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Effect of Germination on Functional Properties and Degree of Starch Gelatinization of Sorghum Flour

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Abstract

Sorghum grains were germinated for 24, 48 and 72 hours with a view to determining the effect of germination on some functional properties and degree of starch gelatinization of the flour. Flour from non-germinated grains served as control. In order to measure the effect of germination on degree of starch gelatinization, the flours were processed into cookies. Germination of sorghum grains for 48 hours and above significantly ($p<0.05$) decreased both loose and packed bulk densities from 0.59 g/ml and 0.77 g/ml to 0.56 g/ml and 0.70 g/ml respectively. The water absorption capacity of the sample germinated for 72 hours was 1.38 g/g which was significantly ($p<0.05$) higher than the other samples. The oil absorption capacity of the samples germinated for 48 and 72 hours (1.16 and 1.18 g/g respectively) were significantly ($p<0.05$) higher than those of the control sample and 24 hour germination (1.03 and 1.04g/g respectively). Germination also significantly ($p<0.05$) increased the swelling power (22-23.2 ml/g), foaming capacity (14-16.2%) and emulsion capacity (58.6-65.5%). The degree of starch gelatinization increased with increasing germination time but decreased with increasing temperature. Generally, germination had a beneficial effect on the functional properties measured. Flour obtained from sorghum grains germinated for 72 hours had the best results.

Keywords: germination, time, sorghum, flour, functional, gelatinization

1. Introduction

1.1 Chemical Nature and Uses of Sorghum

Sorghum (*Sorghum bicolor*) is a cereal native to sub-Saharan Africa and grows well in temperate and tropical areas of the world where other staple cereals such as maize, wheat and rice cannot grow well (Onesmo, 2011). It is consumed as porridge, malted and distilled beverages in Africa and Asia. It is used for the production of syrup, animal feed and ethanol in the United States and other developed countries (Onesmo, 2011).

Like other cereals, the sorghum kernel is composed of three main anatomical parts, namely the pericarp (bran), germ and endosperm (Hoseney, 1994). The pericarp is an outer protective layer making up to 5-6% of the kernel weight. It is a rich source of dietary fiber, minerals and vitamins. The endosperm is the storage tissue and the largest part of the kernel and also a rich source of both starch and protein. The relative proportion of protein and starch in the endosperm is the most important factor affecting grain hardness and density (Onesmo, 2011). Carbohydrate, in the form of starch, is located in the endosperm and is most abundant (60-80%) in the sorghum kernel (Hoseney, 1994). Starch is the main source of energy required for germination and is made of two large molecules: amylopectin, a branched-chain of α-glucose units joined by (1-4) and (1-6) glycosidic bonds with content in sorghum starch ranging from 45-54%, and a straight-chain polymer, and amylose with α-glucose units held together by (1-4) glycosidic bonds (Ridout et al., 2002). Amylose constitutes about 10-17% of sorghum starch and is capable of forming helicoidal structure in solutions (Ridout et al., 2002).

Sorghum is a rich source of various phytochemicals, including tannins, phenolic acids, anthocyanins, phytosterols and policosanols (Awika & Rooney, 2004). The physico-chemical properties of sorghum flour are similar to those of wheat flour (Taylor et al., 2006). However, sorghum possesses low starch digestibility that has been shown to cause a higher loss of energy in humans (Onesmo, 2011). Factors affecting the digestibility of

sorghum starch include cultivars, the extent of starch-protein interaction, and the physical form of the starch granules, presence of inhibitors such as tannins, and the type of starch. Starch granules of the sorghum endosperm are embedded in a dense protein matrix with high levels of prolamin-containing protein bodies that surround starch granules thus acting as barrier to starch gelatinization and starch-protein interactions (Onesmo, 2011). These factors contribute to the lower starch digestibility of sorghum. Therefore, processing methods that expose the starch granules and protein matrix to digestion may help overcome the digestibility problem.

1.2 Importance of Germination and Objectives of Study

Germination is a processing method that enhances the nutritional and functional properties of grains as well as their digestibility (Imtiaz & Burhan-Uddin, 2012). Germination occurs when the grain is rehydrated causing an increase in metabolic activity as a result of reactivation of hitherto dormant enzymes. The metabolic activity results in the production of primary and secondary metabolites thereby improving the nutritional and functional properties of the grain (Bohoua & Yelakan, 2007; Abbas & Mushara, 2008).

Several studies have been undertaken to investigate the effect of germination on sorghum quality. Elkhalifa and Bernhardt (2010) studied the influence of grain germination on functional properties of sorghum flour; Phattanakulkaewmorie et al. (2011) investigated the effect of germination on chemical compositions, physico-chemical properties of malted (germinated) red sorghum flours and evaluated characteristics of gluten free breads from sorghum flour; Elemo et al. (2011) studied the nutritional composition of a weaning food formulated from germinated sorghum and steamed cooked cowpea. This present work was carried out to study the effect of germination time on the functional properties and degree of starch gelatinization of sorghum flour.

2. Materials and Methods

2.1 Materials

Sorghum grains (white cultivar) were purchased from Minna Central Market, Minna, Nigeria. The grains were manually cleaned to remove stones, damaged and discoloured grains and other extraneous materials. This was achieved through winnowing, sieving and hand picking. Subsequently, the grains were packaged in a 10 L plastic bucket and covered from where samples were taken for processing and analysis.

2.2 Flour Preparation

Germination was carried out according to the method described by Ocheme (2007) with some modifications. 1 kg of cleaned grains were washed with tap water and then soaked in 2.5 liters of tap water for 12 hours. The soak water was changed every four hours. At the end of soaking, the water was drained off and the grains were evenly spread on jute bags and covered with the same material in a dark, secluded area and allowed to germinate for 24, 48 and 72 hours. Water was sprinkled on the germinating grains at 24 hour intervals to prevent drying out. At the end of each germination period, the grains were dried in a hot air oven at 60 °C for 1 hour. The rootlets were removed by rubbing the grains between palms. It was then winnowed, milled, sieved with 0.25 mm mesh and packaged in high density polyethylene.

2.3 Preparation of Cookies

Cookies were prepared from the flour samples using the cream-in method as described by Asumugha and Uwalaka, (2000) with slight modifications. Table 1 shows the cookie recipe. Fat and sugar were mixed until fluffy. Whole eggs and powdered milk were added and then mixed with a mixer (HR-2815 Philips Model Mixer) for about 30 minutes. Flour and baking powder were mixed thoroughly and added to the cream mixture. These were then kneaded to form dough. The dough was rolled and cut into round 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

Table 1. Cookie recipe

Ingredient	Quantity
Sorghum flour	100 g
Baking fat	50 g
Baking powder	5 g
Sugar	45 g
Egg	2 (medium size)
Powdered milk	30 g

Source: Asumugha and Uwalaka (2000).

2.4 Functional Properties

Loose and packed bulk densities of the flour samples were determined using the method described by Wang and Kinsella (1976) while the water and oil absorption capacities were determined by methods described by Sosulki et al. (1996). The emulsion capacity was determined using the method described by Yasumatsu et al. (1972) and foaming capacity was determined according to the method described by Narayana and Narsinga (1982). The swelling power was determined by the method outlined by Akpada and Miachi (2001).

2.5 Degree of Starch Gelatinization

The degree of starch gelatinization (DSG) 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 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 absorbances of the samples were read at 600 nm with a spectrophotometer (model 2903, Prkin- 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 the 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, diluted with water to 10 ml and treated with iodine solution (0.1 ml) and the absorbance was measured as described earlier. The degree of starch gelatinization was calculated as:

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

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

2.6 Statistical Analysis

Analysis of variance (ANOVA) of the data obtained and separation of means were accomplished using SPSS (statistical package for social scientists) Version 16.0.

3. Results and Discussion

3.1 Functional Properties

The effect of germination on the functional properties of sorghum flour is presented in Table 2. Germination beyond 24 hours significantly ($p \leq 0.05$) decreased the pH of sorghum flour with values between 6.46 and 6.35. Germinating for 48 and 72 hours significantly ($p < 0.05$) reduced the loose and packed bulk densities of the flours from 0.59 g/ml to 0.56 g/ml and from 0.77 g/ml to 0.71 and 0.70 g/ml respectively. The reduction in bulk density (loose and packed) observed may be due to the breakdown of complex compounds such as starch and proteins as a result of the modification that occurred during germination. According to Wilhelm et al. (2004), the bulk density of a food material affects its mouth feel as well as the type of packaging material used in its packaging. Furthermore, foods, especially cereals, with high bulk densities are a disadvantage nutritionally. This is because a small quantity will yield very thick porridge which has very little nutrients whereas more quantities of less dense flour will be required to obtain the same thickness. Furthermore, a less dense food material will be more portable.

The water absorption capacity of the flour obtained after 72 hours germination was significantly ($p < 0.05$) higher than the others with a value of 1.38 g/g. The increase observed might have been as a result of the production of compounds having good water holding capacity such as soluble sugars. Okaka and Potter (1977) reported that water holding capacity depends on the water bounding capacities of food components. The increase in water absorption capacity as a result of germination is in agreement with the report of Gernah et al. (2011). These workers observed an increase in the water absorption capacity of maize as a result of malting. Ocheme and Chinma (2008) also reported similar results for germinated millet flour. Flours with good water absorption capacities are useful in baking.

The oil absorption capacity of the flours also increased significantly ($p < 0.05$) after 48 and 72 hours germination. Deepali et al. (2013) stated that germination-induced increased oil absorption capacity may be due to solubilization and dissociation of proteins leading to exposure of non-polar constituents from within the protein molecule. Oil binding enhances flavour and mouth feel. Furthermore, foods with good oil binding abilities can be used as meat replacers and extenders.

The swelling power of the flours increased significantly ($p<0.05$) as germination time increased. The swelling power ranged from 22 ml/g to 23.20 ml/g. Ocheme and Chinma (2008) also reported an increase in the swelling power of millet flour as a result of germination. The increase in swelling power was probably due to an increase in soluble solids brought about by the breakdown of lipid, fiber and larger amount of amylose–lipid complex in flour that could inhibit the swelling of starch granules. Fats may complex with starch and limit swelling. Phattanakulkaewmorie et al. (2011) reported that swelling power is positively related to the amount of soluble solids.

Foaming capacity varied from 14.30% to 16.20%, increasing with germination time. The non-germinated sorghum flour had the lowest foaming properties while the 72-hours germinated sorghum flour had the highest. Foam is a colloid of gas bubbles trapped in a solid or liquid. Foam formation and stability are dependent on protein type, pH, surface tension, viscosity and processing method. Eltayeb et al. (2011) reported that proteins in flours are surface active and that is why flours are able to produce foam. The trend recorded is this study is the direct opposite of the report of Adedeji et al. (2014) who reported that the foaming capacity of germinated maize flour decreased with germination time. Food materials with good foaming capacity and stability are useful in the formulation of aerated foods.

The emulsion capacity of the flours also increased significantly ($p<0.05$) with germination time from 58.6% for the control sample to 65.5% for the 72 hours sample. 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). The emulsification of food materials may be due to soluble and insoluble proteins and polysaccharides. According to Sikorski (2002) proteins promote emulsification by reducing surface tension while Dickinson (1994) stated that increased viscosity brought about by polysaccharides also improves emulsification.

Table 2. Selected functional properties of sorghum flour

Properties/Germination time	0hr	24hr	48hr	72hr
Loose bulk density (g/ml)	0.59^{a} ±0.01	0.59^{a} ±0.01	0.56^{b} ±0.03	0.56^{b} ±0.03
Packed bulk density (g/ml)	0.77^{a} ±0.02	0.77^{a} ±0.02	0.71^{b} ±0.03	0.70^{b} ±0.03
Water absorption capacity (g/g)	1.20^{b} ±0.03	1.22^{b} ±0.03	1.22^{b} ±0.01	1.38^{a} ±0.00
Oil absorption capacity (g/g)	1.03^{b} ±0.01	1.04^{b} ±0.01	1.16^{a} ±0.03	1.18^{a} ±0.01
Swelling power (ml/g)	22.00^{c}±0.01	22.62^{b} ±0.01	22.80^{b}±0.01	23.20^{a} ±0.01
Foaming capacity (%)	14.30^{d}±0.01	15.00^{c} ±0.01	15.80^{b}±0.01	16.20^{a} ±0.01
Emulsion capacity (%)	58.62^{d}±0.01	60.00^{c} ±0.01	64.29^{b}±0.03	65.52^{a} ±0.01

Values are means ± standard deviations of triplicate determinations. Means in the same row followed by different superscript are significantly different ($p\leq0.05$).

Table 3 shows the foaming stability values at 15, 30, 60 and 120 seconds. The control sample had the lowest value while the flour sample obtained after 72 hours germination had the highest. Germination significantly ($p<0.05$) increased the foaming stability at all the times considered. This could be due to increased solubility of proteins. Generally, the foaming stability decreased with time

Table 3. Foaming stability of sorghum flours

Germination time	15s	30s	60s	120s
0	13.90^{c} ±0.01	13.60^{c} ±0.01	14.90^{a} ±0.01	13.00^{d} ±0.01
24	14.62^{b} ±0.02	14.33^{b} ±0.03	14.30^{b} ±0.01	14.27^{b} ±0.03
48	14.80^{b} ±0.01	14.50^{b} ±0.01	14.20^{b} ±0.01	13.90^{c} ±0.72
72	15.10^{a} ±0.01	14.90^{a} ±0.01	14.70^{a} ±0.01	14.40^{a} ±0.01

Values are means and standard deviations of triplicate scores. Means in the same column not followed by the same superscript are significantly different ($p\leq0.05$).

3.2 Degree of Starch Gelatinization

Figure 1 shows the degree of starch gelatinization of germinated and non-germinated sorghum flour cookies at different temperatures. Increasing germination time resulted in higher degree of starch gelatinization at all

temperatures. However, increasing temperature lowered the degree of starch gelatinization. Germination increased the degree of gelatinization at different gelatinization time probably due to the presence of adequate crystalline fractions in the starch molecules. Cooke and Gidley (1992) reported that the enthalpy of gelatinization reflects the loss of molecular order and gelatinization temperature is considered a parameter of crystallite perfection. The decrease in the degree of gelatinization with increasing temperature could be due to disruption of the crystalline fraction of the starch as a result of high temperature (Tester & Morrison, 1990).

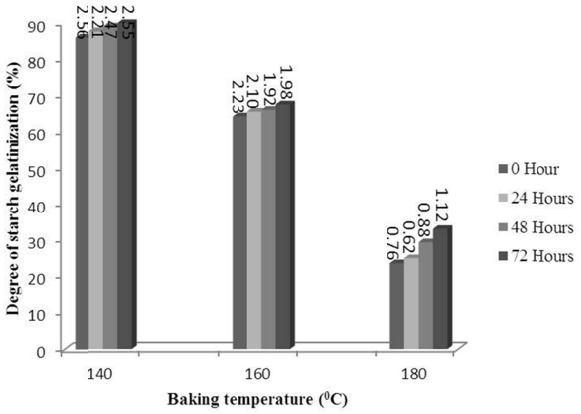

Figure 1. Degree of starch gelatinization of sorghum flour cookies

4. Conclusion

Germination of sorghum grains prior to processing into flour had beneficial effect on functional properties such as bulk density, water and oil absorption capacities, swelling power as well as foaming and emulsion capacities. Germination also increased the degree of starch gelatinization at different temperatures. Flour obtained from sorghum germinated for 72 hours performed best. Generally, germination of sorghum had a beneficial effect on the functional attributes measured. Results from this study indicate that flour obtained from germinated sorghum will perform better as an ingredient in the formulation of baked products, aerated foods and food extenders than flour from non-germinated sorghum.

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