Malted Sorghum as a Functional Ingredient in Composite Bread

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ABSTRACT

To alleviate the adverse effects (grittiness and high crumb firmness) caused by the inclusion of sorghum flour in composite breads, sorghum grain was malted with the aim of decreasing the gelatinization temperature and increasing the water-holding capacity of sorghum flour. Four different heat treatments were investigated: drying the malt at high temperatures (50–150°C), stewing, steaming, and boiling before drying the malt at 80°C. Malting decreased the pasting temperature of sorghum to values approaching those of wheat flour, but the paste viscosity was very low. Increasing the malt drying temperature inactivated the amylases but gave malts of darker color and bitter taste. Stewing, steaming, and boiling the malt before drying almost completely inactivated the amylases and increased the enzyme-susceptible starch content and the paste viscosity of malt flours. Bread made with boiled malt flour (30%) had an improved crumb structure, crumb softness, water-holding capacity, and resistance to staling, as well as a fine malt flavor compared with the bread made with grain sorghum flour (30%). Consumers preferred the malted sorghum bread over the bread made with plain sorghum flour.

Composite breads are breads made from blends of wheat and nonwheat flours (Dendy 1992). Those flours are advantageous to developing countries because they reduce wheat imports and enable the use of locally grown grains. Sorghum is an important cereal crop grown in many developing countries that is potentially suitable for use in composite flours.

Much attention has been given to using sorghum in composite breads. Composite flours containing 30% sorghum produced stronger dough and higher loaf volume with the mechanical dough development process (Chorleywood process) than with the traditional bulk fermentation process (Pringle et al 1969). Good quality bread can also be produced with mechanical dough development process using sheeting rollers (Bushuk and Hulse 1974). Dough additives including potassium bromate (20 ppm), glycerol monostearate (0.5%), and sodium stearoyl lactylate (0.4–1.0%) increase the level of sorghum flour to 10–25% (Haridas Rao and Shurparlekar 1976). Dendy (1992) concluded that a reasonably strong wheat flour, preferably >12% protein (N × 5.7), can make good quality bread with ≤30% sorghum, provided that the sorghum flour is clean, fine, and low in fiber.

Although the use of sorghum flour in composite bread appears promising in terms of loaf volume and crumb structure, its use in breadmaking may not be straightforward. The starch gelatinization temperature range of sorghum (68–78°C) is high compared with that of wheat (58–64°C) (Hoseney 1994). This factor and a lower water-holding capacity (WHC) of sorghum flour may be responsible for the grittiness, dry mouthfeel, and higher firming ratio of sorghum composite breads (Munck 1995).

The role of gelatinized starch in breadmaking has been evaluated. Starch gelatinization was the main factor in structuring the bread crumb (Rotsch 1954). By gelatinization, starch becomes flexible and takes water from gluten, a process which helps gluten to set and become rigid (Kent and Evers 1994). Cereal starches that gelatinized at temperatures higher than wheat starch have poorer baking characteristics, whereas rye and barley starches, which gelatinized around the same temperature as wheat, were nearly equal to wheat starch in breadmaking (Hoseney et al 1971). Also, according to De Ruiter (1978), the breadmaking quality of cassava starch is explained by the gel produced on gelatinization of cassava starch, whose gel possesses far greater cohesion than do gels of grain starches and most other tuber starches.

Therefore, if sorghum is to be used in composite flours to produce acceptable bread, it should be processed in a way that lowers starch gelatinization temperature and increases WHC. This study was conducted with the hypothesis that such conditions could be achieved by malting sorghum and heat treating the malt to promote biochemical modifications in the starch and nonstarch components of the grain.

MATERIALS AND METHODS

Materials

A white, tannin-free Kenyan sorghum cultivar (local white) was used. The grain had an intermediate endosperm texture, a test weight of 72 kg/hL, and a good germinability (germinative energy of 84%). The wheat flour used was Favorita, a commercial bread flour produced by Companhia Industrial da Matola (CIM; Maputo, Mozambique). The flour had a protein content of 12.9% db (N × 5.7) and a water absorption of 63%; mixogram mixing times were peak (3.0 min) and stability to mixing (2.8 min).

Malting Procedure

Lots of cleaned sorghum (500 g) were prewashed, spin-dried for 1 min at 300 × *g*, placed in perforated nylon bags, and steeped for 24 hr in aerated, running tap water at 28–30°C (Morrall et al 1986). After steeping, the grains were spin-dried (1 min) to remove excess surface-held water. Then, the steeped grain was germinated for five days in an incubator set at 28°C and 95% rh. Twice daily, the bags were removed from the incubator, and the grains were turned (to avoid meshing of the roots and shoots) and immersed for 10 min in tap water. Following the short steep, the grains were spin-dried (1 min) and returned to the incubator.

Heat Treatments of Sorghum Malts

After six days from the beginning of steeping, green malts were dried at 50, 80, 100, 120, or 150°C in a forced-draft oven. The drying times varied from 4 hr for malts dried at 150°C to 24 hr for malts dried at 50°C. A second batch of sorghum was malted and subjected to three different wet treatments (stewing, steaming, and boiling) before drying the malt at 80°C. In stewing, green malt was placed in drying pans, covered with aluminum foil, and placed in a forced-draft oven set at 80°C. After 4 hr, the aluminum cover was removed and the malt was dried (4–6 hr). In steaming, the green malt was placed in a perforated pan over a pan containing water and steamed for 4 hr, then dried as above. In boiling, the green malt was placed in a pan with excess water and boiled for 20 min. At the end of 20 min, the malt was removed from the pan, excess water was drained, and the malt was dried, as above.

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Milling of Grain and Malts

Cleaned grain and whole malts (malts with the external roots and shoots) were milled with a hammer mill and then with a pin mill until 80% of the flour particles passed through a 212-μm screen.

Flour Analyses

A Rapid Visco Analyser (RVA) 3D instrument (Newport Scientific Pty Ltd., Narrabeen, Australia) was used to determine pasting properties of flours and malts. Flour (4 g, 14% moisture content) was suspended in 25 mL of distilled water. The suspension was heated from 25 to 95°C in 5 min, held at 95°C for 5 min, cooled to 50°C in 5 min, and held at 50°C for 5 min. The RVA parameters measured were pasting temperature (the temperature at which paste viscosity starts to increase), peak viscosity (the maximum hot paste viscosity), holding strength (the trough at the minimum hot paste viscosity), and final viscosity (the viscosity after cooling to 50°C and holding the temperature) (Batey et al 1997).

Flour moisture was determined using the air-oven method (Approved Method 44-15A, AACC 2000). Protein was determined using the crude protein, Kjeldahl method, boric acid modification (Approved Method 46-12A), and optimum water absorption was determined using the farinograph method (Approved Method 54-21A). Total starch (TS) and enzyme-susceptible starch (ESS) were determined using an α-amylase and amyloglucosidase hydrolysis method (Taylor 1992). Falling number (FN) values were determined (Approved Method 56-81B). Diastatic power, the joint α- and β-amylase activity of malts, was determined according to a standard test method for determination of the diastatic power of malts prepared from sorghum, including bird-proof cultivars, and millet (Method 235, SABS 1970), except that water was used as the extractant. All determinations were repeated at least twice.

Breadmaking

Bread was produced using the formulation of wheat flour (70%), sorghum flour (30%), water (63 and 75% for plain and malted sorghum flour, respectively), active dried yeast (1%), salt (2%), sugar (1%), ascorbic acid (20 ppm), and fat (1%). The dough was mixed to optimum development for 15–20 min with a spiral mixer, rested for 15 min, divided into 950-g pieces, molded, and placed in baking pans of (275 × 100 × 105 mm). The dough was proofed for 45–50 min at 40°C and 95% rh and baked at 230°C for 30 min. Bread volume was determined by rapeseed displacement. Specific volume was calculated from the volume and weight of bread.

Crumb Firmness

Crumb firmness was determined by measuring the amount of force required to compress bread slices using a universal testing machine (Approved Method 74-09). The instrument was fitted with a 28-mm dia. cylinder probe. The crosshead speed was 100 mm/min. Samples were prepared and cooled to ambient temperature for 3–4 hr. After cooling, samples were wrapped in polyethylene bags (35 μm thick). The loaves were then stored in baskets in ambient conditions (≈20°C) until required for testing. Measurements of crumb softness began 4 hr after baking for day one, and thereafter at one-day intervals until the fourth day.

Sensory Evaluation

Bread samples, containing grain sorghum flour (30%) and sorghum malt flour (30%) were evaluated. The consumer testing methodology was based on a liking and preference ranking test (Jellinek 1990) with slight modifications to suit semi-illiterate consumers. The panelists (62) were women, all local residents of the community of Mmotla, near Pretoria.

Statistical Analysis

Analysis of variance was determined. The significance of the number of liking judgments and the degree of ranking preference were determined using the Roessler Table for Paired Preference Test (Stone and Sidel 1993) and the Table of Rank Total (Kramer 1963), respectively.

RESULTS AND DISCUSSION

Flour Properties

Pasting temperature, peak viscosity, holding strength, final viscosity, and the FN values of sorghum flour were much higher than those of wheat flour; whereas the diastatic power and the ESS of sorghum flour were lower than those of wheat flour (Table I). Notable was the substantial rise in viscosity on cooling (final viscosity) of sorghum flour.

TABLE II
Volume and Specific Volume of Composite Breads Containing Sorghum Grain, Sorghum Malt, and Heat-Treated Sorghum Malt Flours[a]

Bread Ingredients	Loaf Volume (cm^3)	Specific Volume (cm^3/g)
Wheat flour	3,567a	4.8a
Sorghum flour[b]	2,708b	3.4b
Malt dried at		
50°C	1,776h	2.2e
80°C	1,875g	2.3e
100°C	1,858g	2.3e
120°C	2,067e	2.6d
150°C	2,067e	2.6d
Stewed malt	2,038f	2.5d
Steamed malt	2,188d	2.7d
Boiled malt	2,350c	2.9c

[a] Values followed by the same letter in the same column are not significantly different ($P < 0.05$).
[b] Recipes contained sorghum (25%) and wheat flour (75%).

TABLE I
Starch and Amylase Properties of Sorghum Grain, Sorghum Malt, and Heat-Treated Sorghum Malt Flours[a]

Flour	Pasting Temperature (°C)	Peak Viscosity (SNU)	Holding Strength (SNU)	Final Viscosity (SNU)	ESS (% of total starch)	Falling Number Values (FNU)	Diastatic Power (SDU/g)
Wheat flour	63e	2,015b	800b	2,775b	8.4e	345a	4.5e
Sorghum flour	72a	2,267a	1,743a	5,733a	0.6f	507b	0.3f
Malt dried at							
50°C	64e	80i	0g	76e	16.0d	62c	38.9b
80°C	63e	98h	48f	80e	17.1d	62c	22.6c
100°C	64e	123g	40f	79e	19.7d	62c	14.4d
120°C	64e	483c	265d	655d	18.8d	79d	0.9f
150°C	66d	483c	175e	457e	17.4d	79d	0.3f
Stewed malt	70b	450d	255d	650d	40.4c	62c	4.7e
Steamed malt	68c	367e	325c	725c	73.4b	62c	1.0f
Boiled malt	66d	315f	333c	610d	87.0a	62c	0.5f

[a] Values followed by the same letter in the same column are not significantly different ($P < 0.05$). SNU = stirring number units; FNU = falling number units (the higher the FNU, the lower the α-amylase activity); SDU = sorghum diastatic units.

Malting decreased the pasting temperature, peak viscosity, final viscosity, and the FN values of sorghum flour, and substantially increased the content of ESS and diastatic power (Table I). The pasting temperature of sorghum decreased to values approaching that of wheat flour. The decrease in pasting temperature of sorghum with malting can be explained by the biochemical modifications occurring in the grain during germination. Glennie et al (1983) reported that, during germination, hydrolytic enzymes progressively degrade the starch and the protein in the endosperm by pitting rather than by surface erosion. This process of modification which hydrolyzes starch and proteins into dextrins, glucose, and amino acids renders the starch in the malt easier to gelatinize, consequently decreasing the pasting temperatures and paste viscosity.

Increasing the drying temperatures of malt reduced diastatic power, increasing the paste viscosity of sorghum. Wet-heat-treating (stewing, steaming, and boiling) the malt virtually inactivated diastatic power and increased the ESS content and the paste viscosity of sorghum malt. However, drying the malt at 100°C and at higher temperatures and wet-heat-treating, increased the pasting temperatures of sorghum malt to values slightly higher than that of wheat flour but still lower than that of sorghum flour. Boiling produced the highest ESS content because boiling gelatinized the starch and almost totally inactivated diastatic power of sorghum malt. Wet-heat treatments also reduced the breakdown viscosity of sorghum; boiling produced malt with the lowest breakdown viscosity. Breakdown viscosity is determined as peak viscosity minus holding strength (Batey et al 1997). Breakdown viscosity gives an indication of hot paste stability. The smaller the breakdown viscosity, the higher the paste stability, presumably due to starch gelatinization. Paste stability of sorghum malts increased with increased amounts of gelatinized starch (ESS).

The FN values did not substantially increase with increasing drying temperatures of malts nor with wet-heat-treating the malts. This suggests that, under the test conditions, malt flour was rapidly liquefied due to dextrinization of starch during germination and not due to α-amylase activity in the malt flour, which would almost certainly be inactivated at high drying temperature and with wet-heat treatments.

The low viscosity of malt dried at 50–100°C (hot-air method) suggests that the grain dried slowly and, hence, gradually reached the amylase inactivation temperatures, thus promoting hydrolysis of starch and other grain components; whereas, with boiling and other wet-heat treatments, the heat penetrated the grain faster, rapidly inactivating the amylases.

Breadmaking Properties of Sorghum Flour and Heat-Treated Sorghum Malt Flours

The substitution of wheat flour with 25% sorghum malt flour gave smaller bread volume than sorghum flour (Table II). Malt dried at 50°C had a deleterious effect on the bread volume, presumably due to the high amylase activity of the malt. High α- and β-amylase in bread flour is detrimental to bread quality because starch dextrinization results in reduced WHC, weak dough, and sticky crumbs (Kent and Evers 1994). Increasing the drying temperatures of malts slightly improved the volume of breads. However, an informal sensory evaluation of the breads revealed that the bread made with malt dried at 80°C had acceptable appearance and flavor, whereas breads made with malt dried at higher temperatures had unacceptable dark color and a bitter taste. The dark color and the bitter taste are attributed to Maillard reactions which are accelerated at higher temperature (Whistler and Daniel 1985).

Wet-heat treatment of the malt improved the bread characteristics. Boiled malt gave the highest loaf volume and the highest loaf specific volume (Table II). The doughs made with wet-heat treatment of malts had higher water requirements; stewed, steamed, and boiled malt required 66, 70, and 75% water, respectively. The doughs made with conventionally dried malts required 62–64% water, while the dough prepared with sorghum flour required 62%. It was also observed that breads containing sorghum malts had higher loaf weight, suggesting a better WHC than the dough containing sorghum flour. The fact that boiled malt gave the largest loaf volume suggests that a complete inactivation of amylases and a higher content of gelatinized starch in the malt are major factors responsible for the satisfactory breadmaking qualities of sorghum malts.

Baking trials to optimize the breadmaking procedure with boiled malt flour were undertaken. Increasing the mixing time of dough from 15 to 20 min and the proofing time from 45 to 50–55 min improved the volume, specific volume, and crumb structure of composite bread. The level of sorghum in the composite flour could also be increased.

Increasing the level of sorghum flour and boiled sorghum malt flour to 30 and 50% had an effect on the volume, crumb structure,

TABLE III
Sensory Evaluation of Sorghum Composite Breads

Bread Ingredients	Panelists Liked Bread	Rank Sum of Sample[a]
Sorghum grain flour (30%)	47	111a
Sorghum malt flour (30%)	53	86b

[a] Rank sum of the sample = ∑(number of panelists × respective rank position). Lower rank sum indicates the better-liked sample.

Fig. 1. Effect of sorghum and sorghum malt flour on the volume and crumb structure of sorghum and wheat composite breads: (left to right) breads made with 100% wheat flour, 30% sorghum flour, 30% sorghum malt, 50% sorghum flour, and 50% sorghum malt.

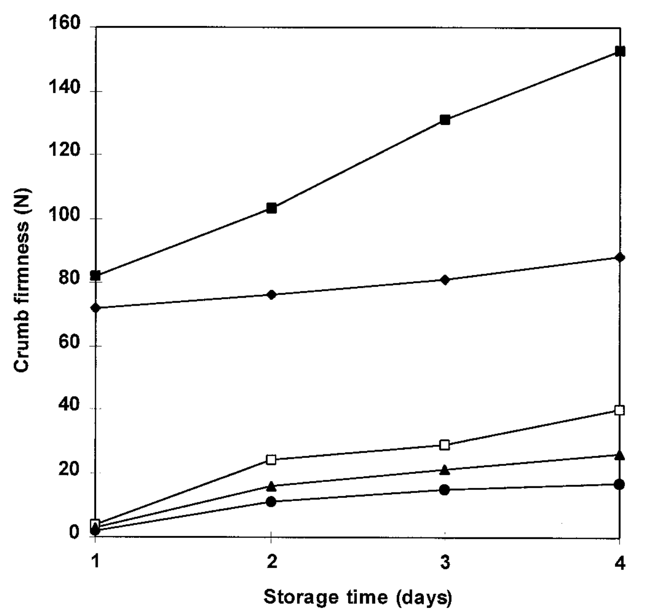

Fig. 2. Crumb firmness of wheat and sorghum composite breads as a function of storage time and level of sorghum ingredient. Wheat flour, 100% (●), sorghum malt, 30% (▲), sorghum flour, 30% (□), sorghum malt, 50% (◆), and sorghum flour, 50% (■).

and color of composite breads (Fig. 1). With 30% sorghum flour and 30% boiled sorghum malt flour, the bread volume increased to 2,998 and 2,888 cm^3, respectively, compared with the volumes of 2,708 and 2,325 cm^3 of bread made with 25% sorghum flour and 25% boiled sorghum malt flour, respectively, before optimizing the baking procedure. Though the volume of bread made with sorghum flour was slightly higher than the volume of bread made with boiled sorghum malt flour, the specific volumes of those breads were almost the same (3.5 and 3.4 cm^3/g, respectively). Increasing the level of sorghum flour and boiled sorghum malt flour to 50% reduced the bread volumes to 2,040 and 1,745 cm^3, respectively. The specific volume of those breads were also reduced to 2.4 and 2.1 cm^3/g, respectively. The level of 50% sorghum had a notable negative effect on the crumb structure of bread made with sorghum flour and on the volume of bread made with boiled sorghum malt flour. The crumb structure of bread made with sorghum flour collapsed to reveal a reduced capacity of the dough to retain the carbon dioxide produced during fermentation. The crumb of bread made with boiled sorghum malt flour (50%) was very dense, almost not developed. This could be explained by the fact that 50% boiled sorghum malt flour gave tough and sticky dough, with poor viscoelastic properties, even though 10% extra water had been added. There was no visual evidence of carbon dioxide escape, such as pitting on the surface of the loaves. It is suggested that the dough was too tough to expand greatly. The reduced breadmaking potential of wheat flour on partial substitution with nonwheat flours is attributed to a reduced capacity of the gluten network to slow down the rate of carbon dioxide diffusion (Hoseney 1984).

Sorghum flour or boiled sorghum malt flour at 30% was the maximum level that could be used in the composite with wheat flour of 12.9% protein and with ascorbic acid (10 ppm) as the dough improver. Though the volume of bread made with 30% boiled sorghum malt flour was slightly lower, this bread was moister and had a better crumb structure than the bread prepared with 30% sorghum flour.

The slightly smaller volume of bread made with boiled sorghum malt flour can be explained in that high dextrinization and gelatinization of starch of boiled sorghum malt flour decreases dough strength and dough gas holding capacity, consequently decreasing the bread volume (Kent and Evers 1994). On the other hand, a higher amount of nonstarch polysaccharides in the malt, particularly the water-insoluble fraction, could have reduced the gas-holding capacity of dough because malt was milled with the roots and shoots included. The moistness of the bread made with boiled sorghum malt flour was attributed to the higher WHC of doughs, which was due to the high amount of gelatinized starch in the malt flour. The improvement of the crumb structure in bread made with boiled sorghum malt flour is explained by the fact that free starch granules, which resulted from the malting process, gelatinized more rapidly and completely than starch in flour particles (De Ruiter 1978). That view is in agreement with that of Rotsch (1954), who also found the degree of gelatinization to be the major factor in determining crumb cohesion.

Crumb Firmness as Function of Storage Time and Amount of Sorghum

Softness is one of the most important textural properties of bread for consumer acceptance. Bice and Geddes (1949) concluded that firmness and crumbliness are related closely to the organoleptic assessment of staleness. Therefore, if wheat and sorghum composite breads are to be produced, it is necessary that they have a soft crumb and a low firmness over storage time.

The initial crumb firmness and the changes in crumb firmness over four days of storage time are presented in Fig. 2. Bread made from 100% wheat flour was the softest and had the lowest rate of firming. The bread made with boiled sorghum malt flour (30%) was softer and more resistant to firming than the bread made with sorghum flour. Bread made from 50% sorghum malt flour was also softer and had a lower firming rate than the bread made with 50% sorghum flour.

The increase of bread firmness, due to increase in crumb rigidity with the storage time, is attributed to starch retrogradation (Lineback and Rasper 1988). Bread with high crumb moisture appears significantly fresher than bread with low moisture content (Bechtel and Meisner 1954, Kulp and Ponte 1981). Maleki et al (1980) concluded that the moisture content of bread affects the absolute softness but not the staling rate. In those studies, the rate of bread staling was related to the protein quality of the flour.

Several authors have investigated the contribution of protein, starch, and nonstarch polysaccharides on the moisture retention to the shelf life of wheat bread (Maleki et al 1980, Martin and Hoseney 1991). The later authors demonstrated that low molecular weight dextrins (DP 3–9) are responsible for the antifirming effect in bread. Dextrins of that particular size interfere with the crosslinks (hydrogen bonds) between starch and proteins and thus prevent staling.

Sensory Evaluation of Composite Breads

Bread prepared with boiled sorghum malt flour was significantly more liked than the bread prepared with sorghum flour (Table III, $P < 0.05$) (Basker 1988). Panelists apparently preferred the bread prepared with malt flour because it was more moist and had a fine roasted malt flavor.

CONCLUSIONS

Boiled sorghum malt flour (30%) can be successfully used as a partial replacement for wheat flour in pan bread. Bread prepared with sorghum malt flour was softer, more resistant to firming of the crumb, and had a better taste and chewing quality than the bread prepared with sorghum flour. Malting of sorghum and wet-heat-treating the malt decreased the pasting temperature and increased the WHC of sorghum flour. Complete inactivation of amylases and a higher content of gelatinized starch in the malt appear to be the major factors responsible for the useful breadmaking qualities of boiled sorghum malt.

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