

Full Length Research Paper

Effects of germination time on the functional properties of maize flour and the degree of gelatinization of its cookies

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Flour was produced from germinated and ungerminated maize grains, and cookies were subsequently produced from the flours. Functional properties of the flours and degree of gelatinization of the cookies were determined. The pH decreased significantly ($p \leq 0.05$) as the germination time increased. pH values ranged between 5.67 and 6.56. Bulk density (loosed and packed) showed no significant difference ($p \leq 0.05$) between ungerminated sample and sample that germinated for 24 h, but there was a significant difference ($p \leq 0.05$) between ungerminated sample and samples that germinated for 48 and 72 h. The values ranged between 0.50-0.58 and 0.70-0.79 g/mL for loose and packed density, respectively. There was a significant difference ($p \leq 0.05$) among the samples in water absorption capacity and oil absorption capacity with the ungerminated sample having the least values of 0.94 and 1.03 ml/g for water absorption capacity and oil absorption capacity, respectively. There was a significant difference ($p \leq 0.05$) in swelling power of the samples with the ungerminated maize having the highest value of 19.81 mg/g. There was a significant difference ($p \leq 0.05$) in the forming capacity with the sample that germinated for 48 h having the least value. There was a significant difference ($p \leq 0.05$) in the forming capacity with the sample that germinated for 48 h having the least value. There was no significant difference ($p \leq 0.05$) between the ungerminated flour and the sample that germinated for 48 h and foaming stability time of 15, 30 and 60 s. Degree of gelatinization of the samples ranged between 74.50-93.10, 86.20-97.40 and 30.00-84.30 at baking temperature of 140, 160 and 180°C, respectively.

Key words: Germination, gelatinization, functional properties, maize flour.

INTRODUCTION

Maize (*Zea mays* L.), the American Indian word for corn literally means "that which sustains life". It is the third most important cereal grain of the world after wheat and rice providing nutrients for humans and animals and serving as a basic raw material for the production of starch, oil and protein, alcoholic beverages, food sweeteners and more recently, fuel (FAO, 1992). These three most important cereals have been reported to

comprise at least 75% of the world's grain production and therefore, humanity has become dependent upon cereal grains for the majority of its food supply (Imtiaz et al., 2011).

Starch is the major constituent of cereal endosperms and an important structural component in many food products made from their flours (Sasaki, 2005). Corn starch is a valuable ingredient in the food industry, being

widely used as a thickener, gelling agent, bulking agent and water retention agent (Singh et al., 2003). Corn starch granule has a polyhedral shape and diameter between 5 and 25 μm (Ribout, 2002). On the basis of amylose and amylopectin ratio, corn can be separated into normal, waxy and high amylose (Singh et al., 2005). In addition, sugary type corn with high sugar content also exists (Singh et al., 2005). Normal starch consists of about 75 wt% branched amylopectin and about 25 wt% amylose, that is linear or slightly branched.

The effective use, attributes and consequent acceptance of cereal flours by consumers are dependent on its functional properties and the degree of starch gelatinization (Miah et al., 2001; Brou et al., 2013), Mantzari (2010) reported that due to its complexity, corn starch exhibits certain unique properties (which are not encountered in other polysaccharides) which are correlated with its physicochemical and functional properties: temperature and enthalpy, gelatinization, pasting characteristics, enzymatic susceptibility, swelling and solubility (Rubi, 2009).

Several works have been done on germination as an alternative to genetic engineering in improving the nutritive values (such as amino acids, vitamins, minerals etc.), functional (temperature and enthalpy, gelatinization, pasting characteristics, swelling, and solubility) and chemical (pH, amylose, total starch etc.) properties of maize, particularly in the developing countries (Oluwamukomi et al., 2003; Obasi et al., 2009; Eneche, 2009; Gernah et al., 2011). Typically, chemical modification could be adopted to extend the range of specific physical properties available for different uses (Nur and Purwiyatno, 2010), however, the use of chemicals are not encouraged due to their side effects, besides, these chemicals are not readily available to vast population of the developing nations who rely mostly on these cereals. FAO/WHO (1985) stated the guidelines of an ideal weaning food to be nutrient dense, easily digestible, of suitable consistency and affordable.

This study was therefore undertaken to investigate the effects of germination time on some functional properties of maize starch and the degree of gelatinization of its cookies.

MATERIALS AND METHODS

Source of material

White maize grains (TZW, 2008 harvest) were purchased from Minna Central Market, Minna and were identified at the Department of Crop Production, Federal University of Technology, Minna, Niger State, Nigeria. These were utilized for research work between June, 2009 and January, 2010.

Cleaning

The maize grains were manually cleaned to remove husks, stone, cob, damaged and coloured seeds. These were achieved through

Table 1. Cookie recipe.

Parameter	Measurement
Maize flour	100 g
Baking fat	50 g
Baking powder	5 g
Sugar	45 g
Egg (raw)	2
Powdered milk	30 g

Source: Asumugha and Uwalaka (2000) with little modification.

winning, sieving and hand picking. Subsequently, the seeds were packaged in a 10 L plastic bucket, hermetically covered and stored in a refrigerator at $10\pm 2^\circ\text{C}$ from where samples were taken for processing and analyses.

Germination

Germination was carried out according to the method described by Ariahu et al. (1999). The seeds were washed in 5% (w/v) sodium chloride solution to suppress mould growth and soaked in tap water in ratio of 1:3 (w/v) grain for 12 h at room temperature ($32\pm 2^\circ\text{C}$), the water drained at 4 h interval after which the seed were drained and divided into four equal portions and labeled A, B, C and D, spread separately on a clean jute bag, covered with damp cotton and were allowed to germinate for 0, 24, 48 and 72 h, respectively. Water was sprinkled at 12 h interval to facilitate the germination process. At the end of germination, root hairs were removed from the germinated seeds.

Production of germinated flour

The seeds were dried at 60°C in an oven to a moisture content of 10% and ground into flour using attrition mill (globe p44 Chima). Each flour sample was passed through a 0.5 mm mesh size sieve. They were packaged in an air tight polyethylene bags, stored in plastic containers with lids and then stored in cool dry place from where samples were taken for analyses.

Production of cookies

Cookies were prepared from the flour samples using the cream-in method as described by Asumugha and Uwalaka, (2000) with little modification. Table 1 shows the cookie recipe. Fat and sugar were mixed until fluffy. Whole eggs and powdered milk were added while mixing (HR-2815 Philips Model Mixer) and then mixed for a total of about 30 min. Flour and baking powder were mixed thoroughly and added to the cream mixture and were kneaded to form dough. The dough were rolled and cut into shapes of 5 cm diameter. Baking was carried out at 140, 160 and 180°C for 25 min. Cookies were cooled and stored till when needed.

Sample analysis

Functional properties

Loosed and packed bulk densities of the flour samples were determined using the method described by Wang and Kinsella (1976), water absorption capacity (WAC) and oil absorption capacity

Table 2. Functional properties of maize flour samples.

Parameter	Germination time			
	0 h	24 h	48 h	72 h
pH	6.56±0.01 ^a	6.20±0.02 ^b	6.28±0.04 ^b	5.67±0.02 ^c
LBD (g/mL)	0.58±0.03 ^a	0.57±0.02 ^a	0.55±0.00 ^b	0.50±0.00 ^c
PBD (g/mL)	0.79±0.00 ^a	0.76±0.00 ^b	0.75±0.00 ^b	0.70±0.00 ^c
WAC (ml/g)	0.94±0.00 ^d	2.65±0.00 ^c	2.73±0.03 ^b	2.79±0.00 ^a
OAC (mg/g)	1.03±0.00 ^c	2.45±0.05 ^b	2.52±0.01 ^b	2.57±0.00 ^a
EC (%)	47.22±0.00 ^c	58.62±0.02 ^b	60.00±0.00 ^b	65.52±0.00 ^a
SP (mg/g)	19.81±0.00 ^a	19.10±0.02 ^b	18.80±0.00 ^c	15.00±0.00 ^d
FC (%)	3.10±0.00 ^c	2.50±0.02 ^b	2.00±0.00 ^c	2.50±0.00 ^b

Values are means and standard deviations of triplicate scores. Values followed by different superscript in row are significantly different ($p \leq 0.05$) from one another. LBD, Loose bulk density; PBD, packed bulk density; WAC, water absorption capacity; OAC, oil absorption capacity; EC, emulsion capacity; ES, emulsion stability; SP, swelling power; GPC, gelation power capacity; FC, foaming capacity.

(OAC) were determined by methods described by Sasulki et al. (1996), emulsion capacity and stability were determined using the method described by Yasumatsu et al. (1992), foaming capacity was determined according to the method described by Narayana and Narsinga (1992), swelling power was determined by Akpada and Miachi (2001) method and pH was determined using AOAC (2000) method.

Determination of degree of starch gelatinization

Determination of degree of starch gelatinization of cookies was determined by the method described by Marshall et al. (1993). 2 g of the sample was macerated with 100 ml distilled water in a warming blender (HR-2815 Philips model). The suspension was centrifuged at 500 rpm for 10 min and duplicate aliquots (1 ml) were diluted with water to 10 ml and treated with 0.1 ml iodine solution. The absorbance of the sample were read at 600 nm with spectrophotometer (model 2903, perkin- Elmer co. Ltd.), against a reagent blank. A further suspension of the product (2 g) was prepared in 95 ml of distilled water (instead of 100 ml distilled water) as described earlier. To this suspension, 5 ml of 10 M aqueous solution of potassium hydroxide was added and mixture was allowed to stand for 5 min with gentle agitation. The alkaline suspension was centrifuged and 1 ml of duplicate aliquots was treated with 1 ml of 0.5 M hydrochloric acid and diluted with water to iodine solution (0.1 ml) and their absorbance was measured as described earlier. The degree of starch gelatinization was calculated as:

$$\frac{A_1 \times 100}{A_2} (\%)$$

Where A_1 and A_2 are absorbance of the iodine complex prepared from the aqueous suspension before and after alkali solubilization, respectively.

Statistical analysis

The data obtained were statistically analyzed by subjecting them to analysis of variance (ANOVA) using the completely randomized design (CRD) with comparison made between the group means using the Duncan's new multiple range test to separate the mean (at 5% probability level) using SPSS (statistical package for social scientists), version 16.0, Windows 2006.

RESULTS

Table 2 shows the functional properties of maize flour samples. The pH decreased significantly ($p \leq 0.05$) as the germination time increased. Maize grains that germinated for 72 h had the lowest pH value of 5.67. Bulk density (loosed and packed) showed no significant difference ($p \leq 0.05$) between ungerminated sample and sample that germinated for 24 h, but there was a significant difference ($p \leq 0.05$) between ungerminated sample and samples that germinated for 48 and 72 h. There was a significant difference ($p \leq 0.05$) among the samples in water absorption capacity with the ungerminated sample having the least value.

Oil absorption capacity varied significantly ($p \leq 0.05$) among the samples with germination done for 72 h having the highest value. Emulsion capacity of the flour samples also differ significantly ($p \leq 0.05$) with germination for 72 h having the highest value. There was a significant difference ($p \leq 0.05$) in swelling power of the samples with the ungerminated maize having the highest value. There was a significant difference ($p \leq 0.05$) in the foaming capacity with the sample that germinated for 48 h having the least value.

Table 3 shows the foaming stability of the maize flour samples. There was no significant difference ($p \leq 0.05$) between the ungerminated flour and the sample that germinated for 48 h at foaming stability time of 15, 30 and 60 s both having higher foaming stability than samples that germinated for 24 and 72 h at the same foaming stability time.

Table 4 shows the effect of germination time on the degree of gelatinization of cookies produced from the maize flour samples. At 140°C, the degree of gelatinization of the ungerminated sample was higher than those of germinated samples, although it was not significantly different ($p \leq 0.05$) from the sample that germinated for 72 h. At 160°C, there was a significant difference ($p \leq 0.05$) among the samples with the ungerminated sample having

Table 3. Foaming stability of the maize flour samples.

Germination time (h)	Foaming stability time (seconds)			
	15	30	60	120
0	50.90±0.000 ^a	41.00±0.000 ^a	25.15±0.000 ^a	15.00±0.000 ^a
24	40.10±0.028 ^b	35.00±0.028 ^b	20.15±0.000 ^b	10.00±0.000 ^b
48	50.57±0.000 ^a	42.00±0.000 ^a	25.00±0.000 ^a	9.50±0.000 ^b
72	30.50±0.000 ^c	20.10±0.028 ^c	10.00±0.000 ^c	10.00±0.000 ^b

Values are means and standard deviations of triplicate scores. Values followed by different superscript in column are significantly different ($p \leq 0.05$) from one another.

Table 4. Effect of germination time on the degree of gelatinization of the cookies.

Germination time (h)	Temperature (°C)		
	140	160	180
0	93.10±0.000 ^a	86.20±0.283 ^d	30.00±0.000 ^d
24	74.50±0.000 ^c	91.90±0.000 ^c	40.90±0.000 ^c
48	90.50±0.283 ^b	93.70±0.283 ^b	65.40±0.283 ^b
72	92.90±0.000 ^a	97.40±0.283 ^a	84.30±0.000 ^a

Values are means and standard deviations of triplicate scores. Values followed by different superscript in column are significantly different ($p \leq 0.05$) from one another.

the least value and the sample that germinated for 72 h having the highest value.

DISCUSSION

The decrease observed in pH might have been as a result of secretion of enzymes resulting in the hydrolysis of complex organic molecules such as phytin and protein into simpler and more acidic compounds such as phosphate and amino acids, respectively. Evans et al. (2003) reported a marked increase in alpha amylase and other amylases during cereal germination. Egwim and Oloyede (2004) reported 72 h as optimum sprouting time for maximum amylase activity in maize. Results obtained for loosed and packed densities were in line with earlier work of Gernah et al. (2011). The reduction in bulk density observed might have been as a result of reduction in weight of the flour owing to the breakdown of complex denser compounds inherent in maize into simpler ones during germination (Gernah et al., 2011). Germination increased water absorption capacity of the samples, this contrasted the work of Imtiaz et al. (2011) but in line with the work of Gernah et al. (2011). The increase observed might have been as a result of the production of compounds having good water holding capacity such as soluble sugars. According to Okaka and Potter (1997), water holding capacity depends on the water bounding capacities of food components. Germination increased oil absorption capacity in line with earlier work of Imtial et al. (2011). Giani and Bekebain (1992) reported that germina-

tion of grains enhances the oil absorption capacity due to the entrapment of oil related to the non polar side chains of proteins. The increase observed in emulsion capacity could be due to an increase in the area of stabilized oil droplet at interface which is a function of the food components (Imtiaz et al., 2011). Germination decreased the swelling power of the samples probably as a result of disruption of hydrogen atoms inherent in maize by amylases and proteases into sugars and amino acid respectively (Okafor, 1987; Egwim and Ademonom, 2009). The decrease observed in foaming capacity might have been as a result of denaturation of protein molecules during milling and germination processes. Brou et al. (2013) reported that native protein provide higher foam capacity than denatured protein.

Brou et al. (2013) reported increasing foaming stability with increasing protein content while characterizing complementary food made from maize, millet, beans and soybeans. They further reported higher protein stability for native proteins. The increase in foaming stability observed for sample that germinated for 48 h might have been as a result of bioavailability of inherent proteins which were probably bound by antinutritional factors such as phytin in the sample. Singh and Raghuvanshi (2012) reported that antinutritional factors in cereals bind to both exogenous and endogenous proteins including enzymes of the digestive tract affecting utilization of proteins. The reduction in stability observed for sample that germinated for 72 h could have been due to denaturation of protein (Brou et al., 2013). The ungerminated sample had a higher stability than the germinated samples at 120 s. The result

from the tables show that foaming stability of the samples decreased with time.

At 140°C, short germination period was not favourable probably due to the resistance of the amylose portion of the starch to the enthalpy produced at this temperature. The amylose content greatly influences the physicochemical properties of starch, such as gelatinization, retrogradation, and gelation (Parovuori, 1997; Czuchajowska, 1998; Fredriksson, 1998). Sasaki (2005) reported that starch with higher amylose content has more amorphous region and less crystal line, lowering gelatinization temperature. Germination increased the degree of gelatinization at 160°C probably due to the presence of adequate crystalline fractions in the starch molecules. The enthalpy of gelatinization reflects the loss of molecular order (Cooke and Gidley, 1992), and gelatinization temperature is considered a parameter of crystallite perfection (Tester and Morrison, 1990). At 180°C, the degree of gelatinization of the flour samples reduced remarkably probably due to disruption of the crystallite fractions of the samples.

Conclusion

The study indicated that germination has tremendous effects on the functional properties of maize flour samples considered, and on the degree of gelatinization of the cookies produced at various baking temperature. Germinated samples performed better in terms of water absorption capacity, oil absorption capacity and emulsion capacity. Sample that germinated for 48 h had the highest foaming capacity at time 15, 30 and 60 s. These are indications of improved nutritional value and functionality. Sample that germinated for 72 h performed best in water absorption capacity, oil absorption capacity and emulsion capacity. Germination resulted in cookies with better gelatinization at different baking temperature with sample that germinated for 72 h having the best result.

REFERENCES

- Akpada MI, Miachi OE (2001). Proximate composition and selected functional properties of *Detarium microcarpum*. *Plant Foods Hum. Nutr.* 56:297-302.
- AOAC (2000). Official methods of Analysis, Association of official Analytical chemist 17th Edition, Washington.
- Ariahu CC, Ukpabi U, Mbajunwa KO (1999). Production of African Breadfruit (*Treculia Africana*) and Soyabean (*Glycine max*) based food formulations, 1: Effects of germination and fermentation on nutritional and organoleptic quality. *Plant Foods Hum. Nutr.* 54: 123-266
- Asumugha VU, Uwalaka BC (2000). Chemical and organoleptic evaluation of snacks developed from cocoyam (*Colocasia esculenta*, *Xanthosoma mafafa*) and wheat (*Triticum spp*) composite flours. *Niger. Agric. J.* 31: 78-88.
- Brou K, N'Da-Kouassi A, Kouadio J, Guehi T, N'Guessan K, Gnakri D (2013). Biochemical Characterization and Functional Properties of Weaning Food Made from Cereals (Millet, Maize) and Legumes (Beans, Soybeans). *J. Food Chem. Nutr.* 1 (1) : 22-32.
- Cooke D, Gidley MJ (1992). Loss of crystalline and molecular order during starch gelatinization: origin of the enthalpic transition. *Carbohydr. Res.* 227:103-112.
- Czuchajowska Z (1998) Structure and functionality of barley starches. *Cereal Chem.* 75: 747-754.
- Egwim E, Adenomon M (2009). Predicting α -amylase yield and malt quality of some sprouting cereals using 2nd order polynomial model. *Afr. J. Biochem. Res.* 3(8):288-292
- Egwim E, Oloyede B (2004). Comparison of α -amylase activity in some sprouting Nigerian cereals. *Biokemistri* 18(1):15-20
- Eneche HE (2009). Rate of water absorption in maize grain during soaking. Proceedings of the AGM/Conference, Nigerian Institute of Food Science and Technology, Yola. pp. 41-42.
- Evans DE, Van Weger B, Ma YF, Eghinton J (2003). The Impact of the Thermostability of alpha-amylase, beta-amylase and limit Dextrinase on Potential work Fermentability. *J. Am. Soc. Brewing Chem.* 61: 210-218.
- FAO (1992). Maize in Human Nutrition. FAO Food and Nutrition Series, No. 25. ISBN92-5103013-8
- FAO/WHO (1985). Energy and Protein Requirements. Report of the FAO/WHO/UNU Expert Consultation Technical Series No. 724, Geneva, Switzerland World Health Organisation.
- Fredriksson H (1998). The influence of amylose and amylopectin characteristics on gelatinization and retrogradation properties of different starches. *Carbohydr. Polym.* 35: 119-134.
- Gernah DI, Ariahu CC, Ingbian EK (2011). Effects of Malting and Lactic Fermentation on Some Chemical and Functional Properties of Maize (*Zea mays*). *Am. J. Food Technol.* 6:404-412
- Giani SY, Bekeba DA (1992). Proximate composition and functional of raw and processed full fat fluted pumpkin (*Telfairia occidentalis*) seed flour. *J. Sci. Food Agric.* 3: 321-325
- Imtiaz H, BurhanUddin M, Gulzar M (2011). Evaluation of weaning foods formulated from germinated wheat and mungbean from Bangladesh. *Afr. J. Food Sci.* 5(17): 897-903.
- Mantzari G (2010). Effect of sorbitol addition on the physicochemical characteristics of starch-fatty acid systems. *Carbohydr. Polym.* 79(1):154-163
- Marshall WE, Wadsworth JI, Verma LR, Velupillai L (1993). Determining the degree of gelatinisation in parboiled rice: comparison of a subjective and objective method. *Cereal Chem.* 70: 226-230.
- Miah MAK., Haque A, Douglass MP, Clarke B (2001). Parboiling of rice. Part II: Effect of hot soaking time on the degree of starch gelatinization. *Int. J. Food Sci. Technol.* 37:539-545.
- Narayana K, Narsinga Rao MS (1992). Functional properties of raw and heat processed winged bean (*psophocarpus tetragonolobus*) flour. *J. Food Sci.* 47: 534-538.
- Nur A, Purwiyatno H (2010). Gelatinization properties of white maize starch from three varieties of corn subject to oxidized and acetylated-oxidized modification. *Int. Food Res. J.* 17: 961-968
- Obasi N, Agim EL, Uchechukwu N (2009). Effects of different soaking periods on the chemical composition of pearl millet grains (*Pennisetum glaucum*). Proceedings of the AGM/Conference, Nigerian Institute of Food Science and Technology, Yola. pp. 57-58.
- Okafor N (1987). Processing of Nigerian Indigenenous Foods: A Chance of Innovation. *Niger. Food J.* 1: 32-34.
- Okaka JC, Potter NN (1997). Functional properties of cowpea wheat flour blends in bread making. *J. Food Sci.* 42:828-833.
- Oluwamukomi MO, Eleyinmi AF, Enujingha VN, Atofarati SO (2003). Nutritional, Physicochemical and Sensory Evaluation of Sorghum and Cowpea Based Weaning Formulations. *Niger. Food J.* 21:11-17.
- Parovuori P (1997). Effects of enzymically modified amylopectin on the rheological properties of amylose-amylopectin mixed gels. *Food Hydrocoll.* 11:471-477.
- Ribout M (2002). Using AFM to image the internal structure of starch granules. *Carbohydr. Polym.* 50: 123-132
- Rubi G (2009). Blue Maize: Morphology and Starch Synthase Characterization of Starch Granule. *Plant Foods Hum. Nutr.* 64:18-24.
- Sasaki T (2005). Effect of Wheat Starch Characteristics on the Gelatinization, Retrogradation, and Gelation Properties. *JARQ* 39 (4): 253 - 260.
- Sasulki FW, Garrant MD, Slinkard AE (1996). Functional properties of fern legume flour. *Inst. Food Sci. Technol. J.* 9:66-69.
- Singh N, Sandhu KS, Kaur M (2005). Physicochemical properties including granular morphology, amylose content, swelling and solubility, thermal and pasting properties of starches from normal,

- waxy, high amylose and sugary corn. *Prog. Food Biopolym. Res.* 1: 44–54.
- Singh N, Singh J, Kaur L, Sodhi NS, Gill BS (2003). Morphological, thermal and rheological properties of starches from different botanical sources. *Food Chem.* 81:219–231.
- Singh P, Raghuvanshi RS (2012). Finger millet for food and nutritional security. *Afr. J. Food Sci.* 6(4): 77-84
- Tester RF, Morrison WR (1990). Swelling and gelatinization of cereal starches. II. Waxy rice starches. *Cereal Chem.* 67:558–563.
- Wang JC, Kinsella JE (1976). Functional properties of novel proteins Alfalfa leaf protein. *J. Food Sci.* 41:286-289.
- Yasumatsu KI, Sawada K, Moritaka S, Misaki M, Tado J, Woda T (1992) . Whipping and emulsifying properties of sorghum product. *J. Agric. Biol. Chem.* 36: 719-725