Effect of Decorticated Sorghum Addition on the Rheological Properties of Wheat Tortilla Dough[1]

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ABSTRACT

Sorghum flour from decorticated kernels was tested at several replacement levels for wheat flour in a tortilla formula. Three types of decorticated sorghum flours with different particle size distribution were used: coarse (A), medium (B), and fine (C). Each sorghum flour replaced wheat flour at levels of 15 and 30%. Composite doughs were prepared according to mixing requirements. The amount of water required was defined by a modified farinograph procedure. The rheological properties of dough were determined using the uniaxial compression method. Maximum stress peak, stress during relaxation period, stress at a given strain, and dough viscosity increased when sorghum flour replaced 30% of wheat flour in wheat-sorghum doughs. Composite doughs containing sorghum flour with smaller particle size distribution had higher stress during relaxation and higher stress at a given strain, even though higher amounts of water were used for their preparation. Differences in consistency of the composite doughs were not detected with the farinograph procedure. However, differences in rheological properties were well detected with uniaxial compression tests.

Wheat flour tortillas are chemically leavened flat breads consumed in México and the United States. Tortilla dough differs from that of pan bread in the fat and moisture contents. Bread formulas contain 2–4% shortening and 63–70% water. Dough for flour tortillas contains 5–15% shortening and is usually hydrated with 45–55% water (Serna-Saldívar et al 1988). Hence, tortilla and bread doughs will differ in their rheological properties. Bello et al (1991), using a modified farinograph procedure, found that the water required to center the farinograph curve at 750 BU is optimum for proper consistency of tortilla dough being processed by the hot press procedure. Bagley and Christianson (1986) measured the response of commercial, chemically leavened dough in uniaxial compression. They proposed that a stress growth treatment (compression) is useful in characterizing doughs and relating such characteristics to processing behavior. Since the same principle is applied during processing, these compressional studies can be especially useful in characterizing flour tortilla doughs. Dough balls are compressed between hot plates in the hot press procedure or between rollers in the hand stretch procedure. Therefore, the effect of processing variables and chemical agents will be apparent on rheological parameters.

Blending wheat flour with flour from other cereals or starchy products has been used to extend wheat flour for the production of bakery products (Dendy 1970, 1988). This blending is important in those countries where wheat is scarce or where there are severe restrictions on the importation of wheat flour. Rooney et al (1980), using regular straight-dough and short-time dough, replaced 5–100% of wheat flour in bread with sorghum flour. Results indicated that the level of sorghum that can be successfully substituted is higher in short-time doughs than it is in straight-dough formulas. Morad et al (1984) replaced part of the wheat flour used in the production of pan bread, balady bread, and cookies with flour from five genetically different sorghums. They found that when the sorghum level was increased, water absorption, peak time, and stability decreased. Mixing time, however, increased. Navickis (1987) observed a strengthening of the dough when corn flour was added to bread dough. The modulus of rigidity in simple shear increased as wheat solids were replaced by corn solids. It was suggested that the corn flour acted as a strengthening filler in the developed gluten.

Sorghum with white pericarp and secondary tan plant color produces high yields of flour with light color and bland flavor. Sorghum flour is cheaper than wheat flour and can be used as an extender of wheat flour for tortilla production with economical benefits. The purpose of this research was to investigate the effect on the rheological characteristics of flour tortilla dough when part of the wheat flour was replaced with decorticated sorghum flour.

MATERIALS AND METHODS

Sorghum Flours Preparation

Sorghum (ATx631 × Tx8505) with intermediate thick white pericarp, tan plant color, and a density of 1.36 g/cm^3 was used to prepare sorghum flours. Sorghum was grown under irrigation at Halfway, TX, in 1984. The grain was clean, bright, and free of molds.

Sorghum decortication was performed as reported by Torres et al (1993). Three types of flours with different particle size distribution were prepared: A, coarse; B, medium; and C, fine. Sorghum flour A was prepared from decorticated sorghum using a hammer mill (Fitz mill, comminuting machine, model D, Fitzpatrick Co., Elmhurst, IL) equipped with a 1-mm screen. Sorghum flour B was obtained from flour A; the grits retained by U.S. sieve 60 were separated, pulverized in a cyclone mill (model 25084 U-3, Udy Corp., Fort Collins, CO), and reincorporated in the flour. Sorghum flour C was prepared from decorticated sorghum using a pin mill (Alpine American Corp., Natick, MA). Water absorption indices (Anderson et al 1969) for sorghum flours A, B, and C, respectively, were 1.11, 2.38, and 3.48 g of water per gram of dry sample. Torres et al (1993) presented the particle size distribution of these sorghum flours.

Composite Flours Preparation

Commercial enriched and bleached hard wheat flour (Bakers GM 44, 10.8% protein, General Mills, Minneapolis, MN) was used to prepare the composite wheat-sorghum doughs. Each sorghum flour replaced wheat flour at levels of 15 and 30%.

Dough Preparation

The basic formula of ingredients to prepare the dough was: 84.5% composite flour, 12% shortening (Crisco, Procter &

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Gamble, Cincinnati, OH), 2% salt, 1% baking powder (Clabber Girl Double Action, Hulman & Co., Terre Haute, IN), 0.1% citric acid (Miles Laboratories, Elkhart, IN), and 0.4% potassium sorbate (Sorbitat-K, Pfizer, New York, NY). Mixing requirements and water absorption for each composite dough were determined using a modified farinograph procedure (Bello et al 1991). The results are listed in Table I.

Composite flour and dry ingredients were mixed with a paddle at speed 1 in a mixer (Hobart, model A 200) for 5 min. Then the predetermined optimum amount of water was added and mixed with the dry ingredients for 2 min at speed 1, using a hook attachment. Finally, the dough was mixed at speed 2 for a longer period of time (3–10 min), depending upon the dough mixing requirements. The farinograph method provided information about the mixing time required for a proper dough development. Dough development was attained when dough acquired a silky appearance and formed a membrane when a piece of dough was stretched between fingers. Dough was placed in a proofing chamber at 32°C and covered with a plastic sheet.

Dough Rheology Evaluation

The squeezing flow method was used. After 25 min of resting in the proofing chamber, the dough was molded in a cylindrical container (1.25 cm height, 5.3 cm diameter) and rested for 30 min at 25°C. Then dough samples were placed between two parallel stainless steel plates (6.9 cm in diameter) and lubricated with petroleum jelly. Each sample was subjected to uniaxial deformation using the Instron universal testing machine (UTM) (model 1112, Instron Co., Canton, MA) with a 1,000-lb compression-tension load cell. Cross-head and chart speed used were 50 and 100 mm/min, respectively. Samples were deformed up to 40% of their original height. After deformation, cross-head motion was stopped and dough was allowed to relax. A force-deformation curve was obtained from the chart recorder. From this data, curves of stress-time, stress-strain, and elongational viscosity-biaxial strain rate were plotted. The mathematical treatment used was that described by Bagley and Christianson (1986).

Stress was defined as the quotient of force by cross-sectional area to which the force was applied. Considering extensional flux:

$$\text{strain } \epsilon = \ln (h_o/h)$$

where h = height at time t and h_o = initial sample height, radial extension rate $\dot{\epsilon}_r$ was:

$$\dot{h}/2h$$

where $\dot{h}$ = cross-head speed (∂h/dt).

Apparent biaxial extensional viscosity (η_{be}) was calculated as:

$$(\eta_{be} = Fh/R^2{}_o h_o \dot{\epsilon}_r$$

where $R^2{}_o$ = initial radius and h_o = initial height.

TABLE I
Dough Water Absorption and Mixing Time Measured with the Farinograph

Flour	Water Absorption[a] (%)	Development Time (min)
Wheat	44.7	5.5
Sorghum A		
15%	39.8	8.0
30%	36.0	7.5
Sorghum B		
15%	42.0	6.5
30%	39.2	6.5
Sorghum C		
15%	44.6	6.0
30%	44.6	10.0

[a]Modified farinograph procedure. Water required to center the curve on the 750 BU line. Duplicate determinations. Least significant difference = 0.85 (α = 0.05).

Statistical Analysis

Tests were duplicated and analysis of variance was performed for the measured rheological parameters. Fisher's least significant differences (LSD) at an $\alpha = 0.05$ were also calculated. SAS statistical software (SAS Institute Inc., Cary, NC) was used to make the statistical analysis.

RESULTS AND DISCUSSION

Stress-Time Curves

Stress relaxation time was not determined because of the limitations imposed by the dough characteristics of nonlinear viscoelasticity (Bagley and Christianson 1986). Instead, relaxation curves were plotted in wheat-sorghum doughs.

Significantly ($P < 0.05$) higher maximum stress and higher stress during relaxation period was observed when sorghum flour replaced 30% of the wheat in wheat-sorghum doughs. However, there were no significant differences ($P < 00.05$) among wheat dough and doughs containing 15% sorghum (Fig. 1A–C). Figure 2 shows stress-time plots for doughs prepared with 30% decorticated sorghum of flours A, B, and C. Doughs with sorghum flour C (fine) had significantly ($P < 0.05$) higher stress values than did doughs prepared with flour A (coarse), even though the latter was prepared using less water. However, stress values for doughs with sorghum flour B (medium) were not significantly different ($P < 0.05$) from those of doughs containing flours B and C.

Stress-Strain Curves

Doughs for compression studies were prepared at optimum farinograph water absorption. Even though doughs had the same consistency measured with the farinograph, wheat-sorghum doughs behaved differently during compression. Doughs containing 30% sorghum flour were harder than the control dough. Significantly higher ($P < 0.05$) stress at a given strain was observed for doughs containing 30% sorghum when compared to control and 15% sorghum doughs (Fig. 3A–C). Doughs containing sorghum

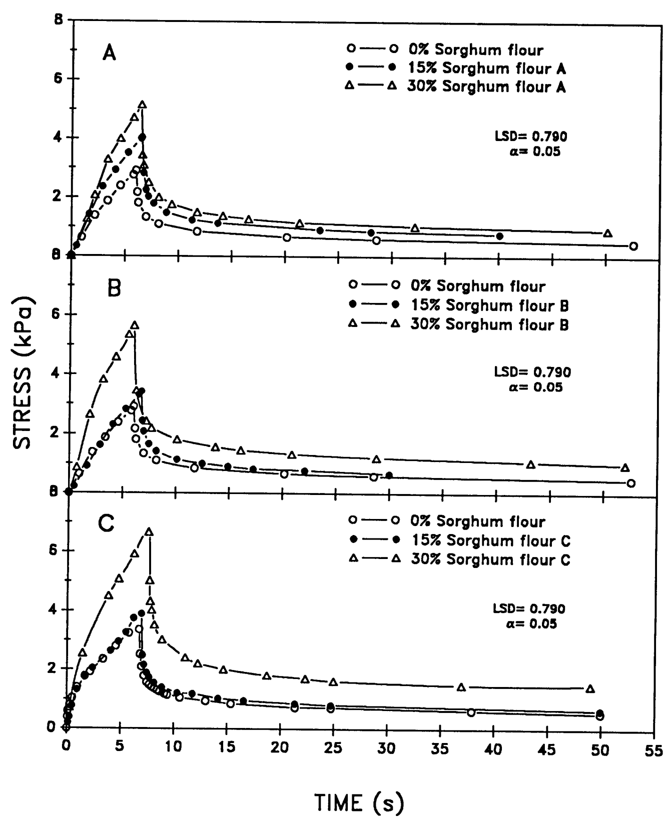

Fig. 1. Lubricated uniaxial compression provided stress versus time curves for composite wheat-sorghum flours (A, B, and C) at different levels of replacement. After deformation to 40% (maximum peaks), cross-head motion stopped, and stress relaxation occurred.

flour A showed significant ($P < 0.05$) differences in stress at a given strain when sorghum was substituted for 0, 15, and 30% of wheat in doughs (Fig. 3A).

It is evident that sorghum flour particle size affected dough rheological properties (higher stress during relaxation and higher stress at a given strain). However, it is not clear whether these changes were due to an increase in water absorption related to starch damage (not detected with the farinograph) or to the effect of the flour particle size. This changes will affect the behavior of wheat-sorghum dough during processing, and consequently, the characteristics of the tortilla end product.

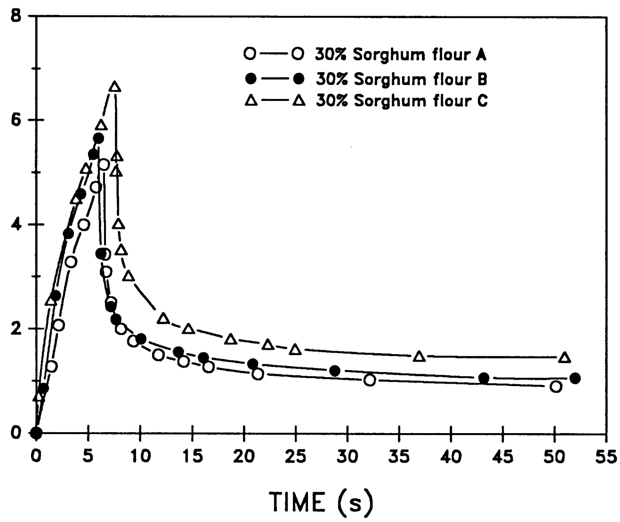

Fig. 2. Stress-time curves for doughs prepared with 30% decorticated sorghum of flours A, B, and C. After deformation to 40% (maximum peaks), cross-head motion stopped, and stress relaxation occurred.

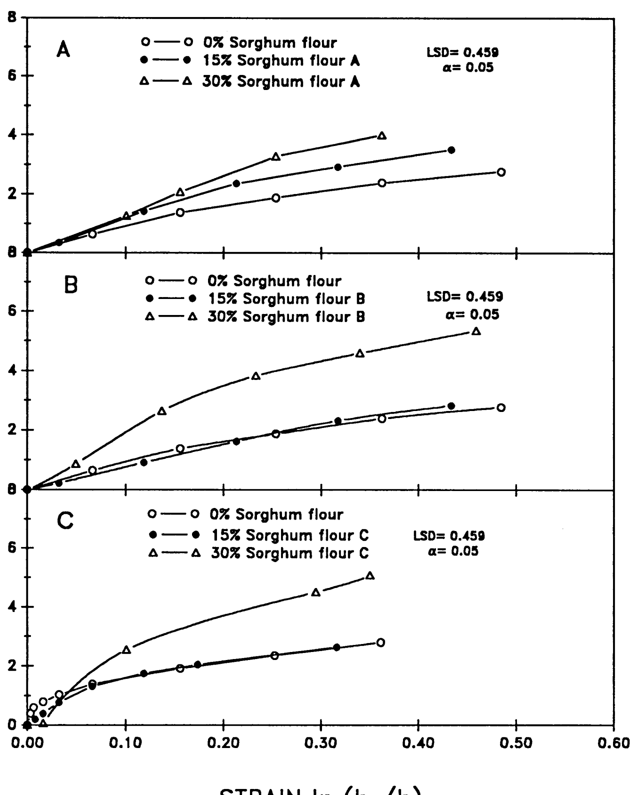

Fig. 3. Stress-strain curves for composite wheat-sorghum flours (A, B, and C) in tortilla doughs compressed up to 40% deformation during lubricated uniaxial compression.

Reducing the particle size of the sorghum flour increased starch damage. The reduction in water absorption that could be expected by the gluten dilution is compensated for by the absorption of water by the damaged starch. This absorption of water due to starch damage was not generally detected by the farinograph. It could be due to the different rheological characteristics of gluten and starch. However, it was detected in the measurements of rheological properties with lubricated compression. The increase in farinograph water absorption when pin-milled flour C was used can be explained by a competition of the damaged starch with the gluten for the available water. Damaged starch was hydrated very fast, reducing the available water for gluten development.

Biaxial Elongational Viscosity-Strain Rate Curves

Level of sorghum replacement affected apparent dough viscosity (Fig. 4A–C). The first part of the logarithmic plots of viscosity versus radial extension rate were transitional effects (Bagley and Christianson 1986). A newtonian region was observed when the plot line was horizontal. In this region, the viscosity was constant and independent of the radial extension rate.

A significant ($P < 0.05$) increase in apparent viscosity was observed when sorghum flour replaced 30% of the wheat flour in the doughs. However, there were no significant ($P < 0.05$) differences in apparent dough viscosity in doughs with replacement levels of 0 and 15% sorghum flour.

Figure 5 compares apparent viscosity of doughs containing 30% decorticated sorghum flour A, B, and C. No significant ($P < 0.05$) differences were observed among these three doughs. Changes in dough apparent viscosity due to different particle size distribution of the added nongluten flour were not detected.

CONCLUSIONS

Particle size distribution of the sorghum flour and the type of milling process used to prepare the sorghum flour were important factors affecting water absorption of composite wheat-sorghum doughs. Pin milling produced finer sorghum flours and apparently more starch damage. Pin-milled sorghum flour (C) had a higher water absorption index than did hammer-milled

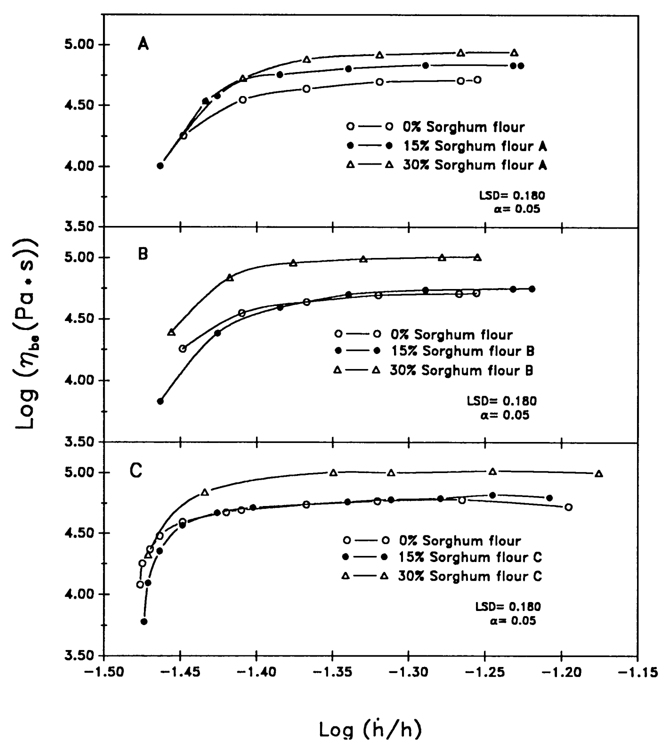

Fig. 4. Apparent elongational viscosity versus radial extension rate for composite wheat-sorghum flours (A, B, and C) in tortilla doughs compressed up to 40% deformation during lubricated uniaxial compression.

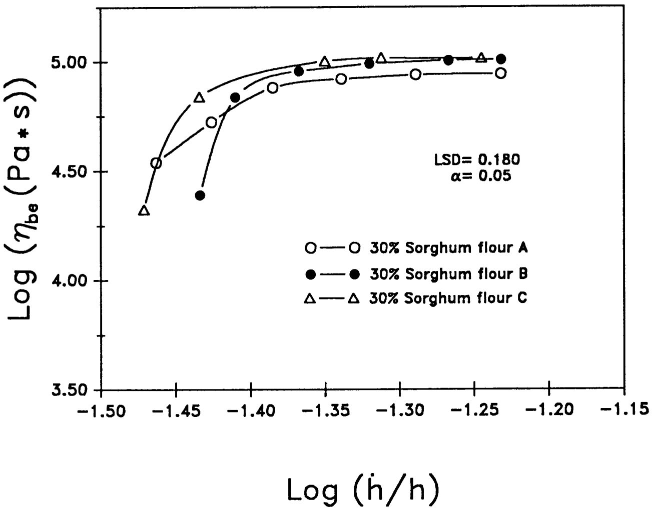

Fig. 5. Apparent elongational viscosity versus radial extension rate for composite wheat-sorghum flours prepared with 30% decorticated sorghum. Tortilla doughs were compressed up to 40% deformation during lubricated uniaxial compression.

flours (A, and B); doughs prepared with pin-milled flour had the same, or greater, water absorption as that of the control doughs. Hammer milling produced gritty flours that produced wheat-sorghum doughs with reduced resistance to mixing. Consequently, doughs exhibited lower water absorption than did control doughs.

Higher maximum stress peak and higher stress during the relaxation period were observed for composite wheat-sorghum doughs when compared with wheat dough. Also, an increase in dough viscosity was observed when sorghum flour replaced 30% of wheat in tortilla doughs.

Even though wheat and composite doughs had the same consistency when measured with the farinograph, dough rheological properties, including dough viscosity when measured with the squeezing flow method, changed with sorghum replacement. Doughs prepared with sorghum flour with smaller particle size had higher stress values during relaxation and higher stress at a given strain. The squeezing flow method for measuring viscosity was especially useful in detecting rheological changes in doughs where wheat flour was replaced with a nongluten flour. These changes were not detected with the farinograph. It could be a good tool that gives better control in the wheat tortilla-making process.

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