NOTE

A Device for the Preparation of Cereal Endosperm Bricks

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The study of cereal chemistry has been advanced by the analysis of the material properties of cereal endosperm. In particular, the study of wheat (*Triticum* sp. L.) endosperm hardness (kernel texture) has been a topic of intense interest for the past ≈100 years (Pomeranz and Williams 1990; Morris 2002). One of the first recorded devices for measuring wheat kernel texture was that of Roberts (1910), which determined the force required to crush individual kernels. There are two reasons why the assessment of kernel texture in wheat, in particular, is of great interest: 1) wheat exhibits distinct classes of kernel texture, namely soft, hard, and durum; and 2) the differences in kernel texture among these classes has a profound effect on flour milling, starch damage, particle size distribution, water absorption, and end-use quality (Morris and Rose 1996; Morris 2002). As we will describe, our objective was to produce a geometrically defined subsample of the endosperm as opposed to studying the whole kernel.

The measurement of wheat kernel texture has been largely empirical because kernels and endosperm are difficult to work with due largely to their diminutive size. Current methods (AACC International 2000) such as near-infrared reflectance (Approved Method 39-70A), particle size index (Approved Method 55-30), and single kernel characterization System (Approved Method 55-31) provide measurements in arbitrary unitless proportions or scales. Generally, to obtain objective measures of material properties in universal units of force, work, etc., complex geometries must be simplified, and in the case of wheat, the bran, germ, and pigment strand should also be eliminated. A few researchers have been successful in achieving this goal. Glenn of the USDA developed a method of "turning" on a lathe endosperm cylinders of defined geometry, and then subjecting them to testing in both compression and tension (Glenn et al 1991; Jolly 1991; Jolly et al 1996; Delwiche 2000; Osborne et al 2001; Dobraszczyk et al 2002). This same technique was studied in the senior author's lab and found to be exceedingly tedious. The centering of the kernel "cheek" on the lathe stub was particularly problematic. Haddad, Abecassis and co-workers (Haddad et al 1998, 1999, 2001; Samson et al 2005) eliminated the problems associated with "turning" cylinders, by preparing through sanding rectangular parallelepipedal test samples. Here we term such specimens "bricks". We have devised and constructed a similar device that eliminates the need for adhesive paper and glue to hold specimens during their preparation (see Haddad et al 1998). Furthermore, one of the processing steps in the technique described by Haddad et al (1998) as "Two machined half-grains are placed between two sheets, and a wedge is set at height l of the extremities of the sheets" has been eliminated. We have used the device described here to prepare hundreds of bricks of various wheat (*Triticum aestivum* and *T. turgidum* var. *durum*) cultivars, including vitreous and nonvitreous (mealy) kernels selected from individual grain lots. These bricks are amenable to material property analysis using common instrumentation such as the TA-XT2i in compression mode. Our experience to date indicates a very low rate of "aberrant" failure, which could be ascribed to cracks or other "defects", of the bricks so prepared and tested, on the order of ≈1–2%.

Description of the Device

The kernel sander is comprised of two parts, the base (lower) and sander (upper) components (Figs. 1 and 2, respectively). The salient features of the base include 1) a series of channels of various dimensions to accommodate and hold the specimens during their sequential machining, and 2) side rails that support and guide the sander. Here the machining process involves the gradual removal of kernel material through the use of very fine sandpaper (silicon carbide ANSI Grade 320) ('413Q 320 Wetordry Tri-M-ite', 'A' weight paper, 3M Corp., St. Paul, MN). The sandpaper is held in place by clamps to the bottom surface of the sander. Although not deemed absolutely necessary, the leading and trailing edges of the bottom surface of the sander were beveled to reduce the sander thickness by 1.2 mm and sloping 13 mm from each end toward the center. The device was made from aluminum '6061' and common sizes and types of bolts, for example the side rails are attached to the bottom part with #10-32 Allen head (hexagonal socket) cap screws. For wheat kernels, the dimensions of the channels in the base were determined empirically and could be modified for different cereal grains. Figure 3 shows in detail the channels and their dimensions.

Endosperm Bricks

The wheat kernel was first placed crease-side-up (Fig. 3, "X") and split in two with a razor blade or scalpel. We found this preferable (and safer) to trying to hold the kernel with fingers. Each kernel half (cheek) was then placed in "C" where one smooth side was produced by sanding. In all sanding operations, no more weight than the upper component itself (≈735 g) was applied to the specimen; often less, as some of the weight of the upper component was partially supported by hand. The specimen was then flipped over and the other side was sanded smooth until the sander was supported by the side rails. Channels "A" and "B" provided additional thickness options. Once the half kernel had been reduced to a specimen with two parallel faces, the specimen was placed in "I", sanded down until the side rails supported the sander and then placed in "H" and again sanded until the rails supported the sander. "D" and "E" were designed to provide equivalent specimen preparation in concert with "B"; and "F" and "G" in concert with "A" (Fig. 3). After machining, the ends were trimmed using a razor blade or scalpel. Generally, machining each face required less than a dozen passes with the upper component.

Figure 4 shows endosperm bricks prepared using the kernel sander device. Specimens were sputter-coated with gold to 300 Å thickness and imaged in a scanning electron microscope (Hitachi

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S-570, San Jose, CA) at 20 kV and a 15-mm working distance. Figure 4A and B shows that the kernel sander is effective in producing bricks of uniform dimensions, flat faces, and square corners from soft and hard hexaploid wheat kernels, respectively. Figure 4C provides an example of a brick prepared from the vitreous portion of a kernel of a commercial yellow dent maize hybrid.

Because of the limitations of the size of wheat kernels and the design of the kernel sander device, the bricks are ≈2.08 by 1.06 by 0.76 mm in size. Clearly, if larger cereal grains were the focus of material research, the base channels could be modified accordingly. Similarly, machining tolerances need only meet the practical needs of brick preparation. As opposed to attempting to measure directly the dimensions of the bricks by the use of calipers (micrometers) (Haddad et al 1998), we routinely used digital photography where the specimen size was determined using a calibrated image of a 2-mm scale on an NIST stage micrometer microscope slide (AT#12-561-SM3, Fisher Scientific, Hampton, NJ) as reference to ascertain the number of pixels per unit length of the digital images of the brick. An accurate measure of brick dimensions is important to the conversion of compression data to common material property units such stress, strain, and Young's elastic modulus.

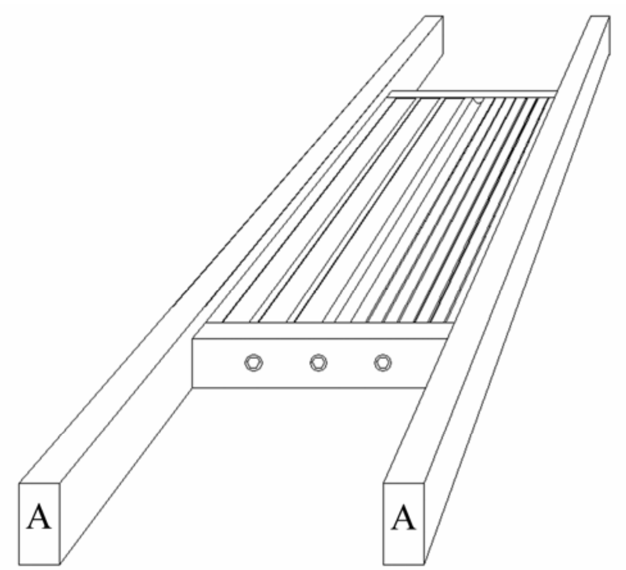

Fig. 1. Schematic of the base of a kernel sander device for preparing rectangular parallelepipedal cereal endosperm test samples ("bricks"). Dimensions of each side rail (A) are ≈12.8 mm × 25.6 mm × 360 mm; the central portion of the base with channels is ≈101.4 mm × 152.5 mm × 18.7 mm.

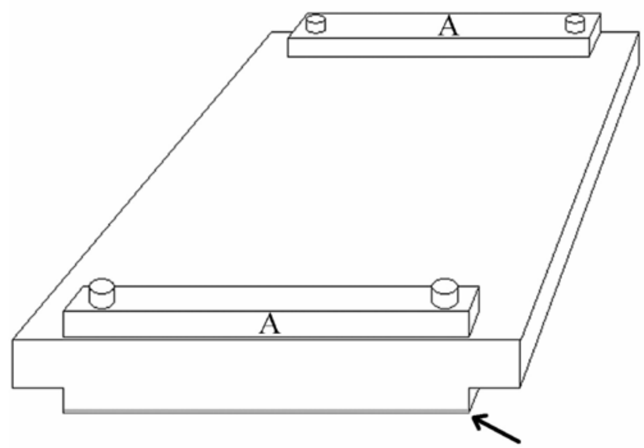

Fig. 2. Schematic of sander (upper component) of a kernel sander device for preparing cereal endosperm bricks. Outer dimensions are ≈114.8 mm × 127.1 mm × 18.9 mm. Clamps for holding sandpaper with bolts are shown (A). Arrow points to the leading lower edge which can be optionally beveled; the beveled area is shaded gray and is very thin in the image.

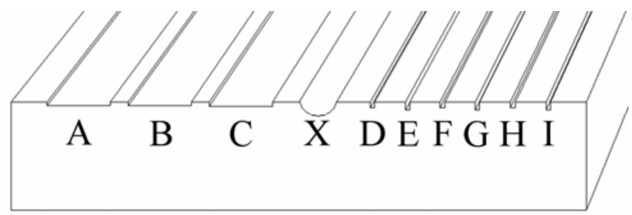

Fig. 3. Schematic of the base of a kernel sander device showing channel detail. Channel dimensions are (depth by width): A, 0.58 × 11.0 mm; B, 0.63 × 11.0 mm; C, 0.68 × 11.0 mm; D, 1.0 × 0.72 mm; E, 1.4 × 0.72 mm; F, 1.0 × 0.77 mm; G, 1.4 × 0.77 mm; H, 1.0 × 0.82 mm; I, 1.4 × 0.82 mm; X is a half-cylinder of 6-mm diameter.

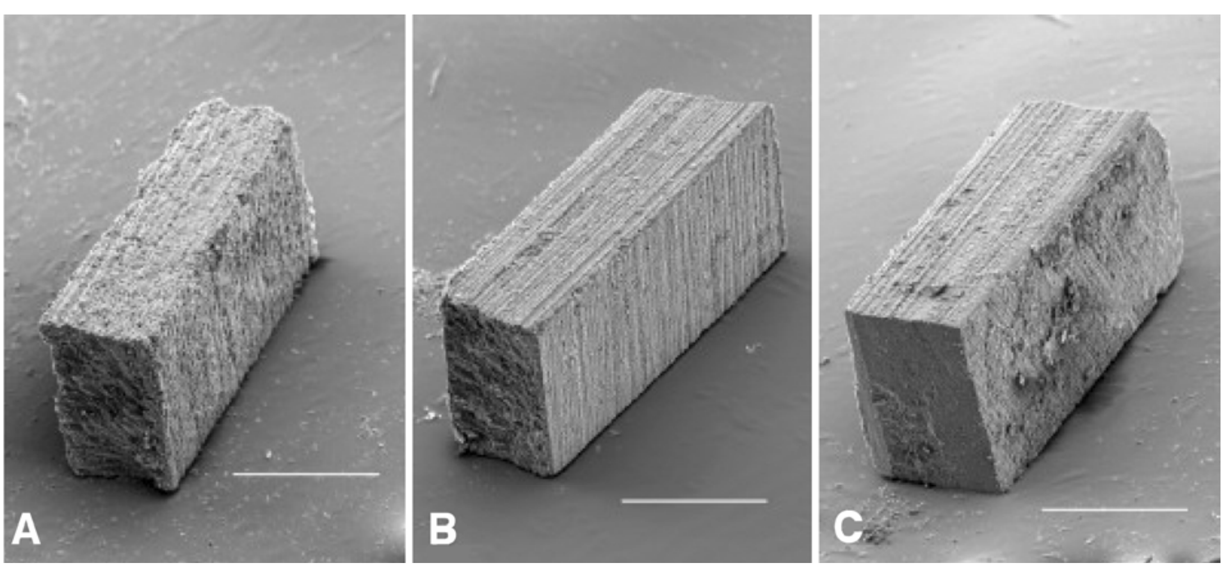

Fig. 4. Scanning electron microscope images of endosperm "bricks" prepared using the kernel sander device from (**A**) a soft wheat kernel, (**B**) a hard wheat kernel, and (**C**) the vitreous portion of a kernel of a commercial yellow dent maize hybrid. Bars = 0.75 mm.

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