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Research Paper

Effect of germination and pre-gelatinization on the proximate composition and pasting properties of maize flour a base ingredient for cereal-based infant complementary food

Patience C. Obinna-Echem* • Lucretia I. Barber • Peace C. Jonah

Department of Food Science and Technology, Rivers State University, P.M.B 5080, Port Harcourt, Rivers State, Nigeria.

*Corresponding author. E-mail: patience.obinna-echem@ust.edu.ng

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Abstract. Effect of germination, pre-gelatinization on the proximate composition, viscosity and pasting properties of maize flour as a base ingredient for the formulation of infant complementary food, were investigated. The flour samples were 100% of raw, germinated and pre-gelatinized maize flours and a blend of 50% germinated and 50% pre-gelatinized. The moisture, ash, fat, protein, crude fibre, carbohydrate and Energy content of the maize flours varied from 9.25 to 10.45%, 1.04 to 1.17% 4.73 to 6.71%, 8.79 to 10.62%, 2.22 to 3.12%, 69.93 to 71.10% and 365.67 to 379.99 Kcal/100g respectively. Germination resulted in significant ($P \leq 0.05$) decrease in moisture, fat and carbohydrate while significant increase ($P \leq 0.05$) in crude fibre, protein and energy was observed for the germinated and pre-gelatinized blend. The viscosity varied from 222.00 to 507.40 Pa.s for the pre-gelatinized and the 50% blend of pre-gelatinized and germinated maize flours respectively. The pasting properties: peak viscosity, trough viscosity, breakdown viscosity, final viscosity, set back viscosity, peak time and pasting temperature ranged from 6.42 to 87.67 RVU, 2.59 to 81.33 RVU, 0.75 to 7.00 RVU, 6.00 to 257.00 RVU, 3.42 to 175.75 RVU, 3.64 to 7.00 min and 48.98 to 50.43°C respectively. Germination significantly ($P \leq 0.05$) decreased the viscosity and pasting properties (peak viscosity, trough, breakdown, final viscosity, setback and peak time) of the flour. The improved proximate and pasting properties of the germinated and pre-gelatinized maize flours makes for a good base ingredient for the formulation of infant complementary food.

Keywords: Maize flour, germination, pre-gelatinization, proximate composition, viscosity, pasting properties.

INTRODUCTION

Pre-processing applications on cereal grains yield much of favourable responses via: improved flavours, nutrient bio-availability, extended shelf-life, reduction of anti-nutrients and rheological characteristics too. A list of these pre-processing applications includes soaking, germination, pre-gelatinization and many more (Kayode *et al*., 2012; Amoin *et al*., 2015). Germination is an inexpensive and effective technology for improving availability of nutritionally valuable substances such as antioxidants, minerals, vitamins, and dietary fibres and diminishing the anti-nutritional factors in cereals and legumes (Kaukovirta-Norja *et al*., 1998; Daramola *et al*., 2008; Sodipo and Fashakin, 2011). Germination provides non-conventional legume flours with higher nutritional quality and better physicochemical properties than the raw flours. Physicochemical properties such as oil holding, water holding, water absorption and gelation capacities have been improved and emulsifying and foaming capacities were decreased by germination as reported by Benitez *et al*. (2013).

Pre-gelatinization 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 cereals such as rice (Lai 2001), maize (Loisel *et al*., 2006; Lagarrigue *et al*., 2008) and millet (Adebowale *et al*., 2005). This physical modification of cereal starches, through pre-gelatinization, is usually accompanied by such changes as granule swelling, loss of crystallinity, disruption of starch granule structure, among others (Lai, 2001). Unmodified starches have limited usage due to its inherent weakness of hydrations, swelling and structural organization. Utilization of native starch is limited due to its weak-bodies, cohesive, rubbery paste and undesirable gels when cooked (Sriroth *et al*., 2002). To enhance viscosity, texture, stability, among many desired functional properties for many food and industrial applications, starch and their derivatives are modified by chemical, physical, and biotechnological means. However, there is increasing awareness on the danger of chemically modified starches in food components (Jaspreet *et al*., 2007) and this has led to physical modification processes such as pre-gelatinization (Ikegwu *et al*., 2011).

Complementary foods are formulated food mixtures meant to be fed along with breast milk for infants from 6 months until completely weaned off breast milk (FAO/WHO, 2002). In Nigeria as in most other developing countries, infant complementary food consisting mainly of un-supplemented cereal pap made from maize, sorghum and or millet are grossly inadequate in some macro-and micronutrients (Nnam, 2000). The complementary foods are often of low nutritional quality and given in insufficient amounts. When introduced too early or too frequently, they displace breast milk as the main sources of nutrition in infants (Villapando, 2000; WHO, 2003, Dolan *et al*., 2015). Globally, 161 million under-five year olds were estimated to be chronically malnourished or stunted in 2013 while roughly 33% of these children reside in Africa (Krasevec *et al*., 2014). The World Health Organization (WHO) recommends the use of local staples for complementary feeding, as these are most likely to be available, easy to prepare from family foods, and more affordable (WHO, 2000). However, most staple-based complementary foods in developing countries are starchy (Gibson and Hotz, 2000). Starchy foods form a highly viscous porridge on cooking and this necessitates dilution with large volumes of water for effective infant feeding (Svanberg, 1988). The over-dilution, leads to a watery, reduced energy and nutrient food, which is generally referred to as nutrient thinning (Temesgen, 2013). Nutrient thinning is one of the major causes of poor growth during the weaning period (Ljungqvist *et al*., 1981). The complementary feeding is a critical period for the child's growth. Information on the effect of germination and pre-gelatinization in the preparation of sufficiently fluid porridge with high concentrations of dry matter and energy while reducing the quantity of water is required. Hence, this study is aimed at the determination of the effect of germination and pre-gelatinization on the proximate composition and pasting properties of maize flour for use as a base in the formulation of cereal-based infant complementary food.

MATERIALS AND METHODS

Maize samples

The yellow variety of maize (*Zea mays*) used in this study was purchased from mile 3 market in Port Harcourt, Rivers State.

Preparation of the maize flours and the flour blend for analysis

The steps in the preparation of the raw, germinated and pre-gelatinized maize flours are shown in Figure 1. The method reported by Edema *et al*. (2005) with some modifications was used in producing the untreated maize flour. Briefly, the maize grains were sorted by removing insect-infested and broken grains, husks, stones, sticks, leaves and soil. The sorted grains were washed with clean tap water, oven dried (Gallenkamp, UK) at 70°C (overnight), milled into powder and then sieved with 0.2 mm sieve size to obtain the raw maize flour. The flour was stored in a well labelled transparent plastic container at room temperature until required for use.

For the germinated maize flour, the grains of maize were germinated as described by Traoré *et al*. (2004). The sorted and cleaned grains were soaked in distilled water at room temperature overnight and then spread out on a humidified thick towel for 3 days. Germinated grains were washed, oven dried (Gallenkamp, UK) at 70°C overnight to arrest germination, milled and sieved with 0.2 mm sieve size. The flour from the germinated grain was stored in a well-labelled transparent plastic container.

For the pre-gelatinized maize flour, the maize grain was pre-gelatinized by a modification of the methods described by Pomeranz (1985). The sorted and washed grains were heated at 100°C for 2 h, oven dried in hot air oven (Gallenkamp, UK) overnight at 70°C overnight, milled, sieved with 0.2 mm sieve, and stored in a well-labeled transparent plastic container. The prepared flour used for analysis was 100% of each of the flours: maize, germinated and pre-gelatinized and a blend of 50% of the pre-gelatinized and the germinated flour.

Proximate analysis of the germinated and pre-gelatinized maize flour samples

Proximate analysis was carried out on all the samples

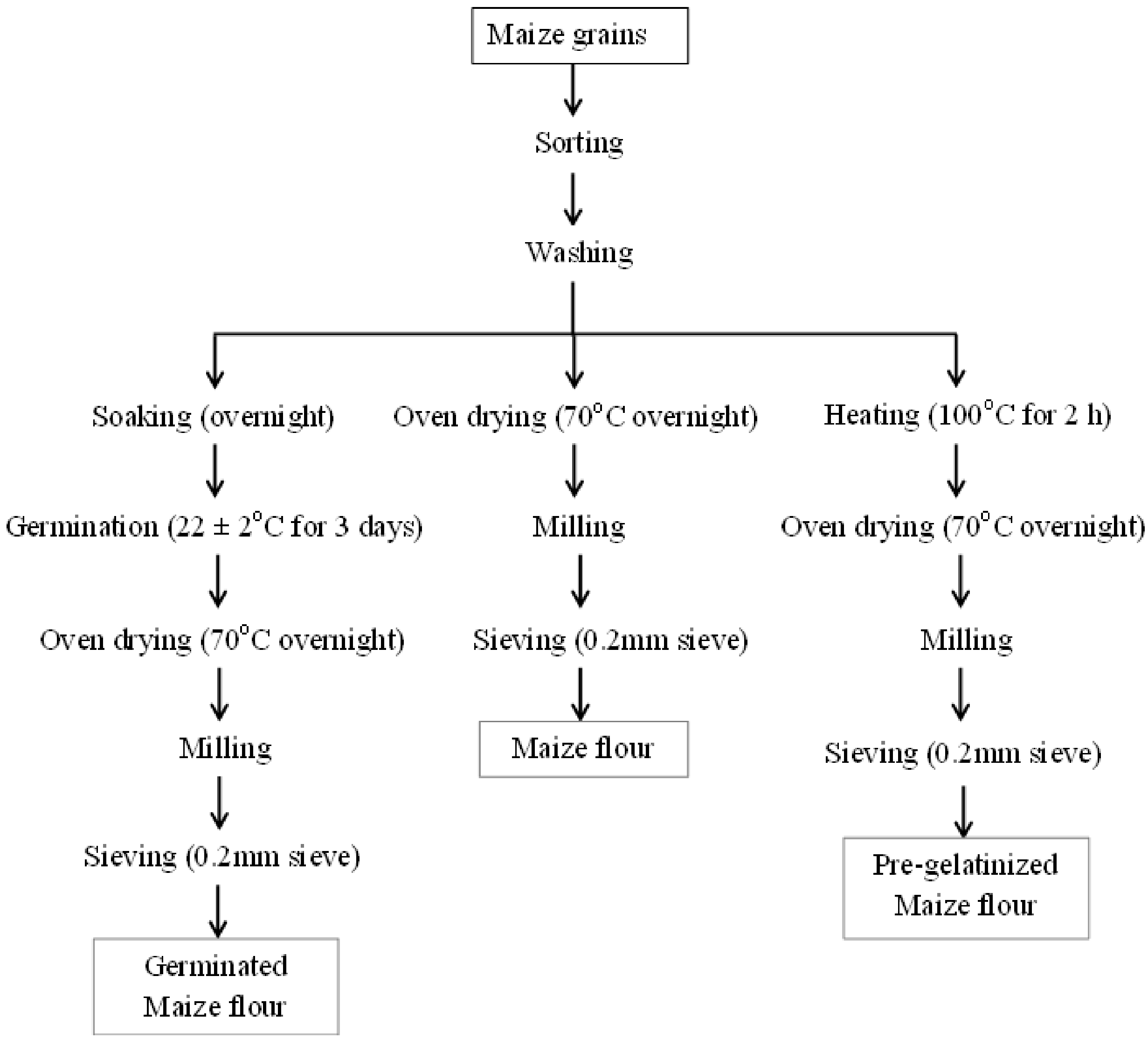

Figure 1. Flow chart for the production of the maize, germinated, pre-gelatinized maize flours.

using Standard AOAC methods (AOAC 2012). The moisture content was determined using a moisture analyzer (ANDML-50, A&D Company Ltd.) at 130°C. One gram of sample was weighed onto the moisture analyzer and after about 5 to 8 min, the result was shown on the screen in percentage. Determination of protein was by Kjeldahl method. The efficiency of the nitrogen values was corrected with acetanilide values and multiplied by the factor of 6.25 to obtain the protein value. Lipid was estimated by exhaustive extraction of known weight of samples with petroleum ether using rapid Soxhlet extraction apparatus (Gerhardt Soxtherm SE-416, Germany). Ash was determined gravimetrically after incineration in a muffle furnace (Carbolite AAF-11/18, UK) for 24 h at 550°C. Crude fibre was obtained by difference after the incineration of the ash-less filter paper containing the insoluble materials from the hydrolysis and washing of moisture free defatted sample (0.5 g). Carbohydrate content was determined by the difference: 100% - (% MC + % Ash + % Crude protein + % Fat + % Crude fibre). Energy (Kcal/g) was calculated using the Atwater factor of 4.0 Kcal/g for protein and carbohydrate and 9 Kcal/g for fat.

Determination of viscosity of germinated and pre-gelatinized maize flour samples

Viscosity of the samples was determined using a Torsion Gallenhamp Viscometer (Ndj-8S, China). Briefly, about 20 g of the sample were weighed into beaker and 180 ml of distilled water added. A lump free gel was formed by gentle heating for 8 to 10 min with continues stirring on a heating mantle. After cooling, the sample was placed in the measuring cup of the viscometer and then the measuring arm was lowered into the cup. Measurement

Table 1. Proximate compositions of raw, germinated, pre-gelatinized and a blend of the germinated and pre-gelatinized maize flours.

Sample	Moisture (%)	Ash (%)	Fat (%)	Protein (%)	Crude Fibre (%)	CHO (%)	Energy (Kcal/100g)
MF	10.00±0.14[a]	1.17±0.11[a]	6.71±0.91[a]	8.79±0.00[c]	2.22 ±0.04[c]	71.10±0.90[a]	379.99±3.77[a]
GMF	9.25±0.35[b]	1.07±0.04[a]	4.73±0.53[b]	9.37±0.31[b]	2.51±0.03[b]	70.77±0.98[a]	372.33±0.99[b]
PMF	10.45±0.07[a]	1.05±0.00[a]	4.83±0.14[b]	10.29±0.15[a]	3.12±0.04[a]	70.27±0.11[a]	365.67±0.70[c]
GPMF	10.15±0.21[a]	1.04±0.07[a]	5.15±0.05[b]	10.62±0.30[a]	3.11± 0.01[a]	69.93±0.49[b]	368.55±0.73[bc]
LSD	0.60	0.15	0.94	0.53	0.08	1.06	4.01

Values are mean ± standard deviation of duplicate samples. Means with different superscript within the same column differ significantly (P ≤ 0.05). MF - 100% raw maize flour; GMF - 100% germinated maize flour; PMF - 100% pre-gelatinized maize flour; GPMF - 50% germinated and 50% pre-gelatinized maize flour.

was taken following some minutes of spindle rotation (spindle 4 and speed 0.3).

Determination of pasting properties of the germinated and pre-gelatinized maize flour samples

Pasting properties of the flour blends were characterized using the Rapid Visco Analyzer (RVA Model 3c, Newport Scientific PTY Ltd, Sydney) as described by Pomeranz (1985). Briefly, 5±0.01g of sample was weighed into a weighing vessel; 25 ml of distilled water was dispersed into a new test canister. Samples were transferred onto the water surface of the canister after which the paddle was placed into the canister. The blade was vigorously joggled up and down through the sample ten times or more until no flour lumps remained either on the water surface or the paddle. The paddle was properly centred into the canister and the measurement cycle initiated. Peak viscosity (RVA), peak time (min), peak temperature (°C), trough (RVU), pasting temperature (°C) and final viscosity (RVU), breakdown and setback viscosities (RVU) were read on the instrument. The RVA pasting curve was automatically plotted. The viscosities, temperature and time were expressed in Centipoise (cP), degree Celsius (°C) and minutes respectively.

Statistical analysis

The data obtained were analysed statistically with Microsoft excel using one-way analysis of variance (ANOVA). Means were separated by calculating the least significant difference (LSD) at (P ≤ 0.05).

RESULTS AND DISCUSSION

Proximate composition of the germinated and pre-gelatinized maize flour samples

The proximate compositions of raw, germinated, pre-gelatinized and the blend of the germinated and pre-gelatinized maize flours are presented in Table 1.

The moisture content of the flours ranged from 9.25 to 10.45%. There was no significant difference (P ≤ 0.05) in moisture among the samples except for the flour from the germinated maize that had significantly (P ≤ 0.05) the least moisture content. This is in agreement with the report of Afify *et al*. (2012) and Offiah *et al*. (2017) that germination resulted in the decrease in moisture content sorghum and maize flour. There was no significant difference in the moisture content of the pre-gelatinized and the raw maize flour. This is at variance with the report by Piyaporn *et al*. (2016) where pre-gelatinization led to increase in moisture content of native mung bean flour, although maize is a cereal while mung bean is a legume. Moisture content in food sample is an index of stability and determines the appearance, keeping quality and yield of product (Ejoh *et al*., 2006). The low moisture content of the maize flours is desirable as it is whining the acceptable limits for flours (10 to 14%) (Posner, 2011) and low moisture indicates higher dry solids content, inactivates enzymatic activities and controls microbial activities.

Ash is a measure of the inorganic component present in the flour. The ash content ranged from 1.04 to 1.17%. This result is similar to other findings (Adeyeye *et al*., 1992; Kavitha and Parimalavali, 2014). There was no significant (P ≤ 0.05) difference in the ash content of the flours. This is an indication that germination and pre-gelatinization had no significant (P ≤ 0.05) effect on the ash content of maize flours.

Fat content of the maize flours ranged between 4.73 and 6.71% for the germinated and the raw maize flour respectively. Germination resulted in a significant (P ≤ 0.05) decrease in the fat content of the maize flours. The observed decrease in the fat content of the germinated seed might be due to the increased activities of the lipolytic enzymes during germination. They hydrolyze fats to simpler products, which can be used as source of energy for the developing embryo (Anisa and Anju, 2016). Similar observation was made for bambara groundnuts (Elegbede, 1998) and malted millet (Inyang and Zakari, 2008). The crude fat content is less than 10g/100g recommended by WHO (2000) for complementary weaning foods. Fat provides the infant with energy, essential fatty acids and fat-soluble vitamins

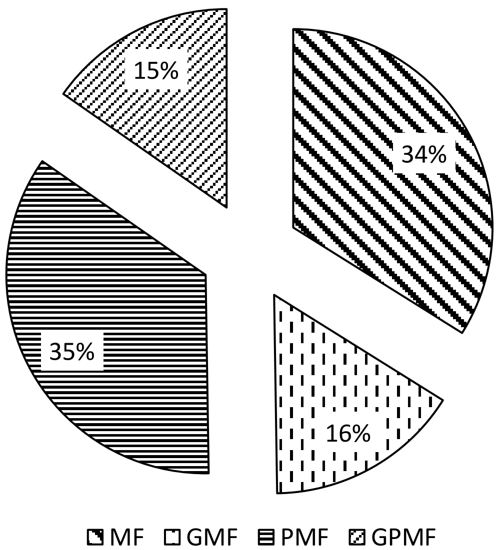

Figure 2. Percentages of the viscosities (Pa.s) of the Maize flours. MF - Raw maize flour; GMF - Germinated maize flour; PMF - Pre-gelatinized maize flour; GPMF - 50% Germinated and 50% Pre-gelatinized maize flour.

A, D, E and K. It also heightens the palatability of the food. In infant mixed diet, fat does not increase the viscosity of the food hence can be used to increase the energy density of the food without resulting in over thick food. During the complementary feeding period, it is required that a child's diet should derive 30 to 40% of energy from fat. The fat content of the maize flour contributed, 16, 11, 12 and 13% of the respective energy content for the raw maize flour, germinated maize flour, pre-gelatinized maize flour and the blend respectively.

Protein content of the maize flours ranged from 8.79 to 10.62%. The protein content of the blend of 50% pre-gelatinized and 50% germinated maize flour was significantly ($P \leq 0.05$) the highest and it did not differ significantly ($P \leq 0.05$) from the pre-gelatinized maize flour. The raw maize flour had significantly ($P \leq 0.05$) the least protein content. The increase in protein could be attributed to a net synthesis of enzymatic protein by germinating seeds (WHO, 1998) and mobilization of storage nitrogen producing the nutritionally high quality protein which the young plant needs for its development (Tsaio *et al*., 1975). Some studies have also observed increase in protein during germination and pre-gelatinization. Anisa and Anju (2016) reported increased in the protein content of germinated maize flour (11.83%) as compared to the raw flour (9.96%). Nzeribe and Nwasike (1995) also reported increase in protein during germination of acha (*Digitaria exilis*). The recommended nutrient intake for protein per day for infants 10 - 12 months is 14.9 g (WHO, 2000). The protein content of the maize flours will meet 59 to 71% of the daily protein requirement. Considering the fact that other protein sources such as milk, fish, crayfish etc, are added to infant complementary food, the use of these flours in the formulation of infant complementary food will not pose any malnutrition challenge.

The crude fibre content of pre-gelatinized maize flour (3.12%) was significantly ($P \leq 0.05$) the highest while the untreated maize flour had significantly ($P \leq 0.05$) the least crude fibre content of 2.22%. Germination and pre-gelatinization therefore resulted in an increase in the crude fibre content of the maize flours. This is similar to the finding of Anisa and Anju (2016) and is in agreement with the range recommended for infant weaning food as reported by Mosha *et al.,* (2000). According to the Codex Alimentarius guidelines, dietary fibre and other non-absorbable carbohydrate are partially fermented by the intestinal flora to short chain fatty acids, lactate and ethanol which may be subsequently absorbed and metabolized; and he required content for formulated complementary food should not exceed 5 g /100 g on dry weight basis (FAO/WHO, 2013). The levels of the fibre in the maize flours are in compliance with this guideline.

Carbohydrate content ranged from 71.10 to 69.93%. There was no significant difference ($P \leq 0.05$) among the samples except for the germinated maize flour that had significantly ($P \leq 0.05$) the least carbohydrate content. The decrease might be due to increase in alpha-amylase activity (Lasekan, 1996). Alpha amylase breaks down complex carbohydrates to simpler and more absorbable sugars which are utilized by the young seedlings during the early stages of germination. Inyang and Zakari (2008) reported similar decrease in the carbohydrate content of germinated pearl millet.

Energy content of the maize flours ranged from 365.67 to 379.99 Kcal/100 g with the content of the untreated maize flour significantly ($P \leq 0.05$) the highest. Energy content decreased significantly ($P \leq 0.05$) with germination and pre-gelatinization. Similar result was reported by Offiah *et al*. (2017) who found an increase in energy level of maize flour on malting and attributed it to the increase in protein and fat contents. The energy content of 100 g of the maize flours will meet more than 39% of the WHO (2000) recommended energy intake of 920 Kcal/day for infants of 10-12 months old.

Viscosities of the germinated and pre-gelatinized maize flour samples

The viscosity of the raw, germinated, pre-gelatinized and the blend of the germinated and pre-gelatinized maize fours were 492.30 ± 14.28, 230.05 ± 13.93, 507.40 ± 3.11 and 222.00 ± 2.83 Pa.s respectively. The percentage of these values is shown in Figure 2.

The pre-gelatinized maize flour had significantly ($P \leq 0.05$) the highest viscosity of 507.40 Pa.s, while the blend of 50% pre-gelatinized and 50% germinated maize flour

Table 2. Pasting properties of the germinated and pre-gelatinized maize flour samples.

Sample	Peak viscosity (RVU)	Trough viscosity (RVU)	Breakdown viscosity (RVU)	Final viscosity (RVU)	Set back viscosity (RVU)	Peak time viscosity (Min)	Pasting temperature (°C)
MF	87.67± 8.72[a]	81.33±9.19[a]	6.34±0.47[a]	257.09±21.80[a]	175.75±12.61[a]	7.00±6.00[a]	48.98±0.11[a]
GMF	6.42± 0.12[c]	2.59±0.04[c]	3.84±0.23[b]	6.00±0.11[c]	3.42±0.23[c]	3.64±0.05[c]	49.78±0.88[a]
PMF	47.83±0.71[b]	40.84±0.83[b]	7.00±0.11[a]	98.00±1.59[b]	57.96±0.76[b]	7.00±0.00[a]	50.43±0.11[a]
GPMF	16.30±0.53[b]	5.55±0.53[c]	0.75±0.00[c]	12.88±0.29[c]	7.34± 0.23[c]	4.57±0.05[b]	49.78±1.10[a]
LSD	10.81	11.34	0.61	26.48	15.17	0.07	1.90

Values are mean ± standard deviation of duplicate samples. Means with different superscript within the same column differ significantly (p<0.05)
MF - 100% raw maize flour
GMF - 100% germinated maize flour
PMF - 100% pre-gelatinized maize flour
GPMF - 50% Germinated and 50% pre-gelatinized maize flour

had significantly (P ≤ 0.05) the least viscosity of 222.00 Pa.s. Pre-gelatinization changes the elasticity of the flour and this is in line with findings of Fatemeh *et al*. (2016) who observed an increase in the viscosity of pre-gelatinized wheat flour batter. Malting/germination tend to cause a decrease in the viscosity due to an increase in amylolytic activity. The blends had a lower viscosity due to the presence of the germinated maize flour sample. Gimbi *et al*. (1997) and Sajilata *et al*. (2002) stated that adding germinated flour to weaning cereal or root flour reduces bulk and viscosity with increase nutrient density. Therefore, reduced viscosity is a good indicator for the appropriateness of a weaning food blend for infants.

Pasting properties of the maize flours

Table 2 shows the pasting properties of raw, germinated and pre-gelatinized maize flours. The pasting properties significantly (P ≤ 0.05) varied. The raw maize flour exhibited significantly (P≤0.05) the highest pasting properties (peak viscosity, trough, breakdown, final viscosity, setback and peak time). Germination and pre-gelatinization significantly (P ≤ 0.05) decreased the pasting properties of the maize flour.

Peak viscosity of the maize flour ranged from 6.42 to 87.67 RVU. There was a significant (P ≤ 0.05) decrease in the peak viscosities of the treated maize flour with that of the germinated maize flour significantly (P ≤ 0.05) the least. The peak viscosity (RVU) and the viscosity of the maize flour as determined using the Viscometer had a similar trend. The decrease in the peak viscosity of germinated and pre-gelatinized maize could be attributed to structural changes in the starch granules at germination and heat process during pre-gelatinization. The natural unmodified starch of the raw maize flour may have allowed more water absorption and granular starch extension leading to increase in viscosity. Viscosity is an important constraining factor in weaning foods, low peak viscosity is desirable in infant complementary food formulation for low gel strength and elasticity as high peak viscosity is an indication of high starch content (Osungbaro, 1990). Peak viscosity is also related to the water-binding capacity of the starch granules and the frailty of swollen granules (Obinna-Echem, 2017). It is often correlated with the final product quality. Decrease on the pasting properties of maize and millet flours due to germination has also been reported by Temesgen (2013). Piyaporn *et al.* (2016) reported a decrease in the pasting properties of native mung bean flour as affected by pre-gelatinization.

The trough varied between 2.59 RVU for the germinated maize flour and 81.33 for the raw maize flour. Trough viscosity is the minimum viscosity value in the constant temperature phase of the RVA profile and measures the ability of the paste to withstand breakdown during cooling. This could explain why the breakdown (≥6.34 RVU) of the raw and pre-gelatinized maize flours were significantly (P≤0.05) the highest while the breakdown (0.75 RVU) of blend of the pre-gelatinized and the germinated was significantly (P≤0.05) the least. This implies a positive correlation between the Trough and the breakdown. The decrease in the breakdown of the germinated maize flour could also be attributed to the sensitivity of the modified starch to shear. The mechanical agitation from the paddle generates shear force greater than that of the granules in starch/water system, thereby causing the swollen granules to loss integrity and rupture followed by decrease in viscosity (Alamri *et al*., 2013).

Final viscosity of the maize flours varied from 6.00 to 257.09 RVU for the raw maize and the pre-gelatinized maize flour respectively. There was no significant (P ≤ 0.05) between the germinated maize flour and its blend with the pre-gelatinized maize flour. The decrease in the final viscosity of the flour blend could be from the addition of the germinated maize flour. The process of cereal malting normally releases certain enzymes such as α-amylase which is capable of digesting amylose and amylopectin to dextrins and maltose. These low molecular weight carbohydrates contribute to less water-binding capacity, reduced viscosity, and may be more easily digested and absorbed as required by infants (Alvina *et al*., 1990). Final viscosity also marks the ability of the material to form gel after cooking and cooling, the raw and the pre-gelatinized maize flours could be said to be more stable than the germinated maize flour.

The setback viscosity of the samples differed significantly (P ≤ 0.05). The raw maize flour had significantly (P ≤ 0.05) the highest setback of 175.75 RVU and the germinated maize flour had the least setback of 3.42 RVU. Setback is related to the viscosity on cooling. On cooling, the viscosity of the raw maize and the pre-gelatinized maize flour was greater than the peak viscosity while the reverse was the case for the germinated maize flour and its blend with the pre-gelatinized maize flour. The lower setback values of germinated maize flour indicate its lowest rate of retrogradation and this will be useful in the prolonged shelf life of the flour.

Peak time viscosity of the maize flours ranged from 3.64 to 7.00 min. The peak time of the raw and the pre-gelatinized maize (7.00 min) did not differ significantly (P≤0.05) while a significant (P≤0.05) decrease was observed in the germinated maize flour (3.64 min) and its blend (4.57 min). Pasting temperature is an indication of the minimum temperature required to cook the sample. The pasting temperature of the maize flours ranged from 48.98 - 50.43°C. This temperature is below that of boiling water (100°C) and implies that the addition of warm water to processed maize flour can yield a cooked gelatinized gruel for consumption. There was no significant (P ≤ 0.05) difference in the pasting temperature of the maize flours indicating their ability to form gel at same temperature range, but the variation in the peak time implies that even at the same temperature, the germinated maize flour and the blend will gelatinize faster that the raw and pre-gelatinized maize flour.

The low viscosity of the germinated and the pre-gelatinized maize flour and the addition of germinated flour to weaning cereal or root flour however, would be desirable for infant complementary food for a nutrient-dense product without dilutions with excess water. Therefore, the reduced viscosity is a good indicator for the appropriateness of a weaning food blend for infants.

CONCLUSION

The study revealed that germination and pre-gelatinization improved the moisture, fat, protein, carbohydrate and energy content of the maize flours and that of their blends. Germination resulted in the decrease of the viscosity and pasting properties (peak viscosity, trough, breakdown, final viscosity, setback and peak time) of the flour. Reduced viscosity is desirable for an easily digestible and absorbable nutrient-dense food without dilutions with excess water as required by infants. Based on the improved proximate and pasting properties of the germinated and pre-gelatinized maize flours they can be as good base ingredients for the formulation of infant complementary food.

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