Quality dynamics of maize ‘tuwo’ (non-fermented maize-based dumpling) as influenced by steaming of maize grits at different resident time

Mathew K. Bolade · Isaac A. Adeyemi

Revised: 30 August 2012 / Accepted: 11 September 2012 / Published online: 27 September 2012
© Association of Food Scientists & Technologists (India) 2012

Abstract This study was aimed at investigating the influence of starch pregelatinisation of maize flour, through grit steaming, on the quality characteristics of maize *tuwo* (non-fermented food dumpling). Maize grits were variously steamed, batch-wise, for a period of 15, 30, 45 and 60 min respectively from which flour was obtained. The damaged starch value (13.4–16.2 %) of the pregelatinised maize flour increased with an increase in the steaming duration while that from 0-min steaming period was 12.2 %. The water absorption capacity (3.2–3.7 g/g) and oil absorption capacity (2.1–2.5 g/g) of the pregelatinised maize flour increased with an increase in the steaming duration while those from 0-min steaming period were 2.1 g/g and 2.0 g/g respectively. The pasting variables were found to decrease with an increase in the steaming duration include the peak viscosity (80.5–106.1 RVU), breakdown viscosity (17.9–23.1 RVU), final viscosity (102.4–136.8 RVU), setback-I (41.9–56.6 RVU) and setback-II (21.9–35.5 RVU) while those from 0-min steaming period were 108.3, 36.9, 147.4, 76.0 and 39.1 RVU respectively. The colour characteristics of maize flours and *tuwo* showed that the L*-value of the flours (85.2–88.7) and *tuwo* (65.1–67.2) decreased with an increase in the steaming duration while those from 0-min steaming period were 90.0 and 67.7 respectively. The rheological properties of maize *tuwo* showed that the strain at peak, taken as the cohesiveness index of the food product, ranged between 18.0 and 21.7 % while that from 0-min steaming period was 15.4 %. The softness index of the food product also ranged between

17.5 mm and 17.9 mm while that from 0-min steaming period was 17.4 mm. The sensory quality rating of maize *tuwo* prepared from the pregelatinised flour showed that the food product obtained from the 30-min steaming duration was rated the highest in terms of texture (mouldability), taste and overall acceptability.

Keywords Maize *tuwo* · Maize flour · Maize grit · Pregelatinised starch · Steaming · Quality

Introduction

Maize *tuwo* (*tyuu-woh*) is one of maize-based food products commonly consumed in Nigeria and other Hausa-speaking communities of West African countries such as Ghana, Mali and Burkina-Faso (Bolade et al. 2002). It is a food dumpling usually prepared from non-fermented maize flour involving a combination of the flour, water and thermal energy to form a gel-like food product. The quality attributes normally used by the consumers for assessing maize *tuwo* are colour (white to creamy), texture (ease of mouldability and swallowability) and pleasant taste (Bolade et al. 2009).

Various efforts have been made to solve the peculiar problems of textural and sensory quality inadequacies associated with maize *tuwo* and these include the use of hydrothermally-treated maize grains in the preparation of the food product (Bolade et al. 2002); the use of size-categorized maize flour for its preparation (Bolade et al. 2009); and the use of maize-cassava flour mixes for its preparation (Bolade and Adeyemi 2012). Maize *tuwo*, being a cereal food product, is normally influenced by the physical and chemical properties of maize grains from which it is produced (Akingbala et al. 1995). These properties, however, may be modified through chemical, physical and enzymic processes so as to obtain desired functional characteristics (Hermansson and Svegmarm 1996).

M. K. Bolade (✉)
Department of Food Science and Technology,
Federal University of Technology,
P.M.B. 704, Akure, Ondo State, Nigeria
e-mail: bolademk@saatfuta.edu.ng

I. A. Adeyemi
Department of Food Science and Engineering,
Ladoke Akintola University of Technology,
P.M.B. 4000, Ogbomosho, Oyo State, Nigeria

Pregelatinisation of starches in cereal grains is one physical method through which the functionality of the starches can be modified and it has been carried out on such cereals as rice (Lai 2001), maize (Loisel et al. 2006; Lagarrigue et al. 2008) and millet (Adebawale et al. 2005). This physical modification of cereal starches, through pregelatinisation, is usually accompanied by such changes as granule swelling, loss of birefringence and crystallinity, disruption of starch granule structure, among others (Lai 2001).

The objective of this study therefore was to subject maize grits, meant for *tuwo* production, to physical modification through steaming with a view to producing pregelatinised flour of modified functionalities capable of giving *tuwo* of enhanced textural and sensory qualities.

Materials and methods

The white maize grains (DMR-LSR-W) used for this study were obtained from the Institute of Agricultural Research and Training (IAR&T), Ibadan, Nigeria.

Production of maize grits This was done by initially cleaning the maize grains manually by the removal of 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. The decortication was immediately carried out on a Grantex decorticating machine, which removed the brans and the germ to obtain the grits. The grits finally obtained were then kept in airtight polythene bags until needed.

Steaming of maize grits and flour production The steaming of maize grits was carried out in four different batches (3.5 Kg each). Each batch was initially soaked in cold water for 3 h (with an hourly water replacement to discourage grit fermentation). After soaking, the grits (a batch) were drained and subjected to steaming for 15 min using an electric steamer operating at an atmospheric pressure. Other three batches were similarly subjected to steaming for 30, 45 and 60 min respectively.

After steaming, the steamed grits were transferred into an air draught oven and dried at 55 °C for 20 h. After oven drying, each batch of the grits was cooled and then 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.

Maize flour was also produced from the grits that were not steamed at all which serves as the control. The flour was equally sieved using a sieve with 300-µm aperture and then kept in airtight polythene bags until needed.

Evaluation of functional properties of flour samples The functional properties (i.e. water and oil absorption capacities) of the flour samples were evaluated. The water absorption capacity was determined by the method of Sefa-Dedeh et al. (2003). Five grams of the tested flour were weighed into a centrifuge tube and 30 ml of distilled water at an ambient temperature ($30^{\circ}\pm 2^{\circ}\text{C}$) was added. The mixture was stirred and allowed to stand for 30 min and then centrifuged at 3,000 rpm for 15 min. The supernatant was decanted and the increase in weight noted by weighing. The water holding capacity was expressed in g/g (i.e. amount of water held per gram of flour sample). The water absorption capacity was evaluated in order to ascertain the behaviour of the flour samples in case of ingredient formulation involving water and the flour.

The oil absorption capacity was determined according to the modified method of Prinyawiwatkul et al. (1997). Each tested flour sample (5.0 g) was thoroughly mixed with 25 ml of vegetable oil (Executive Chef Brand) in 50 ml centrifuge tubes. Suspensions were stirred intermittently over a 30-min period at room temperature (i.e. $30^{\circ}\pm 2^{\circ}\text{C}$) and then centrifuged at $6,000 \times g$ for 30 min. The supernatant was decanted and the increase in weight noted by weighing. The oil absorption capacity was expressed in g/g (i.e. amount of oil held per gram of flour sample). The oil absorption capacity was similarly evaluated in order to ascertain the behaviour of the flour samples in case of ingredient formulation involving oil and the flour.

Evaluation of damaged starch of flour samples The damaged starch of each flour sample 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 $30^{\circ}\pm 0.5^{\circ}\text{C}$ 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 which include the addition of 2 ml each of 10 % sulphuric acid and 12 % tungstate solutions for 2 min after which the mixture was filtered through No.4 Whatman filter paper. One millilitre (1 ml) of the filtrate was pipetted into 10 ml 0.10 N alkaline ferricyanide plus 4 ml buffer solution in a boiling tube. The tube was then immersed in a vigorously boiling water bath for 20 min and subsequently cooled using cold water ($25\pm 2^{\circ}\text{C}$). Twenty five milliliters (25 ml) acetic acid-salt solution was used to rinse the solution into the flask. One millilitre (1 ml) of starch-potassium iodide reagent was added and the solution titrated against sodium thiosulphate giving a creamy white colour at the end-point. Two blank determinations were similarly carried out using 1.46 ml α -amylase preparation (Blank 1) and 2.5 ml distilled water (Blank 2); this was carried out as a check on the reagents.

Damaged starch (%) was calculated as follows: [(Maltose figure–3.5) × 6]; where the maltose figure was similarly calculated from the standardized Maltose Table.

Evaluation of pasting properties of flour samples Each flour sample was subjected to pasting analysis using Rapid Visco Analyzer (model RVA 4; Newport Scientific Limited, Warriewood, Australia). A pasting analysis procedure as described by Bolade (2009) was used for each sample. A sample of 4.0 g 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.

Preparation of maize *tuwo* Maize *tuwo* was prepared from each flour sample 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 (1.0 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 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 *tuwo* samples The colour of *tuwo* from each flour sample was measured using a colour measuring instrument (ColorTec-PCM, model SN 3000421, USA) and the values expressed on the L*, a*, b* tristimulus scale. A colour determination procedure as described by Bolade (2009) was used for each sample. 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/m²); 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 $h^\circ = \tan^{-1}(b/a)$; if a<0 and b>0, then $h^\circ = [\tan^{-1}(b/a)] + 180^\circ$; if a >0 and b<0, then $h^\circ = [\tan^{-1}(b/a)] + 360^\circ$ (McGuire 1992). The value was reported as the mean of triplicate determinations.

Evaluation of rheological characteristics of *tuwo* samples The rheological characteristics *tuwo* obtained from the flour samples was evaluated using the Universal Testing Machine (model M500-50KN, Testometric, England). A determination procedure as described by Bolade (2009) was used for each sample. Maize *tuwo* was initially prepared 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 a 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 rheological variables of the food dumpling (maize *tuwo*) determined were load at yield (N), deflection at yield (mm), strain at yield (%), load at peak (N), deflection at peak (mm), and strain at peak (%). The load at yield is essentially the force at which deflection or deformation increases without a corresponding change in force particularly just beyond the elastic limit of the food sample. The load at peak is the maximum or peak compressive force experienced by the food sample during a compression test. The deflection at yield is the point at which deflection increases without a corresponding change in the applied force. The deflection at peak is the deflection at maximum force. The percentage of such deflection/elongation is known as strain at peak (Testometric 2007). The cohesiveness index of the food sample was equated to the strain at maximum load (%) which is the extent to which the cylindrical *tuwo* mould could be deformed before it ruptured (Szczesniak 1966; Pomeranz and Meloan 1987).

i.e. Cohesiveness Index (Strain at Maximum Load)

$$= \frac{\text{Displacement or Deformation} \times 100}{\text{Original Height or Length}}$$

Determination of softness index of *tuwo* samples The softness index of *tuwo* obtained from each flour sample was determined using Precision Cone Penetrometer (Benchtop model, Pioden Controls Ltd., UK). A determination

procedure as described by Bolade (2009) was used for each sample. 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 quality rating of *tuwo* samples *Tuwo* samples obtained from various flour samples were subjected to sensory evaluation using a scoring test. 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, taste, aroma, texture (mouldability) and overall acceptability using a nine-point hedonic scale (i.e. 9 = like extremely; 5 = neither like nor dislike; 1 = dislike extremely). The scores from the rating were subsequently subjected to analysis of variance (ANOVA) and the means separated using Duncan Multiple Range test (IFT 1981; 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 $P < 0.05$ using Statistical Package for Social Scientists (SPSS) software, version 10.0; on a personal computer.

Results and discussion

Effect of grit steaming on water, oil absorption capacities and damaged starch value of maize flour The effect of steaming on the water and oil absorption capacities of maize flour is shown in Table 1. The water absorption capacity of pregelatinized maize flour from steamed maize grits was observed to increase with an increase in the steaming duration and the values ranged between 3.2 and 3.7 g/g while that from the unsteamed maize grits was 2.1 g/g. The oil absorption capacity of pregelatinized maize flour from steamed maize grits also

Table 1 Physico-chemical characteristics of maize flours and 'tuwo' obtained from maize grits steamed for different times^a

Steaming duration (min)	Water absorption capacity (g/g)	Oil absorption capacity (g/g)	Damaged starch content (%)	Softness index (mm)
0	2.1 ^c ±0.3	2.0 ^b ±0.2	12.2 ^d ±0.4	17.4 ^{ab} ±0.2
15	3.2 ^b ±0.1	2.1 ^b ±0.1	13.4 ^c ±0.5	17.5 ^{ab} ±0.3
30	3.3 ^{ab} ±0.2	2.1 ^b ±0.2	15.2 ^{ab} ±0.5	17.6 ^{ab} ±0.2
45	3.4 ^{ab} ±0.2	2.4 ^{ab} ±0.3	15.8 ^a ±0.4	17.9 ^a ±0.3
60	3.7 ^a ±0.3	2.5 ^a ±0.1	16.2 ^a ±0.2	17.9 ^a ±0.3

^a Each value represents mean ± SD of three replicates. Values followed by different superscripts in each column are significantly different at $p < 0.05$

ranged between 2.1 g/g and 2.5 g/g while that from the unsteamed maize grits was 2.0 g/g. The trend of the values was observed to similarly increase with an increase in the steaming duration. The general increase in both water and oil absorption capacities of maize flour with an increase in the steaming duration may be attributed to the seeming severe disruption in the structural make-up of the starch in the flour occasioned by the steaming operation. It had earlier been observed that the increase in the water absorption capacity of pregelatinized flour might be due to such factors as higher degree of damaged starch in the flour (Chilton and Collison 1974; Kurimoto and Shelton 1988; Adeyemi et al. 1989) while the increase in oil absorption capacity was attributed to degree of denatured protein constituent in the flour, temperature of treatment and particle size of the flour (Richest et al. 1974).

The damaged starch content in maize flour obtained from steamed maize grits is also presented in Table 1. There was a significant increase in the damaged starch value in the flour samples with an increase in the steaming duration and the values ranged between 12.2 % and 16.2 %. The higher damaged starch values observed for maize flour from that of greater steaming duration may be attributed to greater resistance to milling exhibited by the steamed maize grits. The resistance to milling itself seemed to have been conferred on the steamed maize grits through additional unit operations of soaking, steaming and re-drying; which might have toughened the materials thereby resulting in relative high damaged starch value than the unsteamed samples. The technological significance of the degree of damaged starch in flour is related to its influence on many processing variables including water absorption in flour as well as quality characteristics (e.g. dough stickiness, fermentation rate, loaf volume, colour and stability, etc.) of flour-based food products (Craig and Stark 1984; Hoseneey 1994).

Pasting properties of maize flour as influenced by grit steaming The influence of steaming operation on the pasting properties of pregelatinised maize flours from maize

grits are presented in Table 2. There was an increase in the pasting temperature of pregelatinised flours (74.8–75.9 °C) when compared with that of the non-pregelatinised flour (74.6 °C). This observation indicates that the use of pregelatinised flour in the production of maize *tuwo* might lead to an increased pasting or gelatinisation temperature during cooking. The justification for this observation is that the initial pre-gelatinisation (pre-treatment) of the flour, most probably, had toughened the starch granules thereby leading to a retarded granule swelling during pasting and hence an increased gelatinisation temperature. Steaming of maize grits at atmospheric pressure can be likened to a heat-moisture treatment which is defined as a physical treatment that involves incubation of starch granules at low moisture levels (<35 % water, w/w), during a certain period of time, at a temperature greater than the glass transition temperature (T_g) but lower than the gelatinisation temperature, T_o (Jacobs and Delcour 1998). An increase in pasting or gelatinisation temperature was similarly observed for heat-moisture-modified starches by other researchers, regardless of botanical origin (Lorenz and Kulp 1982; Collado and Corke 1999).

There was a general reduction in the peak, breakdown, final and setback viscosities of pregelatinised flours following steaming of maize grits. The reduced peak viscosity (80.5–106.1 RVU) in pregelatinised flours, as against that of non-pregelatinised flour (108.3 RVU), is an indication of reduced rate of water absorption by the starch granules during heating coupled with retarded swelling of the granules (Ragaei and Abdel-Aal 2006). The reduction in peak viscosity of pregelatinised flours could also be attributed to an increased concentration of partially gelatinized starch granules within the flour samples which did not give room for the attainment of higher peak viscosity values (Banigo et al. 1974; Adeyemi et al. 1989). However, the reduced peak viscosity was most severe at 45-min steaming period than other periods. Hidalgo et al. (2008) observed a similar reduction in the peak viscosity of steamed einkorn (*Triticum monococcum*) wholemeal flour. Puspitowati and Driscoll (2007) also observed that higher

degree of gelatinization of starch could lead to the lowering of peak viscosity in rice while Gajula et al. (2008) similarly observed the lowering of peak viscosity in fiber-enriched wheat flour as a result of pre-cooking.

The breakdown viscosity of pregelatinised flours (17.9–23.1 RVU) was observed to be lower than that of the non-pregelatinised flour (36.9 RVU). This observation is an indication of increased paste stability during processing of the pregelatinised maize flour (Zaidul et al. 2007). The lowest breakdown viscosity was observed at 15-min steaming period than other steaming duration. Adebawale et al. (2005) also observed a reduced breakdown viscosity in hydrothermally-treated finger millet (*Eleusine coracana*) starch.

The final viscosity of pregelatinised flours (102.4–136.8 RVU) was also observed to be lower than that of the non-pregelatinised flour (147.4 RVU). The reduced final viscosity of pregelatinised flours from steamed maize grits was most pronounced at 45-min steaming period than other steaming duration. Zhang et al. (2010) similarly observed that the heat-moisture-treated starch of *Canna edulis* Ker exhibited remarkably low values of peak viscosity, hot pasting viscosity and final viscosity when compared to those of native starch. Lai (2001) also observed a reduced final viscosity in pregelatinised rice flour when compared with that of the native rice flour.

The setback viscosity (version I) of pregelatinised flours (41.9–56.6 RVU) was lower than that of the non-pregelatinised flour (76 RVU). The reduction in setback viscosity (version I) of pregelatinised flours from steamed maize grits is an indication that such flour is capable of giving reduced retrogradation tendency of food gels obtainable from the flour (Sandhu and Singh 2007). The lowest setback viscosity (version I) was however observed at 45-min steaming period than other steaming duration. Hoover and Manuel (1996) also observed a reduction in the setback viscosity (version I) of heat-moisture-treated maize starches.

Table 2 Pasting characteristics of maize flours obtained from the steamed maize grits

Steaming duration (min)	Pasting factor ^a						
	Pasting temperature (°C)	Peak viscosity (RVU) ^b	Trough (RVU)	Breakdown value (RVU)	Final viscosity (RVU)	Setback-I (difference between final viscosity and trough; RVU)	Setback-II (difference between final and peak viscosity; RVU)
0	74.6 ^{ab} ±0.2	108.3 ^a ±2.7	71.4 ^b ±4.1	36.9 ^a ±4.4	147.4 ^a ±5.1	76 ^a ±3.6	39.1 ^a ±3.2
15	74.8 ^a ±0.3	106.1 ^a ±3.4	88.7 ^a ±3.8	17.9 ^{bc} ±4.2	136.8 ^b ±3.8	48.1 ^{bc} ±3.5	30.7 ^b ±2.5
30	75.9 ^a ±0.4	92.8 ^b ±4.1	68.7 ^b ±2.2	23.1 ^b ±2.5	121.4 ^c ±3.1	52.7 ^b ±2.8	28.6 ^c ±3.1
45	75.5 ^a ±0.3	80.5 ^c ±3.7	60.5 ^c ±2.6	20 ^b ±1.9	102.4 ^d ±4.5	41.9 ^d ±3.1	21.9 ^d ±2.6
60	75.2 ^a ±0.4	91.3 ^b ±3.2	70.2 ^b ±3.9	21.1 ^b ±2.3	126.8 ^c ±3.7	56.6 ^b ±3.4	35.5 ^a ±2.4

^a Each value represents mean ± SD of three replicates. Values followed by different superscripts in each column are significantly different at $p < 0.05$

^b RVU Rapid Visco Unit

The setback viscosity (version II) of pregelatinised flours (21.9–35.5 RVU) was similarly lower than that of the non-pregelatinised flour (39.1 RVU). The lowest setback viscosity (version II) was observed at 45-min steaming period. Adebowale et al. (2005) also observed a reduction in the setback viscosity (version II) of heat-moisture-treated millet starch.

Effect of grit steaming on the colour characteristics of maize flour and *tuwo* The influence of steaming time on the colour characteristics of pregelatinised maize flour and *tuwo* from steamed maize grits is presented in Table 3. The colour lightness, L*-value, of pregelatinised maize flour was observed to decrease with an increase in the steaming duration and ranged between 85.2 and 88.7 while that of non-pregelatinised flour was 90.0 with significant differences at $p < 0.05$. This observation might be due to the direct exposure of endosperm components of the maize grits to heat coupled with subsequent re-drying (55 °C) which might have initiated a more severe non-enzymatic browning reaction within the endosperm of the grits. Horrobin et al. (2003) had postulated that colour development in steamed cereal grain is as a result of interplay between moisture uptake by the grain undergoing steaming and gelatinisation within the endosperm thereby leading to a non-enzymatic browning reaction. This observation also indicated that steaming of maize grits had a tendency of leading to a reduction in the lightness index, L*-value, of pregelatinised flour. Bhattacharya (1996) similarly observed a reduction in the L*-value of parboiled rice.

The chroma, C-value, of pregelatinised flour from steamed maize grits ranged between 13.2 and 14.5 while that of non-pregelatinised flour was 14.7. The C-value of flour from steamed maize grits was observed to decrease with an increase in the steaming duration. This observation indicated that steaming of maize grits could also lead to a reduction in the colour intensity (chroma) of pregelatinised flour derived from it. This reduction could be attributed to a severe effect of steaming on the grits which led to a more pronounced colour formation through non-enzymatic browning. Ilo and Berghofer (1999) also observed a more pronounced colour formation in maize grits during extrusion cooking.

The colour characteristics of maize *tuwo* derived from the pregelatinised maize flour revealed that the colour lightness, L*-value, ranged between 65.1 and 67.2 while that from the non-pregelatinised maize flour was 67.7. The colour lightness, L*-value, of maize *tuwo* was generally lower than that of corresponding pregelatinised maize flour counterparts which indicated that the conversion of pregelatinised maize flour to maize *tuwo* usually led to a further reduction in colour lightness. This occurrence might be attributed to interaction of components involved in the conversion which

Table 3 Colour characteristics of maize flours and *tuwo* obtained from the steamed maize grits^a

Steaming duration (min)	Maize flour				Maize <i>tuwo</i>					
	L*	a*	b*	Chroma, C	Hue angle, h°	L*	a*	b*	Chroma, C	Hue angle, h°
0	90 ^a ±1.1	-0.08 ^a ±0.03	14.7 ^a ±0.2	14.7 ^a ±0.3	90.3 ^a ±0.5	67.7 ^a ±0.4	-1.9 ^a ±0.2	8.9 ^a ±0.3	8.9 ^a ±0.3	102.1 ^b ±0.4
15	88.7 ^{ab} ±0.5	-0.09 ^a ±0.02	14.5 ^{ab} ±0.3	14.5 ^{ab} ±0.2	90.4 ^a ±0.2	67.2 ^a ±0.5	-2 ^a ±0.3	8.8 ^a ±0.2	8.8 ^a ±0.2	102.6 ^b ±0.9
30	88.1 ^b ±0.8	-0.09 ^a ±0.02	14.1 ^b ±0.2	14.1 ^b ±0.2	90.4 ^a ±0.3	66.2 ^b ±0.2	-2.1 ^a ±0.2	8.3 ^{ab} ±0.3	8.3 ^b ±0.2	104 ^{ab} ±0.6
45	86.4 ^{bc} ±0.9	-0.11 ^{ab} ±0.01	13.9 ^b ±0.3	13.9 ^b ±0.3	90.5 ^a ±0.2	65.9 ^b ±0.4	-2.2 ^a ±0.2	8 ^{bc} ±0.3	8 ^{bc} ±0.2	105.3 ^a ±0.8
60	85.2 ^c ±0.7	-0.13 ^b ±0.01	13.2 ^c ±0.2	13.2 ^c ±0.3	90.6 ^a ±0.4	65.1 ^{bc} ±0.4	-2.3 ^a ±0.3	7.8 ^{bc} ±0.2	7.8 ^{bc} ±0.3	106.1 ^a ±1.2

^a Each value represents mean ± SD of three replicates. Values followed by different superscripts in each column are significantly different at $p < 0.05$

Table 4 Rheological properties of maize *tuwo* obtained from the steamed maize grits

Steaming duration (min)	Rheological parameter of maize <i>tuwo</i> ^a							
	Load at yield (N)	Stress at yield ($\times 10^{-3}$ N/mm ²)	Load at peak (N)	Stress at peak ($\times 10^{-3}$ N/mm ²)	Deflection at yield (mm)	Strain at yield (%)	Deflection at peak (mm)	Strain at peak (%)
0	12.4 ^a ±0.3	4.1 ^a ±0.2	37.3 ^a ±0.8	12.4 ^a ±0.3	3.9 ^a ±0.5	3.6 ^a ±0.6	16.5 ^d ±0.8	15.4 ^d ±0.9
15	12.2 ^a ±0.2	4 ^a ±0.1	35.9 ^{ab} ±0.7	11.9 ^a ±0.4	4.2 ^a ±0.7	3.8 ^a ±0.7	19.8 ^c ±0.5	18 ^c ±0.8
30	11.7 ^b ±0.2	3.9 ^a ±0.2	31.2 ^c ±0.9	10.3 ^b ±0.6	4.4 ^a ±0.4	4 ^a ±0.4	23.9 ^a ±0.9	21.7 ^a ±0.9
45	11.8 ^{ab} ±0.1	3.9 ^a ±0.3	31.4 ^c ±0.7	10.4 ^b ±0.5	4.3 ^a ±0.4	3.9 ^a ±0.8	23.4 ^a ±0.4	21.3 ^a ±0.7
60	11.9 ^{ab} ±0.3	4 ^a ±0.2	32.5 ^c ±0.5	10.8 ^b ±0.3	4.1 ^a ±0.3	3.8 ^a ±0.4	22.8 ^{ab} ±0.4	20.8 ^{ab} ±0.5

^a Each value represents mean $\pm$ SD of three replicates. Values followed by different superscripts in each column are significantly different at $p < 0.05$

were water, flour and thermal energy; thereby leading to a further colour formation through non-enzymatic browning.

The chroma, C-value, of maize *tuwo* derived from steamed maize grits also ranged between 7.8 and 8.8 while that from non-pregelatinised maize flour was 8.9. This observation indicated that the conversion of pregelatinised maize flour to maize *tuwo* could also lead to a reduction in the colour intensity (chroma).

Softness index and rheological characteristics of maize *tuwo* as influenced by grit steaming The softness index of maize *tuwo* obtained from steamed maize grits is similarly shown in Table 1 and ranged between 17.5 and 17.9 mm with no significant difference while that from non-pregelatinised maize flour was 17.4 mm. The softness index of maize *tuwo* prepared from the pregelatinised flour was observed to increase with an increase in the steaming time. The enhanced softness index of maize *tuwo* samples may be attributed to structural modification of the starch granules caused by the weakening of the associative forces within the starch molecules (Moorthy et al. 1996) through steaming. The highest softness index of maize *tuwo* from the steamed maize grits (17.9 mm) was observed at both 45- and 60-min steaming duration.

The compression test characteristics of maize *tuwo* prepared from steamed maize grits are presented in Table 4. There were variations, with significant differences at $p < 0.05$, in virtually all the rheological variables of the food

dumpling (maize *tuwo*) including the load at yield (N), deflection at yield (mm), strain at yield (%), load at peak (N), deflection at peak (mm), and strain at peak(%). The load at yield ranged between 11.7 and 12.2 N, lower than that from 0-min steaming (12.4 N). The load at yield is essentially the force at which deflection or deformation increases without a corresponding change in force particularly just beyond the elastic limit of the food sample (Testometric 2007). When the load at yield is divided by the original cross-sectional area of the food sample, the resultant quantity is known as stress at yield. The load at peak for the food samples ranged between 31.2 and 35.9 N, also lower than that from 0-min steaming (37.3 N). The load at peak is the maximum or peak compressive force experienced by the food sample during a compression test. The implication of this observation is that a lower force would be required to manipulate maize *tuwo* prepared from pregelatinised flour during consumption particularly when it involves hand-mouldability of the food bolus. When the load at peak is divided by the original cross-sectional area of the food sample, the resultant quantity is known as stress at peak.

The deflection at yield for the *tuwo* samples ranged between 4.1 and 4.4 mm, higher than that from 0-min steaming (3.9 mm). The deflection at yield is the point at which deflection increases without a corresponding change in the applied force (Testometric 2007). The percentage of such deflection/elongation is known as strain at yield. The deflection at peak for the food samples also ranged between

Table 5 Sensory quality rating of maize *tuwo* obtained from the steamed maize grits

Steaming duration (min)	Sensory factor ^a				
	Colour	Texture (mouldability)	Aroma	Taste	Overall acceptability
0	7.1 ^a	6.8 ^a	7.0 ^a	6.8 ^{ab}	6.7 ^b
15	6.8 ^{ab}	6.7 ^{ab}	6.9 ^a	6.8 ^{ab}	6.7 ^b
30	6.3 ^b	7.0 ^a	6.6 ^{ab}	7.1 ^a	7.5 ^a
45	6.0 ^{bc}	6.9 ^a	6.4 ^b	6.9 ^a	7.3 ^a
60	5.9 ^{bc}	6.7 ^{ab}	6.2 ^b	6.8 ^{ab}	7.0 ^{ab}

^aEach value represents mean of 40 panelists. Values followed by different superscripts in each column are significantly different at $p < 0.05$

19.8 and 23.9 mm, higher than that from 0-min steaming (16.5 mm). The deflection at peak is the deflection at maximum force. The percentage of such deflection/elongation is known as strain at peak.

The strain at peak for the food samples, taken as the cohesiveness index, was observed to range between 18.0 and 21.7 %, higher than that from 0-min steaming (15.4 %). The implication of this observation is that the use of pregelatinised flour for *tuwo* preparation could lead to enhanced product cohesiveness. The highest cohesiveness index (21.7 %) was observed for maize *tuwo* obtained from steamed maize grits at 30-min steaming. The increase in the cohesiveness index of maize *tuwo* from the pregelatinised flour may be attributed to structural modification in the starch granules of the flour. The increased concentration of partially gelatinised starch granules in the pregelatinised flour as observed by Adeyemi et al. (1989) might have modified the overall structure of maize *tuwo* thereby leading to its increased cohesiveness index.

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 strain at peak indicates that the sample exhibited higher percent height displacement or deformation under compression particularly at maximum compressive force. The cohesiveness of food dumpling like maize *tuwo* is an important quality attribute that usually influences consumer acceptability of the product (Osuji 1983; 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. Even in areas or regions where food mouldability and swallowability seem not to be regarded as strong factors for food preference as against food chewability, it is important to note that it is the peculiarity of the available traditional foods in the environment that might have made the people to surrender to fate thereby turning the practice to a culture.

Sensory quality rating of maize *tuwo* as influenced by grit steaming The sensory quality rating of maize *tuwo* prepared from pregelatinised flour from steamed maize grits are presented in Table 5. Maize *tuwo* from 30-min steaming of maize grits was rated the highest in terms of texture (mouldability), taste and overall acceptability but not significantly different from maize *tuwo* from 45-min steaming of maize grits in terms of texture (mouldability) at $p < 0.05$. Maize *tuwo* from the control (unsteamed maize grits) was rated the highest in terms of colour and aroma but not significantly different from maize *tuwo* from 15-min and 30-min steaming of maize grits in terms of aroma at $p < 0.05$. Therefore, steaming of maize grits at an atmospheric

pressure for a 30-min period was ultimately identified as the most appropriate steaming duration for optimum textural and sensory quality enhancement of maize *tuwo*. It is however important to observe that maize *tuwo* obtained from 0-min steaming was rated the best in terms of colour and aroma and yet rated the least in terms of overall acceptability. This observation may be attributed to the fact that the two parameters (mouldability and taste) seem to have an overbearing influence on the acceptability of the traditional food product; and this is reflected in the data generated.

Conclusion

The conclusion from this study is that pregelatinisation of starch in maize flour meant for *tuwo* production, via maize grit steaming, could lead to the enhancement of textural and sensory quality attributes of the food product. A 30-min steaming duration was found to be an optimum level for the maize grits as maize *tuwo* obtained from this steaming regime was rated the highest in most of the sensory attributes.

The practical application of these findings is that the information would be relevant in the production of maize flour meant for *tuwo* of enhanced quality attributes both at household and commercial levels. It would also be relevant in the promotion of industrial production of maize flour meant purposely for *tuwo* preparation.

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
- Adebowale KO, Afolabi TA, Olu-Owolabi BI (2005) Hydrothermal treatments of finger millet (*Eleusine coracana*) starch. *Food Hydrocoll* 19:974–983
- Adeyemi IA, Komolafe A, Akindele AO (1989) Properties of steam blanched maize flour as a constituent of weaning food. *J Food Process Preserv* 13:133–144
- Akingbala JO, Oguntimein GB, Sobande AO (1995) Physicochemical properties and acceptability of yam flour substituted with soy-flour. *Plant Foods Hum Nutr* 48:73–80
- Banigo EOI, DeMan JM, Duitschaever CL (1974) Utilization of high-lysine corn for the manufacture of ogi using a new improved processing systems. *Cereal Chem* 51:559–572
- Bhattacharya S (1996) Kinetics on colour changes in rice due to parboiling. *J Food Eng* 29:99–106
- Bolade MK (2009) Effect of flour production methods on the yield, physicochemical properties of maize flour and rheological characteristics of a maize-based non-fermented food dumpling. *Afr J Food Sci* 3:288–298
- Bolade MK, Adeyemi IA (2012) Functionality enhancement of composite cassava flour in the production of maize *tuwo* (a non-fermented maize-based food dumpling). *Food Bioprocess Technol* 5:1340–1348

- 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
- 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
- Chilton WG, Collison R (1974) Hydration and gelation of modified potato starches. *J Food Technol* 9:87–93
- Collado LS, Corke H (1999) Heat-moisture treatment effects on sweet potato starches differing in amylose content. *Food Chem* 65:339–346
- Craig SAS, Stark JR (1984) The effect of physical damage on the molecular structure of wheat starch. *Carbohydr Res* 125:117–125
- 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
- Gajula H, Liu S, Alavi S, Herald T, Madl R, Bean SR, Tilley M (2008) Pre-cooked fiber-enriched wheat flour obtained by extrusion. Rheological and functional properties. *Int J Food Prop* 12:27–44
- Hermansson AM, Svegmärk K (1996) Developments in the understanding of starch functionality. *Trends Food Sci Technol* 7:345–353
- Hidalgo A, Brandolini A, Gazza L (2008) Influence of steaming treatment on chemical and technological characteristics of einkorn (*Triticum monococcum* L. ssp. *monococcum*) wholemeal flour. *Food Chem* 111:549–555
- Hoover R, Manuel H (1996) The effect of heat-moisture treatment on the structure and physicochemical properties of normal maize, waxy maize, dull waxy maize and amylomaize V starches. *J Cereal Sci* 23:153–162
- Horrobin DJ, Landman KA, Ryder L (2003) Interior and surface colour development during wheat grain steaming. *J Food Eng* 57:33–43
- Hoseney RC (1994) Dry milling of cereals. In: Hoseney RC (ed) *Principles of cereal science and technology*. AACC, St. Paul, pp 125–145
- IFT (1981) Sensory evaluation guide for testing food and beverage products. *Food Technol* 35:50–59
- Ilo S, Berghofer E (1999) Kinetics of colour changes during extrusion cooking of maize grits. *J Food Eng* 39:73–80
- Jacobs H, Delcour JA (1998) Hydrothermal modifications of granular starch, with retention of the granular structure. A review. *J Agric Food Chem* 46:2895–2905
- Kurimoto Y, Shelton DR (1988) The effect of the flour particle size on baking quality and flour attributes. *Cereal Foods World* 33:429–433
- Lagarigue S, Alvarez G, Cuvelier G, Flick D (2008) Swelling kinetics of waxy maize and maize starches at high temperatures and heating rates. *Carbohydr Polym* 73:148–155
- Lai H (2001) Effects of hydrothermal treatment on the physicochemical properties of pregelatinized rice flour. *Food Chem* 72:455–463
- Loisel C, Maache-Rezzoug Z, Esneault C, Doublier JL (2006) Effect of hydrothermal treatment on the physical and rheological properties of maize starches. *J Food Eng* 73:45–54
- Lorenz K, Kulp K (1982) Cereal and root starch modification by heat-moisture treatment. *Starch-Starke* 34:76–81
- McGuire RG (1992) Reporting of objective color measurement. *Hortscience* 27:1254–1255
- Meilgaard MC, Carr TB, Civille GV (1991) Sensory evaluation technique. CRC Press, Boca Raton
- 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*. CIRAD-SAR, France and CIAT, Colombia (CIAT Publication No. 271), pp 150–155
- 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
- Osuji GO (1983) The effect of glutathione on the cohesiveness of pounded cassava, cocoyam, gari and yam. *J Food Technol* 18:265–270
- Pomeranz Y, Meloan CE (1987) Food analysis. Theory and practice. Van Nostrand Reinhold, New York
- Prinyawiwatkul W, Beuchat LR, McWatters KH, Phillips RD (1997) Functional properties of cowpea (*Vigna unguiculata*) flour as affected by soaking, boiling, and fungal fermentation. *J Agric Food Chem* 45:480–486
- Puspitowati S, Driscoll RH (2007) Effect of degree of gelatinization on the rheology and rehydration kinetics of instant rice produced by freeze drying. *Int J Food Prop* 10:445–453
- Ragaei 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
- Richey SH, Morr CV, Cocney CM (1974) Effect of heat and other factors upon foaming properties of whey protein concentrates. *J Food Sci* 39:42–45
- Sandhu KS, Singh N (2007) Some properties of corn starches II: physicochemical, gelatinization, retrogradation, pasting and gel textural properties. *Food Chem* 101:1499–1507
- Sefa-Dedeh S, Cornelius B, Afoakwa EO (2003) Effect of fermentation on the quality characteristics of nixtamalized corn. *Food Res Int* 36:57–64
- Szczesniak AS (1966) Texture measurements. *Food Technol* 20:52–58
- Testometric (2007) Testometric materials testing machines. [Internet document] URL http://www.testometric.co.uk/cttester/ct_brochures.asp/. Accessed on 16-06-2007
- Zaidul ISM, Norulaini NAN, Omar AKM, Yamauchi H, Noda T (2007) RVA analysis of mixtures of wheat flour and potato, sweet potato, yam and cassava starches. *Carbohydr Polym* 69:784–791
- Zhang J, Wang Z, Yang J (2010) Physicochemical properties of *Canna edulis* Ker starch on heat-moisture treatment. *Int J Food Prop* 13:1266–1279