed highest over-tails from PMDM may be attributed to a seeming large quantity of fibre (from bran) present in the flour due to a possible ineffective manual dehulling operation through pestle and mortar.

Effect of flour production methods on the mean particle size of maize flour

The mean particle size of maize flour obtained from different production methods is presented in Figure 1. It ranged between 203.3 and 220.5 µm with GSM and GNM giving the lowest and highest values respectively with a significant difference ($p < 0.05$).

The lowest mean particle size of flour from GSM may be attributed to the weakened associative forces binding the endosperm together thereby giving rise to smaller-sized particle during milling. Akingbala et al. (1987) and Nche et al. (1996) observed that grain/grit soaking has the ability to stimulate enzyme activity thereby causing partial dextrinization of amylose/amylopectin molecules which in turn can lead to the weakening of associative forces within the starch structure (Moorthy et al., 1996). Mean particle size of flour has been observed to influence the physicochemical properties of the flour and textural characteristics of food products derived from such flour (Hebrard et al., 2003).

Effect of production methods on the damaged starch content of maize flour

The damaged starch content of maize flour from different production methods ranged between 12.2 and 14.5% with GNM and PMDM giving the lowest and highest values respectively with a significant difference at $p < 0.05$ (Figure 2). The highest damaged starch content observed in flour from PMDM may be due to the manual pounding which might have inflicted greater damage to the starch molecules. The relative high damaged starch content in flour from GSM may also be due to the soaking

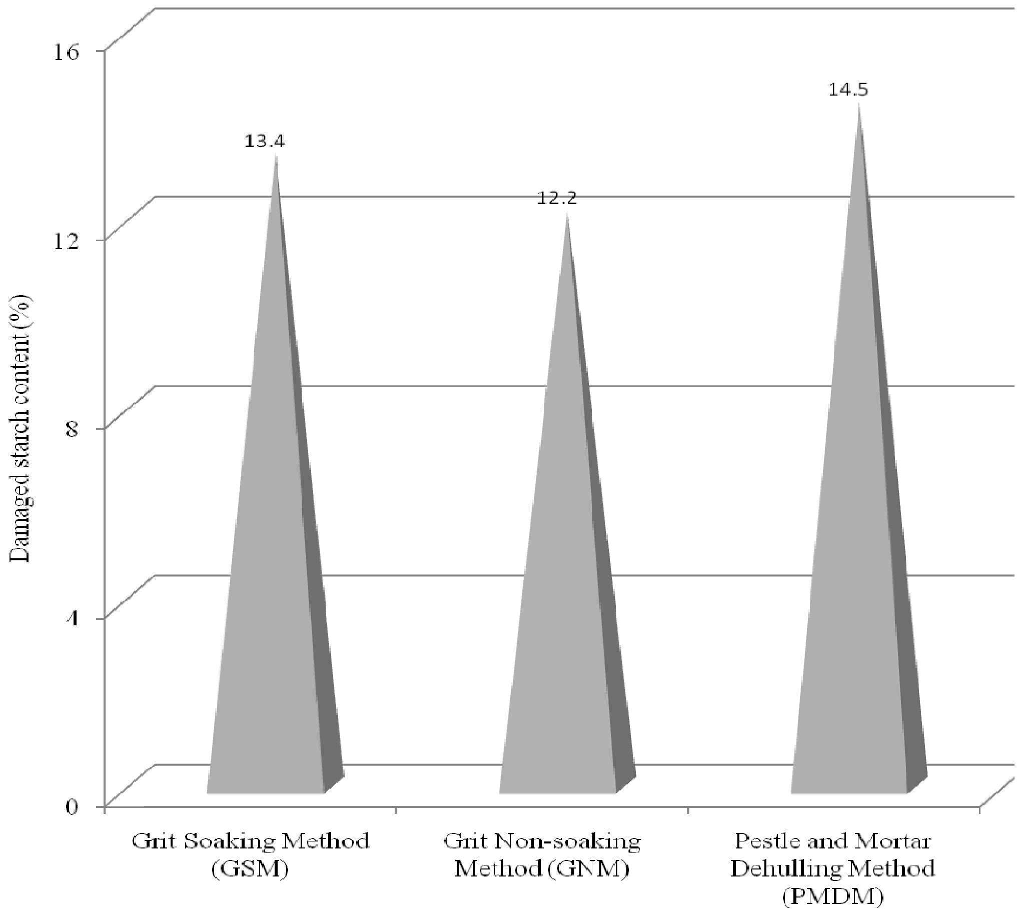

Figure 2. Effect of flour production method on the damaged starch content of maize flour.

and re-drying operations peculiar to the method which might have toughened the grits thereby making them to exhibit more resistance to milling, hence the relative high damaged starch value. Damaged starch is an important parameter particularly in flour-related food processing operations because it could influence so many processing variables including water absorption by the flour, dough or batter stickiness, fermentation rate, loaf volume, colour and stability (Craig and Stark, 1984; Hoseney, 1994). Many factors responsible for variations in damaged starch content is cereal flours include type of cereal grain being handled, grain processing procedures, type and set-up of the milling machine and adjustment made during the milling stage (Kent and Evers, 1994).

Pasting properties of maize flour as influenced by different production methods

The effect of flour production methods on the pasting properties of maize flour is presented in Table 2. The pasting temperature of maize flour from GSM was the lowest (73.2°C) while that from GNM was the highest (74.6°C). The implication of this observation is that flour from GSM would gelatinize faster than that from others. This is most probably because the seeming stimulated enzymes in the soaking maize grits are capable of breaking down the matrix embedding starch granules, thus allowing the granules to swell freely and gelatinize faster (Nche et al., 1996).

The peak viscosity of maize flour from different production methods ranged between 84.2 and 110.6 RVU with GSM and PMDM giving the lowest and highest values respectively with a significant difference ($p < 0.05$). The differences observed in the peak viscosities of the maize flours may be attributed to different rates of water absorption and swelling of starch granules of these flours during heating (Ragaee and Abdel-Aal, 2006). Ayernor (1985) also observed that peak viscosity usually occurs at the equilibrium between granule swelling, which increases viscosity and granule rupture, and alignment due to mechanical shear, which causes its decrease.

The breakdown viscosity of the flour samples ranged between 19.6 and 43.3 RVU with GSM and PMDM giving the lowest and highest values respectively with significant difference ($p < 0.05$). The breakdown viscosity is regarded as a measure of the degree of disintegration of starch granules or paste stability during heating (Dengate, 1984). The implication of this observation is that the flour from GSM with the lowest breakdown value was more resistant to heat and shear force during heating and that there was less starch granule rupture

Table 2. Effect of flour production methods on the pasting properties of maize flour[1].

Flour source	Pasting factor[1]							
	Pasting temperature (°C)	Peak viscosity (RVU)[2]	Trough (RVU)	Break-down (RVU)	Final viscosity (RVU)	Setback, version I (difference between final viscosity and trough) (RVU)	Time to reach peak viscosity (min)	Setback, version II (difference between final and peak viscosity) (RVU)
Grit soaking method (GSM)	73.2[b]	84.2 [b]	64.6[b]	19.6[c]	111.4[b]	46.8 [b]	9[a]	27.2[c]
Grit non-soaking method (GNM)	74.6[a]	108.3[a]	71.4[a]	36.9[b]	147.4[a]	76.0[a]	9[a]	39.1[a]
Pestle and mortar dehulling method (PMDM)	74.2[a]	110.6[a]	67.3[ab]	43.3[a]	144.5[a]	77.2[a]	9[a]	33.9[b]

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

which could therefore guarantee a more stable cooked paste (Farhat et al., 1999).

The final viscosity of the flour samples ranged between 111.4 and 147.4 RVU with GSM and GNM giving the lowest and highest values respectively. Higher value of final viscosity has been attributed to the aggregation of the amylose molecules in the paste (Miles et al., 1985). Therefore, the lowest final viscosity value of GSM may be due to a seeming enzymatic activity that might have occurred during the grit soaking stage (Nche et al., 1996), thus reducing the aggregation of its amylose molecules.

The setback viscosity (version I) of the flour samples ranged between 46.8 and 77.2 RVU with GSM and PMDM giving the lowest and highest values respectively with a significant difference ($p < 0.05$). The lowest setback (version I) observed in GSM may be attributed to partial dextrinization of the starch molecules. Akingbala et al. (1987) observed that the stimulated enzymes in the soaking grains are capable of causing partial hydrolysis of the starch molecules thereby reducing the amount of starch to be gelatinized, thus lowering the setback viscosity. The setback viscosity (version I) can be used to predict the storage life of a food product prepared from the flour (Zaidul et al., 2007). Therefore, the implication of this observation is that the food dumpling prepared from GSM is most likely to exhibit lower retrogradation tendency than that of others due to lower setback viscosity (version I).

The setback viscosity (version II) of the flour samples ranged between 27.2 and 39.1 RVU with GSM and GNM giving the lowest and highest values respectively. The reason for the lowest setback viscosity (version II) in GSM is the same as that postulated for setback (version I) and this parameter can be used to predict the textural characteristics of food products prepared from the flour (Otegbayo et al., 2006). Therefore, the food dumpling prepared from GSM would most probably exhibit a higher cohesiveness than that from others due to the lowest setback viscosity, version II (Bolade et al., 2009).

Effect of flour production methods on the colour characteristics of maize flour and 'tuwo'

The lightness index (L*-value) of flours from different production methods ranged between 88.8 and 90.0 with GSM and GNM having the lowest and highest values respectively (Table 3). The additional unit operations (soaking and re-drying) involved in GSM might have contributed to the marginal decrease in the lightness index of the flour. The lightness index of maize 'tuwo' also ranged between 66.9 and 67.2 with GSM and GNM giving the lowest and highest values respectively. The partial non-enzymatic browning which might have occurred during oven-drying of maize grits from GSM may also be responsible for the lowering of the lightness index of both flour and 'tuwo'. McDonough et al. (2004) observed that high temperature heat treatments could increase the brown colour of cereal grains and meals prepared from them due to browning (Maillard) reactions.

The chroma, C-value, of the flour samples ranged between 14.6 and 14.9 with no significant difference ($p < 0.05$). The C-values of 'tuwo' samples also ranged between 8.9 and 9.1 with no significant difference ($p < 0.05$). The chroma is a measure of colour intensity of the samples (DeMan, 1990).

The hue angle (h°) of both maize flour and 'tuwo' were also affected by the production methods. The hue angle (h°) of the flour samples ranged between 90.2 and 90.3° while that of 'tuwo' samples ranged between 99.7 and 102.8°. However, it has been observed that the hue angle (h°) seems not to be a useful indicator for describing

Table 3. Effect of flour production methods on the colour indices of maize flour and tuwo[1].

Sample source	Maize flour					Maize *tuwo*				
	L*	a*	b*	Chroma, C	Hue angle, h°	L*	a*	b*	Chroma, C	Hue angle, h°
Grit Soaking Method (GSM)	88.8[b]	-0.09[a]	14.6[a]	14.6[a]	90.3[a]	66.9[b]	-2.0[a]	8.7[a]	8.9[a]	102.8[a]
Grit Non-soaking Method (GNM)	90.0[a]	-0.08[a]	14.7[a]	14.7[a]	90.3[a]	67.7[a]	-1.9[a]	8.9[a]	9.1[a]	102.1[a]
Pestle and Mortar Dehulling Method (PMDM)	89.6[ab]	-0.06[a]	14.9[a]	14.9[a]	90.2[a]	67.2[ab]	-1.5[b]	8.8[a]	8.9[a]	99.7[b]

[1]Results are mean values of triplicate determination. Mean values within the same column having the same letter are not significantly different at $p < 0.05$.

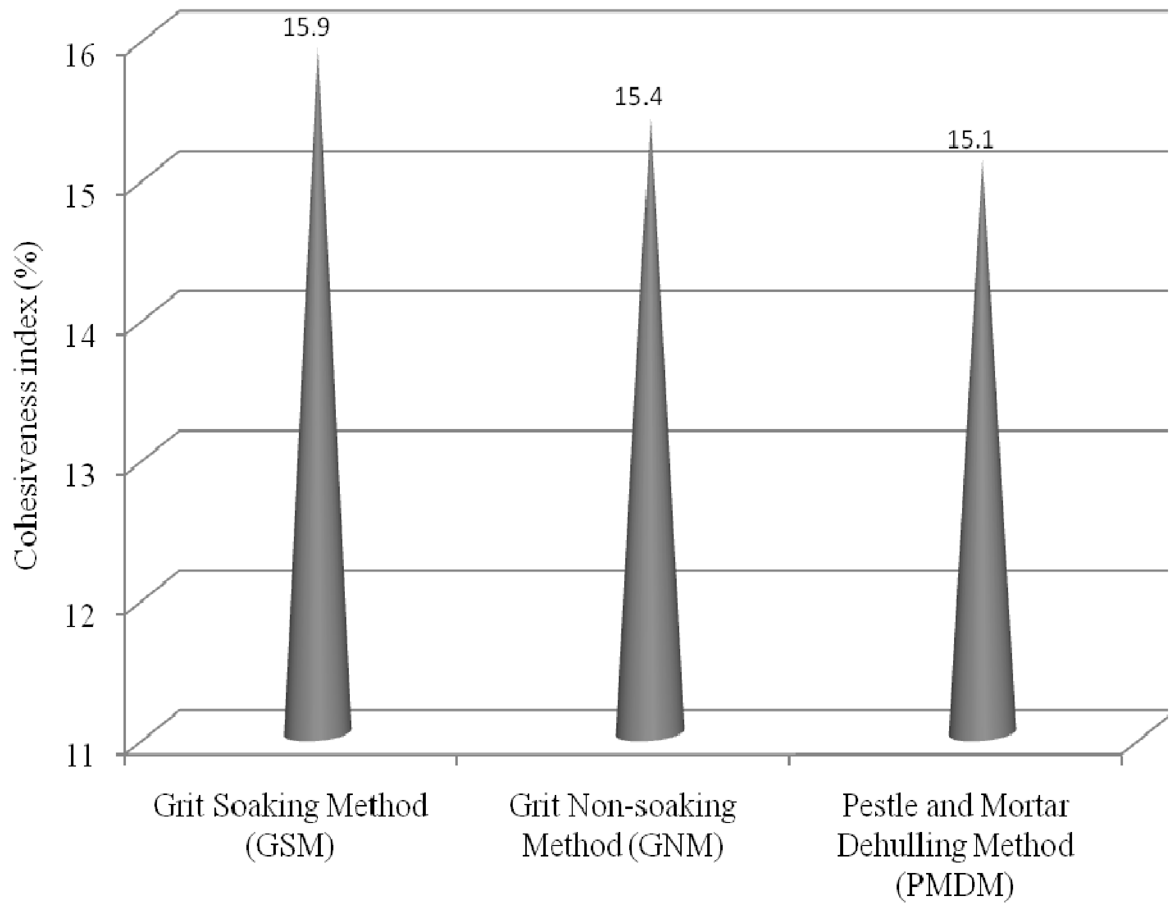

Figure 3. Cohesiveness index of maize *tuwo* from three distinct flour production methods.

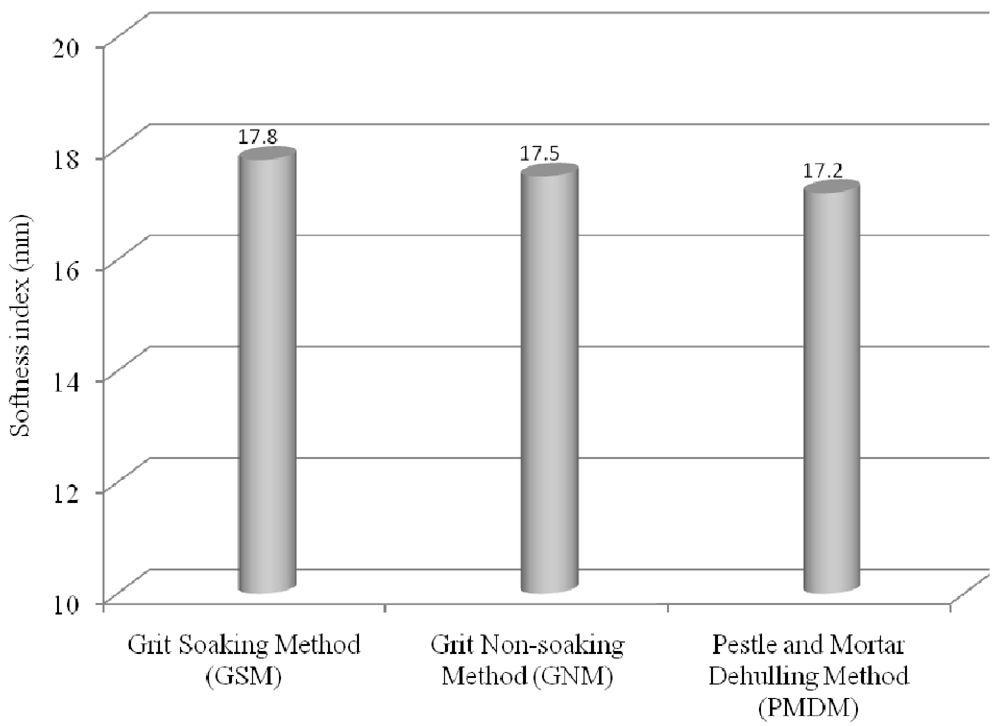

Figure 4. Softness index of maize *tuwo* from three distinct flour production methods.

the colour change in white maize grain processing as red-yellow-green colour indices are seldom applicable (Bolade et al., 2009).

Effect of flour production methods on the cohesiveness index of maize 'tuwo'

The cohesiveness index of maize 'tuwo' samples ranged between 15.1 and 15.9% with PMDM and GSM giving the lowest and highest values respectively with no significant difference at $p < 0.05$ (Figure 3). The marginal increase in the cohesiveness index of maize 'tuwo' from GSM may be attributed to changes that had occurred to the physical and chemical properties of the flour from GSM. These include the resultant relative low mean particle size of the flour and the weakening of associative forces within the starch molecules (Gibbon et al., 2003) by virtue of seeming partial hydrolysis through the stimulated enzymes during grit soaking (Akingbala et al., 1987; Nche et al., 1996). Gomez et al. (1987) observed that relatively small particle size of flour was responsible for acceptable level of cohesiveness in tortilla, among others.

Cohesiveness of food dumplings like maize 'tuwo' is an important quality attribute that usually influences consumer acceptability of the product (Osuji, 1983; Aboubacar et al., 1999). 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 satisfaction. Thus, an enhanced cohesiveness index of maize 'tuwo' will predispose it towards good hand-mouldability and increased psychological satisfaction during consumption.

Softness index of maize 'tuwo' as influenced by flour production methods

The softness index of maize 'tuwo' samples ranged between 17.2 and 17.8mm with PMDM and GSM giving the lowest and highest values respectively with a significant difference at $p > 0.05$ (Figure 4). Additional unit operations of soaking and re-drying involved in the production of flour from GSM might have weakened the associative forces within the starch structure (Gibbon et al., 2003) as postulated earlier thereby leading to a greater softness index of maize 'tuwo' prepared from such flour. Similarly, the lowest softness index of maize 'tuwo' from PMDM might have been caused by a possible presence of additional fibre and fat in the flour due to a seeming ineffective manual dehulling operation. Hardacre and Clark (2006) observed that a food gel or dumpling (e.g. maize 'tuwo') usually exhibits variation in the rheological characteristics as a result of different degrees of interactions of flour components (that is, protein, fat, fibre and non-starch polysaccharides) with solubilised amylose and amylopectin components of the starch granules during heating.

The 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 and can 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). Therefore, lower softness index can predispose the food product towards being masticated or chewed while relative high value encourages swallowability.

Conclusion

It may be concluded that different production methods of maize flour play an important role in the flour yield, physicochemical properties of flour and rheological characteristics of food dumpling (e.g. maize 'tuwo') prepared from the flour. Flours from different production methods showed variation in the particle size, damaged starch value and pasting properties. There was also variation in the rheological characteristics of maize 'tuwo' in term of cohesiveness and softness indexes which usually influence the mouldability and swallowability of the food product respectively; which are important quality indicators for maize 'tuwo' acceptability.

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