PEARL MILLET. II. PARTIAL CHARACTERIZATION OF STARCH AND USE OF MILLET FLOUR IN BREADMAKING[1]

S. M. BADI, R. C. HOSENEY, and P. L. FINNEY[2]

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ABSTRACT

Pearl millet starch ranged in diameter from 8 to 12 μ, somewhat smaller than corn or sorghum starch. Pasting properties of millet starch were similar to those of sorghum starch, except during the 1-hr holding period of 95°C. Millet starch contained 17% amylose compared with 23% in sorghum starch. Amylograms of millet flour gave low peak viscosities compared to sorghum flour, indicating an active α-amylase system. Adding 10% millet flour to a standard baking formula slightly increased loaf volume and improved crumb grain. The addition of 10% millet flour to a formula containing no malt or sugar gave a loaf volume significantly better than the same wheat flour baked with the standard formula containing 6% sugar. Adding small quantities of sorghum flour (5–20%) to the standard formula decreased loaf volume.

The increasing price of wheat and its shortage in many less developed countries prompted us to study replacing part of the wheat flour used in breadmaking with flours of locally grown grains. Millet flour has been used to replace part of the wheat flour in French, baladi (crumbless), and pan bread (1,2). Rooney *et al.* (3) formulated yeast-leavened pan bread, cakes, and cookies containing sorghum flour. The products were acceptable when small quantities of sorghum flour were substituted for wheat flour. Hart *et al.* (4) made acceptable pan bread from sorghum by adding a gum and 4000 cps methocel, and by using a 55% moisture batter system.

[1]Contribution No. 885, Dept. of Grain Science and Industry, Kansas Agricultural Experiment Station, Manhattan, KS 66506.

[2]Respectively: Graduate Research Assistant, Professor, and Research Associate, Dept. of Grain Science and Industry, Kansas State University, Manhattan, KS 66506.

We studied certain properties of millet starch and the effects of adding a millet and a sorghum flour individually to a regular bread formula.

MATERIALS AND METHODS

Grain Samples and Dry Milling

Pearl millet and sorghum grain samples described previously (5) were used. For baking experiments, a millet sample was milled into a straight-grade flour on a Buhler experimental mill and a sorghum sample (bulk) on an experimental sorghum mill.

Scanning Electron Photomicrograph

Isolated starch was dusted on double-sided tape, mounted on aluminum stubs, coated with a 150-Å thick, gold-palladium layer, viewed, and photographed in an ETEC Autoscan scanning electron microscope at an accelerating voltage of 20 kV.

Starch Characterization

A microscope (Thomas Model AHT) equipped with a Model 40 micro hot stage regulated to give a rise of 1°C/min was used to determine gelatinization temperature ranges. Loss of birefringence was taken as the gelatinization point.

Sorghum and millet starches were fractionated into amylose and amylopectin by the method of Lansky *et al.* (6), as modified by Montgomery and Senti (7). Amylose content was determined by iodine blue value at 610 nm (8).

Wet Milling

Clean grain was steeped in distilled water (2 ml/g) at 4°C for 24 hr. After steeping, the excess water was decanted, and the grain washed several times with distilled water. The steeped grain was rough-ground in a blender (low speed) with sufficient water to cover the grain, and then sieved on a 60-mesh nylon bolting cloth. The overs (hulls, germ, endosperm) were slurried with water, and the germ and hulls floated off. The grinding and sieving procedure was then repeated.

After hulls and germ were separated, the endosperm was ground at high speed and sieved on the 60-mesh cloth. The overs were reground, and the process was repeated, until the overs were essentially free of starch. The starch-protein slurry (combined thrus of the 60-mesh cloth) was centrifuged at $1000 \times g$ for 20 min. The supernatant was discarded, and the protein layer on top of the starch removed with a spatula. The starch was washed repeatedly by redispersing in distilled water and centrifuging until it appeared clean.

The cleaned starch was air-dried on a glass plate for 12 hr, redispersed in water, and wet-sieved through a 100-mesh screen. The starch passing through the screen was recovered by centrifugation ($1000 \times g$, 15 min) and again air-dried.

Amylograms

Amylograms were prepared on a Brabender Visco-Amylograph®, type VA-V, 700 cm-g sensitivity cartridge at 75 rpm. The procedure was described in AACC Methods (9); however, 50 g of flour (14% m.b.) was used.

Effects of millet flour and malted wheat flour on paste viscosities (95°C) were determined by adding each flour to a constant weight of standard wheat flour.

Bread-Baking

The straight-dough baking procedure described by Finney and Barmore (10–12) and Finney (13) was used. Certain levels of millet and sorghum flours were added to the 100 g of wheat flour. Water absorption, mixing time, and $KBrO_3$ were optimized for each dough. When used, sodium stearoyl-2-lactylate (SSL) and soybean oil were added with the shortening. Loaf weight and loaf volume (rapeseed displacement) were measured immediately after removing loaves from the oven.

RESULTS AND DISCUSSION

Starch and its Pasting Properties

Millet starch granules (Fig. 1) ranged in diameter from about 8 to 12 μ. Shape of the granules ranged from spherical to polygonal, with many intermediate types, and several granules had deep indentations (I) caused by protein bodies. The spherical starch granules show evidence of enzyme attack (E). We have seen similar preferential attack of spherical starch granules in grain sorghum. Such preferential attack could have been from enzymes being concentrated in the soft endosperm of the kernels or from soft endosperm starch granules being more susceptible to enzymatic attack.

Amylograph properties of millet and sorghum starches are given in Table I.

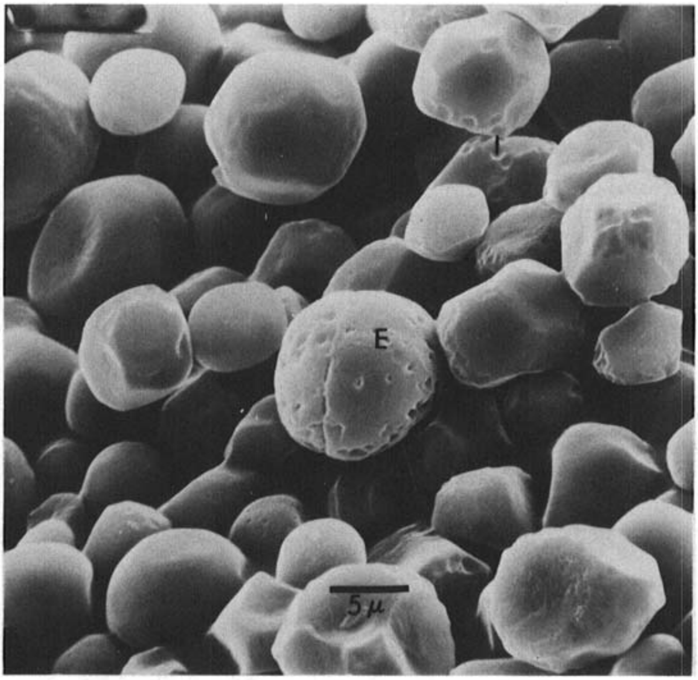

Fig. 1. SEM of isolated millet starch, showing enzyme attack (E) and protein bodies' indentations (I).

Sorghum starches (C-42y and bulk) had the highest pasting temperature (78.5° and 78°C), 6°C higher than millet starch (72°C). Gelatinization temperature ranges determined with the hot-stage microscope were 63°–74°C for sorghum and 51°–69°C for millet.

In general, pasted starches lose viscosity during a 1-hr holding period at 95°C, because the swollen granules progressively fragment and solubilize (14). Millet and sorghum starch, although having similar peak viscosities, differed in viscosity properties during the 1-hr holding period at 95°C. Viscosity of millet starch gradually decreased the first 45 min and then rose abruptly (about 200 Brabender Units (BU) during the last 15 min. The C-42y sorghum starch showed a similar, but smaller, rise late in the holding period and then another decrease in viscosity.

Viscosities of all the starches increased while cooling from 95° to 50°C. The bulk sorghum starch had the highest setback (170 BU), and millet and C-42y sorghum were 140 and 133 BU, respectively. Thus, in contrast to a previous report (15), pearl millet starch tended to retrograde during cooling.

Amylose-Amylopectin Ratio

Pearl millet and bulk sorghum starches were fractionated by sedimentation and precipitation, and the amylose content determined by iodine blue value. The millet starch contained 17% amylose and the bulk sorghum starch, 23% amylose. Millet (species not specified) starch has been reported to contain 12–19% amylose (16), compared with 22–28% for sorghum grain starches (17). Thus, our data and the earlier reports indicate that millet starches contain less amylose than do sorghum starches.

Flour Hot-Paste Viscosity

Amylograms of millet flour gave drastically lower peak viscosity than similar amylograms of sorghum flour. The low peak viscosity of the millet flour used in this study compared with the normal peak viscosity for millet starch isolated from that flour suggested that the millet flour contained an active amylase system.

Hot-paste viscosity was used to compare the amylase activity of the millet flour with malt (a flour milled from malted wheat) when each was added to an unmalted wheat flour (Figs. 2 and 3). Approximately 10% millet flour (based on wheat-flour weight) or 0.15% of malt lowered hot-paste viscosity of an unmalted wheat flour equally.

TABLE I
Pasting Properties of Millet and Sorghum Starches

Starch[a]	Pasting Temp. °C	Peak Viscosity BU	Peak Temp. °C	Viscosity, BU[b] 1 hr at 95°C	Cooled to 50°C	1 hr at 50°C
Pearl millet	72.0	560	95	640	780	755
Bulk sorghum	78.0	570	95	515	685	675
C-42y sorghum	78.5	635	95	605	738	740

[a]40-g samples.
[b]Brabender Units.

Bread-Baking

Adding 10% millet flour to our standard baking formula (malt omitted) increased loaf volume from 855 to 890 cc (Table II and Fig. 4) and improved crumb grain. Wheat flour, baked without malt and sugar in the formula, gave a poor loaf volume (400 cc), a compact crumb grain, and pale crust. Adding 10%

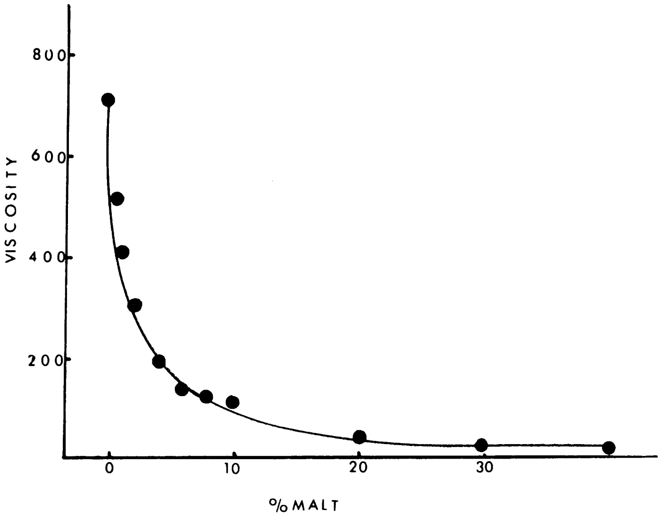

Fig. 2. Effect of malted wheat flour on wheat-flour (60 g, 14% m.b.) hot-paste viscosity (% of malt based on wheat-flour weight).

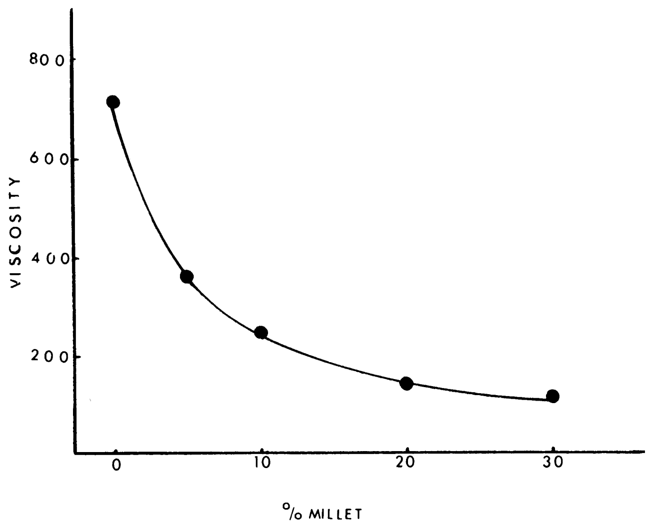

Fig. 3. Effect of millet flour on wheat-flour (60 g, 14% m.b.) hot-paste viscosity (% of millet flour based on wheat-flour weight).

(based on wheat-flour weight) millet flour to that formula (no malt and sugar) gave a loaf volume (925 cc) significantly better than the same wheat flour baked with the formula containing 6% sugar (855 cc).

Sorghum flour added to the standard baking formula deleteriously affected loaf volume (Table II). There was no difference in loaf volumes with 5 or 20% sorghum flour. Adding 10% sorghum flour to a formula containing no malt or

TABLE II
Loaves Bakes from 100 g of Wheat Flour (14% m.b.) Plus Indicated Levels of Sorghum and Millet Flour

	Loaf Volume, cc	
Treatment	**6% Sugar—no malt**	**No sugar or malt**
Wheat control	855	400
5% Millet	905	850
10% Millet	890	925
15% Millet	880	905
20% Millet	830	...
5% Sorghum	820	400
10% Sorghum	820	400
15% Sorghum	822	400
20% Sorghum	822	400

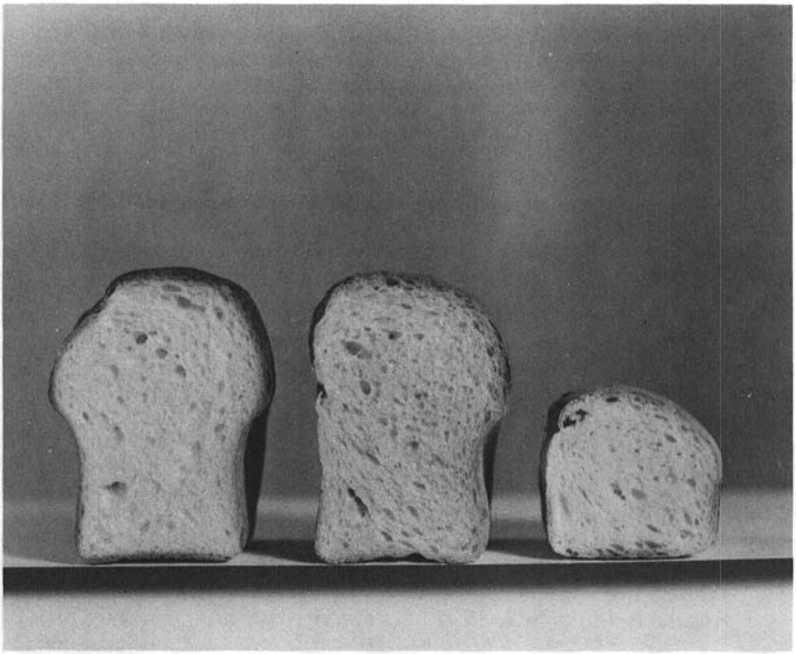

Fig. 4. Cut loaves of bread: (*left*) regular formula; (*center*) 10% millet flour, no sugar or malt; (*right*) no millet flour, no sugar or malt.

sugar gave a loaf volume (400 cc) equal to the wheat flour alone baked with the same formula. Surfactants (soybean oil and/or sodium stearoyl-2-lactylate) did not improve loaf volume with either millet or sorghum flour.

The improving action of millet flour added to wheat flour in a formula without sugar or malt indicated that the millet flour contained a highly active α-amylase system. No evidence is available that all millet varieties contain such an active amylase system. Bread containing 10% millet flour had an excellent texture and a flavor similar to whole wheat bread. Replacing malt and sugar in the baking formula with millet flour appears to be highly important economically, particularly in countries where millet is grown, where sugar is a cash crop for foreign exchange, and where malt and wheat must be imported.

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