Hardness of Pearl Millet and Grain Sorghum[1]

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ABSTRACT

The hardness of various populations of pearl millet and cultivars of grain sorghum was determined by particle size analysis after the grains were milled on attrition and roller mills. Millets grown in Sudan were, in general, softer than Kansas-grown ones. However, kernel vitreousness did not parallel grain hardness as determined by particle size analysis. Furthermore, tempering either millet or sorghum before milling shifted the particle distribution to larger sizes compared with those of nontempered samples.

Grain hardness has always been a major concern of millers because it determines grinding time and energy expenditure as well as the performance and appearance of the final product. Grain hardness also concerns people in developing countries where much milling is done by hand with wooden or stone mortars or with hand-operated stone mills (Vogel and Graham 1979).

Although a substantial number of reports have dealt with techniques to measure wheat hardness (Obuchowski and Bushuk 1980), only limited data are available on hardness of grain sorghums and pearl millets (Maxon et al 1971; Rooney and Sullins 1969, 1970). We determined the hardness of various populations of pearl millet and cultivars of sorghum by characterizing particle sizes after milling the grains in attrition and roller mills.

MATERIALS AND METHODS

Materials

Proximate compositions and pedigrees of the millet and sorghum samples were described previously (de Francisco et al 1981). One additional pearl millet, HMP557A, had a proximate composition of 10.4% protein, 9.8% moisture, 1.6% ash, and 5.7% fat. It was grown near Mineola, KS, in 1979.

Grain Cleaning

The millet samples were cleaned in a model FC9 Kice aspirator (Kice Metal Products Co., Wichita, KS) to remove light-weight debris. Adhering glumes were removed in a Satake (Tokyo, Japan) rice polisher, and broken and undersized kernels were removed by passing the grain over a Tyler Rotap sieve 8 in. in diameter with 2,362-μm openings. Glumes on sorghum kernels were removed by hand.

Moisture Determination

Moisture contents of millet and sorghum were determined by the AACC method (1976).

Milling and Sieving Studies

Grain samples (50 g) were milled in a Hobart coffee grinder attrition mill, model 275 (Hobart Mfg. Co., Troy, OH), at the finest setting. The milled product was then collected and placed on a stack of Tyler Rotap sieves 8 in. in diameter (Table I) for 1 min to separate the different particle sizes.

The separated particles were combined into two fractions. One, called the fines, consisted of the overs of the 295, 208, and 147-μm sieves and the pan fraction. The other fraction, the coarse particles, included the overs of the 1, 191, 833, 589, and 417-μm sieves. Those two fractions were milled separately in a Ross E-2 laboratory mill equipped with 6-in. smooth rolls operated at a differential of 1–1.5.

TABLE I
Tyler Rotap Sieve Stack Used for Particle Size Distribution

U.S. Equivalent	Opening (μm)
16	1,191
20	833
30	589
40	417
50	295
70	208
100	147
pan	<147

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Roll gaps for fine and coarse fractions were 80 and 100 μm, respectively. Sieve analyses were then performed on the Tyler Rotap sifter as described. Standard deviations for two to three replicates of each sample ranged from ± 0.14 to 0.89%.

Tempering of Millet and Sorghum

Sudan Yellow and Serere millets were conditioned with water for 15 hr to 15, 18, and 21% moisture contents. In addition, Serere was tempered to 18 and 21% moisture contents for 15 hr with 0.5% sodium metabisulfite as described by Badi et al (1978). Sorghums were tempered with water to 18% moisture content.

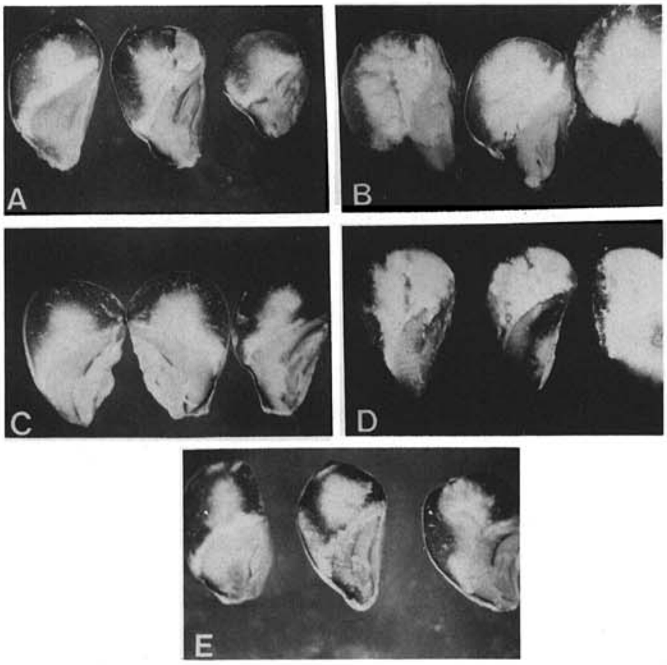

Fig. 1. Pearl millet kernels, showing distribution of opaque and translucent endosperm in various populations: **A,** Serere 3A; **B,** HMP550; **C,** Sudan Green; **D,** Sudan Yellow; **E,** RMPI(S)CI.

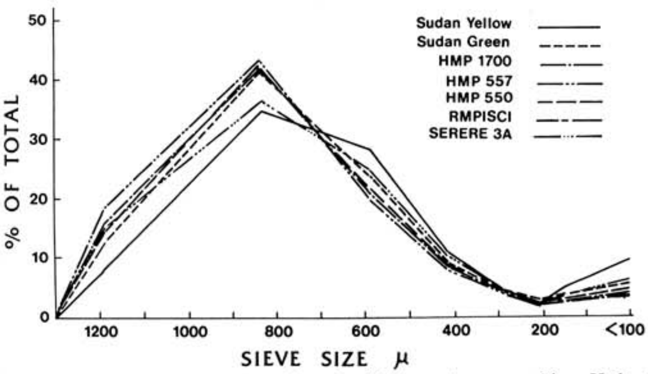

Fig. 2. Particle size distribution of pearl millet samples ground in a Hobart mill.

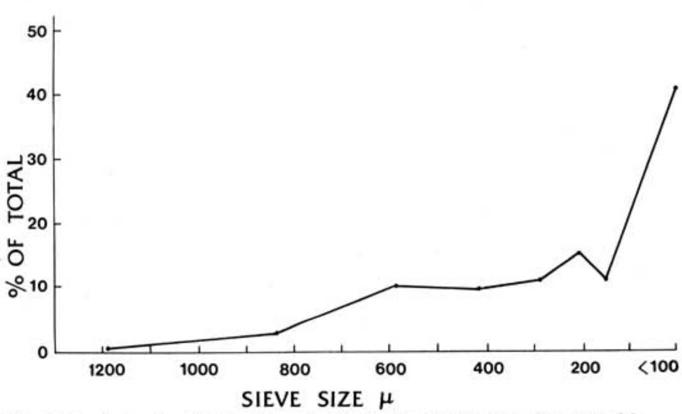

Fig. 3. Particle size distribution of soft wheat ground in a Hobart mill.

Scanning Electron Photomicrographs

Samples of the fine fractions were dusted on double-stick tape mounted on aluminum stubs. Coarse fractions were mounted on stubs with conductive silver paste. Samples were coated with 150-Å gold/palladium (60:40) and then viewed and photographed in an ETEC U-1 autoscan electron microscope at an accelerating voltage of 20 kV.

RESULTS AND DISCUSSION

Millet

Visual observations of representative hand-dissected kernels of pearl millet (Fig. 1) showed that the populations differ in proportions of translucent and opaque endosperm. Serere 3A, RMPI(S)CI, and Sudan Green have higher proportions of translucent endosperm than do HMP550 or Sudan Yellow. Opaque and soft are generally assumed to be synonomous. To test that assumption, we used a series of milling and sieving operations to study the relationship between vitreousness (and opacity) of millet samples and physical hardness as determined by particle size distribution after grinding.

Grinding pearl millet samples in the Hobart mill did not differentiate the samples by particle size (Fig. 2). If the opaque endosperm were soft, it should have broken into smaller particle sizes during Hobart milling. Soft wheat similarly ground gave a finer particle size distribution (Fig. 3). Further grinding of the millet fine particle fraction, which presumably originated from the opaque endosperm, in a Ross laboratory mill equipped with smooth rolls, did not change the particle size distribution of the fine fraction. Thus, that fine fraction is characterized by strong bonds between starch granules and protein matrix (Fig. 4), which is typical of hard endosperm particles.

Milling the coarse fraction, which contained the major portion of the pericarp, with Ross smooth rolls shifted the particle size distribution to finer sizes (Fig. 5). The reduction in particle size probably does not reflect grain softness but simply the fact that larger particles are easier to reduce.

In general, the coarse millet samples could be divided into two groups according to particle size distribution after Ross milling

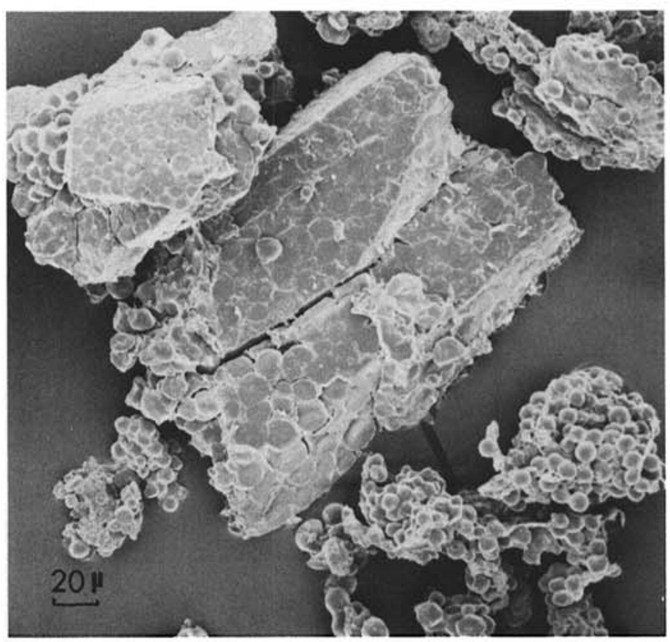

Fig. 4. Scanning electron micrograph of millet particles after roller milling the fine fraction (<417 μm) produced on the Hobart mill.

(Fig. 5). The first group (containing relatively large particle sizes) included all the millets grown in Kansas. Millets obtained from Sudan formed the second group, which gave smaller particle size distributions. Thus, the large endosperm particles of the millets from Sudan were more easily disrupted during milling and, therefore, softer than were the large particles from millets grown in Kansas. Millets from Sudan were nevertheless much harder (ie, gave larger particle sizes) than a soft wheat (Fig. 3).

Sorghum

To determine whether grain sorghums showed the same milling characteristics as pearl millets, we ground the three experimental sorghum lines in the Hobart mill. All gave similar particle size distributions (Fig. 6A). Milling the coarse fractions from the Hobart mill on the Ross smooth rolls gave similar particle size distributions (Fig. 6B) for SRAI W6 and SRAI W4, but a larger percent of the Dwarf White was in the smaller particle sizes. Those results indicate that Dwarf White is softer than the other sorghum cultivars. This is contrary to what might be expected from its higher proportion of translucent endosperm (Fig. 7).

Tempering Studies on Millet and Sorghum

Millet. To determine the effect of tempering on the size of particles produced, we tempered Serere 3A and Sudan Yellow millets to moisture contents of 15, 18, and 21% and then ground the samples in the Hobart mill and sieved them. Tempering and subsequent milling did not significantly change the particle sizes (Figs. 8A and 9A), compared with those of the nontempered samples (Fig. 2). When the coarse fractions were passed through the Ross smooth rolls and sifted, the particle size distribution showed that tempering produced larger particle sizes (Figs. 8B and 9B). For both millet samples, as the tempering level (moisture content) was increased, the particle size of the products increased (ie, they showed less reduction as a result of milling). Thus, tempering appears to make the particles resistant to reduction. This is contrary to reports (for wheat) showing that tempering causes the endosperm to break into finer particles (Butcher and Stenvert 1973).

The factor responsible for grain hardness in wheat is the strength of the protein-starch bond (Simmonds 1974, Simmonds et al 1973), which is weakened by water; the water may therefore be responsible

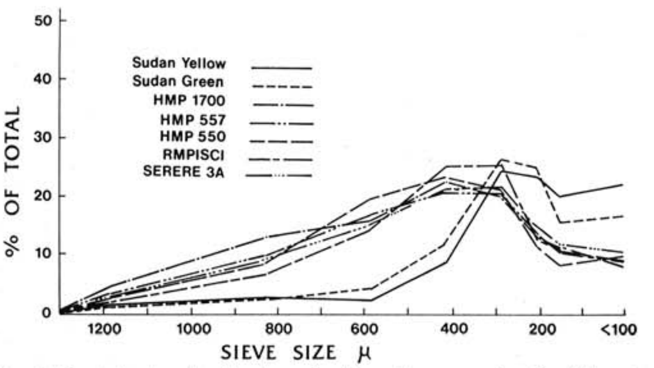

Fig. 5. Particle size distribution of millet after smooth-roll milling the coarse fraction (>417 μm) produced on the Hobart mill.

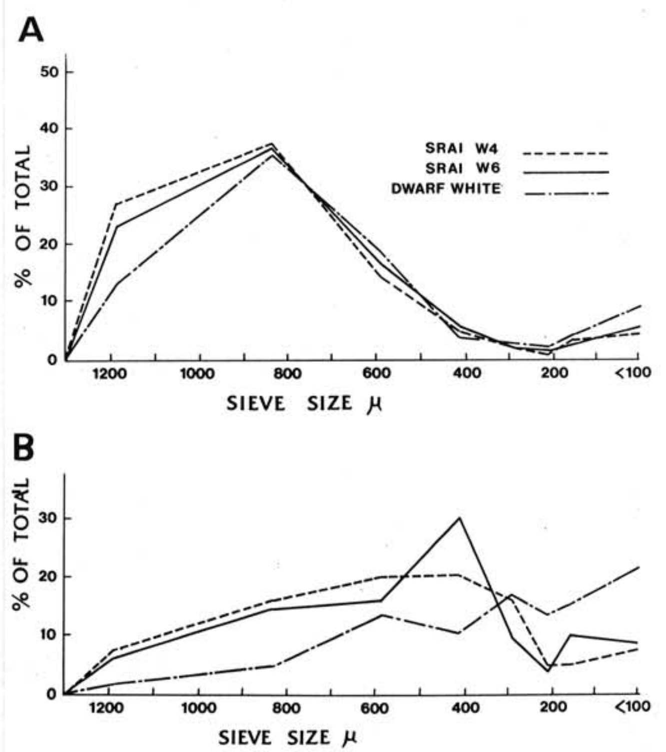

Fig. 6. Particle size distribution of: **A,** sorghums ground in a Hobart mill; **B,** the sorghum coarse fraction (>417 μm) after passing through smooth rolls.

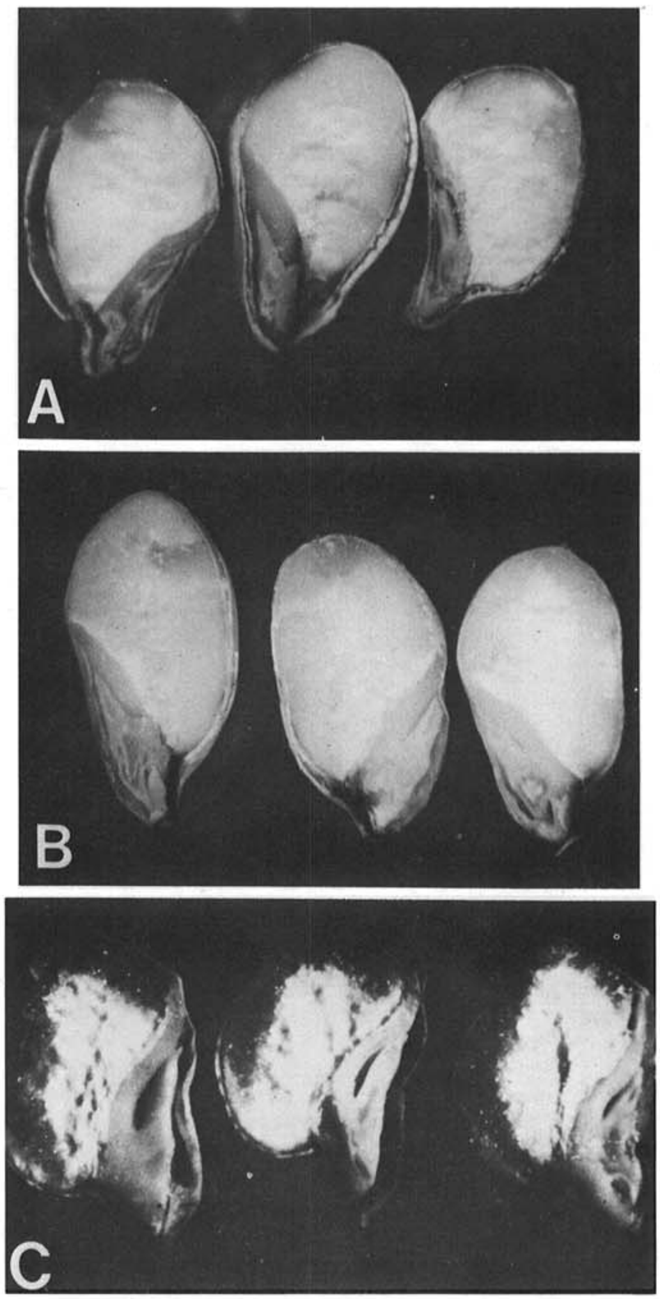

Fig. 7. Grain sorghum kernels, showing distribution of opaque and translucent endosperm in various cultivars: **A,** SRAI W6; **B,** SRAI W4; **C,** Dwarf White.

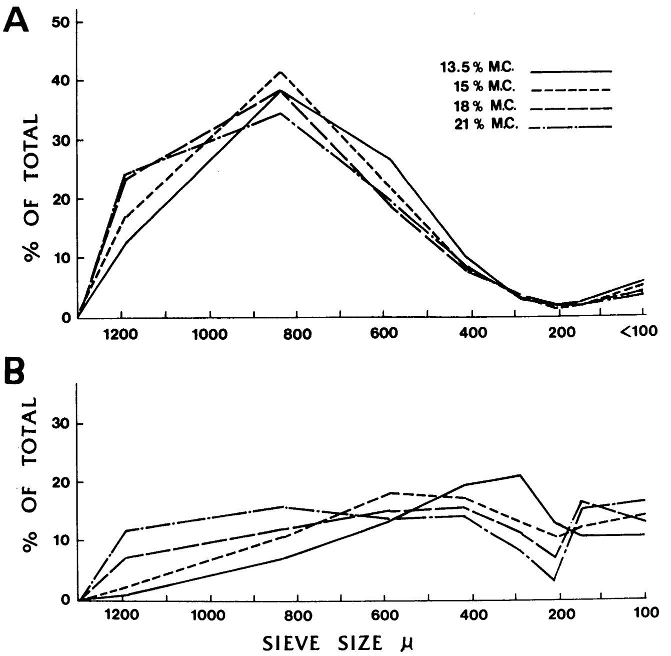

Fig. 8. Particle size distribution of: **A,** tempered Serere 3A millet ground in a Hobart mill; **B,** the coarse fraction (>417 μm) after passing through smooth rolls.

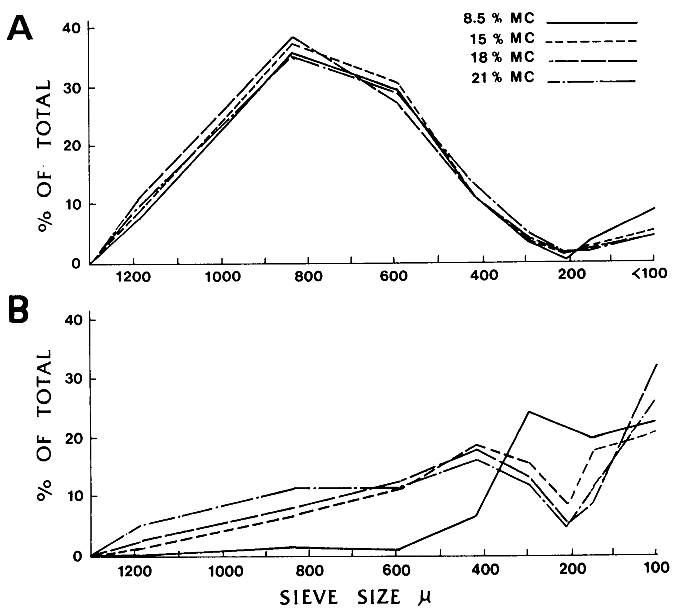

Fig. 9. Particle size distribution of: **A,** tempered Sudan Yellow millet ground in a Hobart mill; **B,** the coarse fraction (>417 μm) after passing through smooth rolls.

for the softening effect during wheat tempering. However, tempering millet with water did not decrease the particle size distribution, ie, it did not soften millet (Fig. 8B). We, therefore, tempered Serere 3A to 21% moisture with 0.5% sodium metabisulfite, an agent that weakens the starch-protein bond (Badi et al 1978), ground it in the Hobart mill, and sifted it as described. The particle distribution after grinding in the Hobart mill was the same as observed with the water temper (Fig. 8A). Similarly, passing the coarse fraction through Ross smooth rolls did not alter particle size distribution from that of the water temper (Fig. 8B). Therefore, tempering with sodium metabisulfite shows no advantage in particle size reduction over tempering with water.

Sorghum. Tempering all three sorghums to 18% moisture and

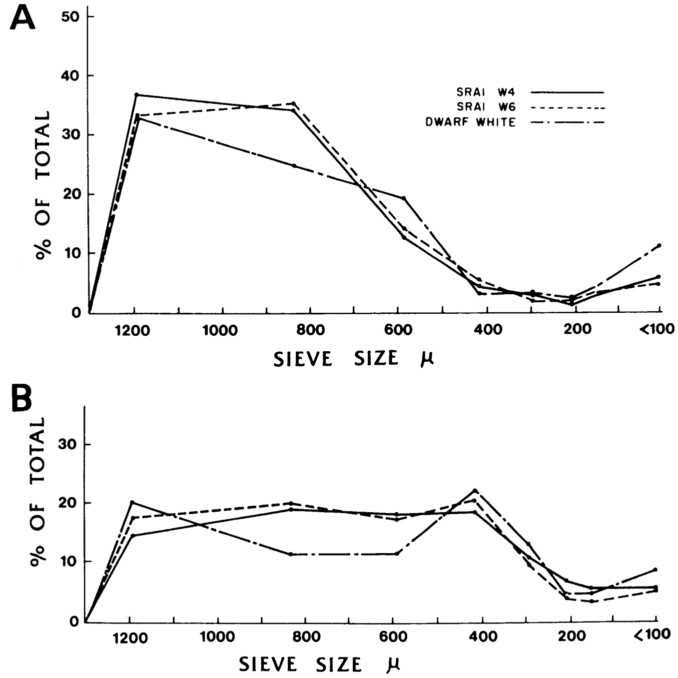

Fig. 10. Particle size distribution of: **A,** tempered sorghum ground in a Hobart mill; **B,** the coarse fraction (>417 μm) after passing through smooth rolls.

grinding them in the Hobart mill gave a larger number of particles exceeding 1,191 μm (Fig. 10A) than was found for untempered sorghum (Fig. 6A), again suggesting that the tempering process made the larger particles more resilient and thus more resistant to breakage. When the coarse fraction of tempered sorghums was passed through the Ross smooth rolls, the distribution shifted to larger particle sizes (Fig. 10B) than those for untempered sorghum (Fig. 6B). This was particularly true for the coarse fraction of Dwarf White. Thus, grain sorghum and pearl millet respond to tempering similarly.

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