NOTE

Sorghum Pericarp Thickness and Its Relation to Decortication in a Wooden Mortar and Pestle[1]

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In Mali, as in most parts of West Africa, sorghum is decorticated as the first step in food preparation (Rooney and Kirleis 1980). The term "milling" usually refers to decortication of the grain plus reduction of the decorticated grain into flour or other products. Traditionally, decortication is accomplished by pounding the grain in a wooden mortar with a wooden pestle. The pestle weighs approximately 3 kg and does not have a metal butt like many pestles used in India. The mortar weighs approximately 12 kg and has an approximate capacity of 12 L. Before decortication, the grain is washed thoroughly to remove dust, glumes, and small stones. During washing, the grain absorbs water and reaches about 20% moisture. Immediately after washing, a 2–3-kg grain lot is introduced into the mortar and pounded. The pounding is done by one or two women, each having a pestle and working face to face. During pounding, additional water is added to soften the pericarp, which facilitates its removal. The grain is inspected periodically to determine satisfactory decortication. After decortication, the grain is washed, drained, and usually milled immediately into flour.

Pericarp thickness of the sorghum kernel is controlled genetically. Ayyangar et al (1934) proposed the symbol *Z*- for the gene controlling pericarp thickness. The thin pericarp (pearly) is manifested in the presence of a single dominant *Z*-allele, whereas the thick pericarp (chalky) is determined by two recessive alleles, *zz*. Scheuring found sorghums with a very thick pericarp (flaky) with inheritance that is recessive to both thin and thick pericarp characters (Scheuring et al 1977). Pericarp thickness has been discussed in terms of rapid water absorption and ease of removal (Ayyangar et al 1934, Swanson 1928), but decortication data using traditional milling methods of grains with contrasting pericarp types have not been reported. Previous studies with abrasive milling techniques led to general conclusions that thin, pearly white sorghum kernels have the best dry-milling properties for pericarp removal (Maxson et al 1971).

The purpose of this study was to document differences in the ease and extent of decortication during traditional manual milling of sorghums with different pericarp thickness but with similar intermediate endosperm hardness.

MATERIALS AND METHODS

Grain Lots

Local Guineense sorghum grain with thick and thin pericarps was obtained from markets at Ouagadougou, Upper Volta and Fana, Mali. Nio-Fionto (*Nervosum* var. *membranaeceum* as classified by Snowden) was harvested from a field in Cinzana, Mali. All the grain samples were harvested during the 1979 crop season.

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Grain samples were evaluated for 1,000-kernel weight, endosperm texture, kernel hardness, and pericarp thickness. Thousand-kernel weight was calculated as the mean of five replications for each sample. Endosperm texture (ratio of corneous to floury endosperm) was rated subjectively for 20 grains of each lot on a scale of 1 (most corneous) to 5 (most floury). Grain hardness was measured as breaking strength (kg) with the Kiya Seisakuyo grain hardness tester 174866 (Phillip Rahm, Houston, TX), and was the mean of 20 observations for each sample of grain. Pericarp thickness was visually rated as thin, thick, and very thick, and was later confirmed by scanning electron microscopy.

The kernels were cut in half with a razor blade. Half-kernels were mounted on metal stubs with silver conductive paint, coated with gold-palladium, and scanned on a JEOL JSM-35 scanning electron microscope with an accelerating voltage of 25 kV. Pictures were taken with Kodak Tri-X film with an ASA of 400.

Traditional Decortication Procedure

Grain lots (2 kg) were decorticated by a Malian woman using a traditional West African mortar and pestle. Only six samples were decorticated per day to minimize the effects of fatigue on the woman. Three replications were done for each Guineense sorghum type and eight replications for the Nio-Fionto sorghum.

Decortication time is defined here as the duration of pounding, from the introduction of the washed grain into the mortar until the pericarp was completely removed. Approximately 300 ml of water was absorbed by the grain during washing, and an additional 300 ml was added during pounding. The decorticated grain was washed to remove the bran and sun-dried for three days. All dry grain lots had 6% moisture before decortication. The weights of the dried, decorticated grain were adjusted to 6% moisture, and the endosperm recovery rate was determined as the percentage of original grain recovered as decorticated grain.

Laboratory Decortication Procedure

Ten-gram grain lots of the very thick pericarp Nio-Fionto and thick and thin pericarp Tiemarifing sorghums, Guineense, were decorticated for 1 min at 1,200 rpm in a Udy pearler (Shepherd 1979). Four replications were done for each grain type. The bran was sieved with a U.S. 40-mesh screen. Recovery of decorticated grain and the weight of the overs and throughs of the 40-mesh screen were determined for each grain lot.

RESULTS AND DISCUSSION

An inverse relationship clearly existed between pericarp thickness and the time required for mortar and pestle decortication (Table I). As pericarp thickness increased, decortication time decreased. Scanning electron microscopy of sorghum kernels with the three different pericarp types revealed clear differences in pericarp structure. The thin pericarp sorghums (Fig. 1A, B) did not have any starch granules in the mesocarp, and the pericarp tissues were tightly layered. The thick pericarp sorghums (Fig. 1C, D) had abundant starch granules held in a loose mesocarp network. The very thick pericarp sorghum (Fig. 1E, F) had a large number of starchy mesocarp cells filled with small starch granules. Photomicrographs were taken at approximately the same location in the periphery of the kernels to permit comparison of pericarp

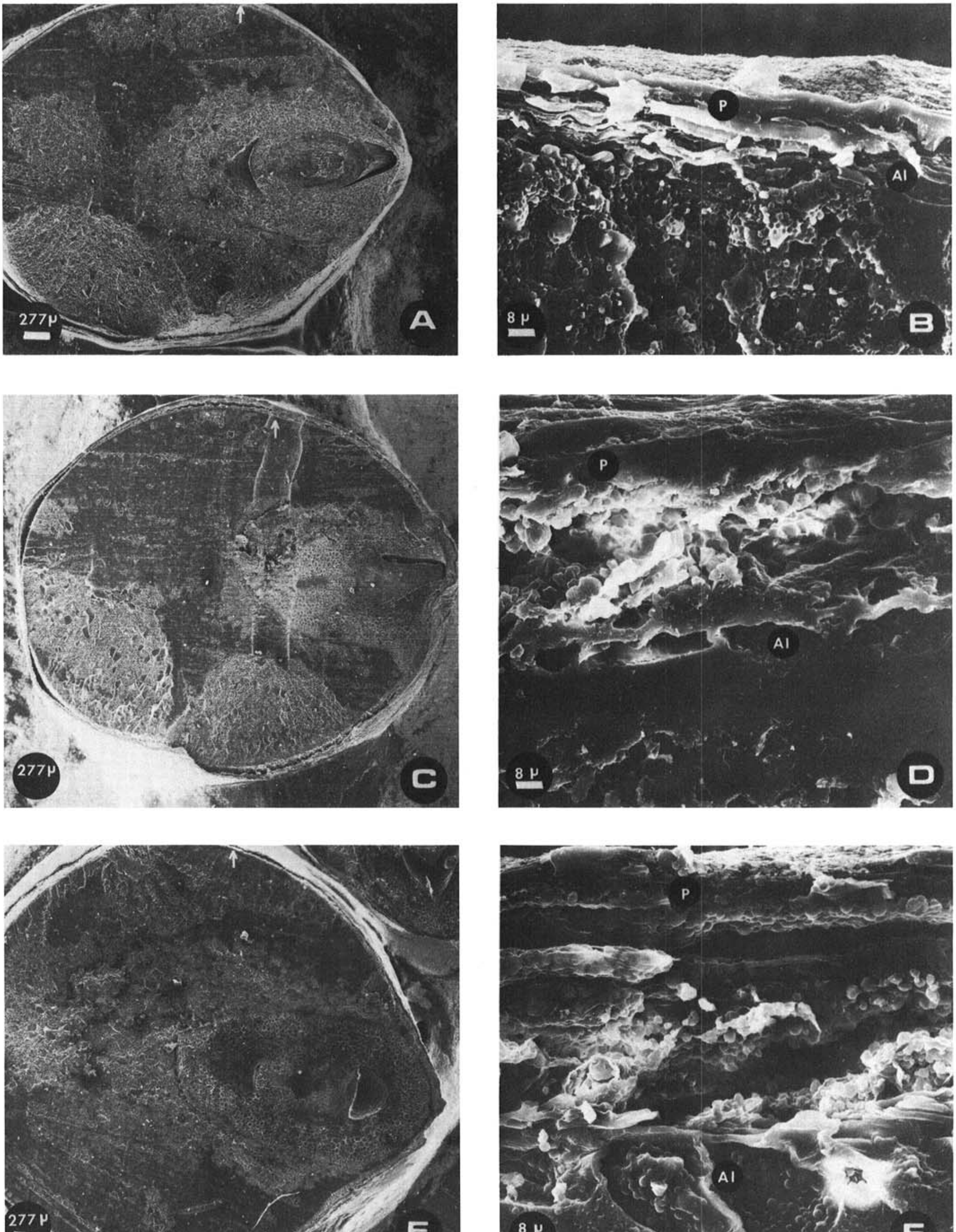

Fig. 1. Scanning electron photomicrographs of three sorghums with varying pericarp thickness. **A, B:** Guineense with a thin pericarp without starch granules; **C, D:** Guineense with a thick pericarp with starch granules in the mesocarp; **E, F:** Nio-Fionto grain with a much thicker pericarp and considerable starch in the mesocarp. P = Pericarp, and Al = aleurone layer. The arrows on A, C, and E indicate where the B, D, and F sections were photographed. The photomicrographs were taken at the same magnification and approximate location in the periphery of the kernel. (Magnification = ×18 for A, C, and E; and ×600 for B, D, and F.)

thickness. The pericarp thickness varied at different locations around the kernel. The kernels of Nio-Fionto sorghum (Fig. 1E,F) were much larger (Table I) and slightly but not significantly softer (0.2 and 0.7 kg less breaking strength required in hardness test when compared to thin and thick Guineense) than those of the Guineense sorghums. In general, the pericarp breaks at the endocarp-mesocarp areas (Shepherd 1981).

During traditional decortication, the washing of grain, followed directly by pounding and wetting, does not allow time for significant amounts of water to move into the endosperm of the grain. Therefore, most of the water remains in the pericarp and germ and is removed with the bran during decortication. The wet bran serves as a soft abrasive agent that helps to abrade the remaining pericarp adhering to the grain. However, most of the decortication action is due to friction between kernels.

For the Nio-Fionto grain, the pericarp starts to rip loose after the third thrust of the pestle, and a bran paste is formed quickly thereafter. The thick spongelike structure of the Nio-Fionto pericarp facilitates its easy separation from the endosperm. After the pericarp is disrupted, additional rapid absorption of water occurs, and the pericarp is removed in large strips and flakes.

The thick pericarp Guineense grain is not as rapidly decorticated as the Nio-Fionto. For Guineense grain, 5–10 min of pounding is required before the bran forms a paste. The denser structure of the thick pericarp is harder to disrupt than the very thick pericarp of Nio-Fionto grain. The thick pericarp breaks apart rather than tearing into strips like the Nio-Fionto pericarp. In contrast, the thin pericarp Guineense grain takes 10–15 min of pounding time before a bran paste is formed. The pericarp adheres strongly to the germ areas, and a much longer time is required to completely remove it. The mesocarp is practically nonexistent in the sorghums that have a thin pericarp, so considerable effort is required to decorticate sorghum kernels with thin pericarps compared to those with thick pericarps. This can easily be observed by scraping the pericarp of sorghum kernels with a knife. The condensed pericarp structure of sorghum with dominant *Z*-genes certainly accounts for the difficulty in manual decortication of thin pericarp sorghums.

The thin pericarp sorghums required at least 25% more decortication time than the thick pericarp sorghums (Table I). Endosperm recovery for the three sorghum types did not differ significantly. However, the trend for endosperm recovery was highest for the Guineense sorghum with a thick pericarp. Recovery was lowest for the Nio-Fionto grain because the kernels were larger and of softer texture, which means that the kernels disintegrated during pounding even though the total pounding time was the lowest of all the grains. The decorticated grain yield was consistently lowest for the Guineense sorghum with the thin pericarp because the extra decortication time caused more breakage of the kernels and loss of endosperm in the bran. Kernel hardness, size, shape, and texture were similar for the two Guineense sorghums. The major difference was in pericarp thickness. Thus, this is an excellent direct comparison of pericarp thickness and shows that decortication time is reduced and yield is increased by manual pounding of sorghum. In traditional manual milling, the pestle weighs about 3 kg, and the Malian woman averages about 60 thrusts per minute. Thus, the saving of even 5 min of such work is substantial in the already difficult life of the Malian woman. Therefore, this preference must be carefully considered in sorghum breeding and improvement programs in which the sorghum is processed by traditional methods.

Mechanical decortication properties of the three sorghums were evaluated by using a small laboratory pearler. When the decortication time was held constant, the total bran yield increased in the following order: thin pericarp < thick pericarp < very thick pericarp (Table II). Laboratory pearling (decortication) confirmed the observations from traditional decortication trials that the sorghums with a thick pericarp produced larger bran flakes (bran over 40-mesh screen) immediately after the start of milling (Table II). Da et al (1982) also indicated that the pericarp could be removed more easily from the grain of thick pericarps than from

TABLE I
Grain Characteristics, Average Manual Decortication Time, and Endosperm Recovery of Sorghums with Contrasting Pericarp Thickness

Grain Type	1,000-Kernel Weight (g)	Endosperm Texture (vitreousness)	Hardness (breaking strength, kg)[a]	Pericarp Thickness	Average Decortication Time (min)[a]	Endosperm Recovery (%)[a]
Nio-Fionto (very thick pericarp)	43.8	3	8.7 a	Very thick	11.0 a	66.3 a
Malian Guineense (thick pericarp)	21.8	2	8.9 a	Thick	19.4 b	71.7 a
Malian Guineense (thin pericarp)	21.3	2	9.4 a	Thin	26.4 c	68.6 a
Voltaic Guineense (thick pericarp)	20.1	2	9.1 a	Thick	20.0 b	...
Voltaic Guineense (thin pericarp)	20.6	2	9.4 a	Thin	29.0 d	...

[a] Values within the same column followed by different letters are significantly different at $P = .05$ according to Duncan's multiple range test.

TABLE II
Milling Properties of Sorghums with Contrasting Pericarp Thickness

	Percent of Whole Grain[a]				
Grain Type	Yield of Decorticated Grain (%)	Bran over 40-Mesh Screen (%)	Bran through 40-Mesh Screen (%)	Total Bran (%)	Total Recovery (%)
Nio-Fionto (very thick pericarp)	82.5 a	4.60 b	11.17 b	15.77 c	98.3 a
Malian Guineense (thick pericarp)	84.9 b	5.52 c	8.53 a	14.05 b	99.0 a
Malian Guineense (thin pericarp)	87.3 c	3.06 a	8.44 a	11.50 a	98.8 a

[a] Values within the same column followed by different letters are significantly different at $P = .05$ according to Duncan's multiple range test. The values are the mean of four replicates.

that with a thin pericarp. However, when a fixed milling time was used to evaluate samples, the sorghum with a thick pericarp had significantly lower yields of decorticated grain than those with a thin pericarp. Kernels with a thick pericarp produced lower yields when milled at fixed times because the pericarp (bran) of sorghums with a thick mesocarp probably constitutes from one to two percentage points more of the total dry weight of the kernel. Thus, additional dry weight is removed during milling of a thick pericarp sorghum. In addition, the relative ease of removing the thick pericarp may mean that, at the same milling times, more of the aleurone and starchy endosperm is removed. Additional studies are required to document these findings.

Clearly, the definition of milling quality of sorghum must be tied specifically to the milling processes used by sorghum consumers. In areas in which flour is produced from decorticated grain, the definition of milling quality should include the hardness, size, shape, pericarp thickness, and the relative ease and completeness of pericarp removal. The development of these definitions will become more important as the industrial use of sorghum increases in Africa. Good milling quality may not be compatible with good or desired agronomic properties of the sorghum. For example, pericarp thickness is related to susceptibility of sorghum grain to molds before and after physiological maturity. A thick pericarp enhances susceptibility of grain to mold deterioration (Glueck and Rooney 1978). Thus, the very thick pericarp of Nio-Fionto sorghums renders the grain very susceptible to grain weathering. For that reason, Nio-Fionto sorghums are grown only in very dry areas of Mali, those with less than 500 mm annual rainfall. The thick and thin pericarp Guineense sorghums are grown throughout the major sorghum zones of Mali and Upper Volta. Many thick pericarp Guineense sorghums resist grain weathering, yet most thick pericarp non-Guineense sorghums are susceptible to grain weathering. Thus, high-yielding hybrids and varieties with both thick pericarps and weathering resistance should be possible to obtain in sorghum-breeding programs in West Africa. In this way, the milling properties of the grain will meet the needs of the rural consumer. The extra effort required to maintain milling and food quality along with agronomic improvements in sorghum is necessary.

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LITERATURE CITED

AYYANGAR, G. N. R., VIJARAGHAVAN, C., and RAO, V. P. 1934. Inheritance of characters in sorghum—The great millet. VI. Pearly and chalky grains. Indian J. Agric. Sci. 4:96.

DA, S., AKINGBALA, J. O., ROONEY, L. W., SCHEURING, J. F., and MILLER, F. R. 1982. Evaluation of tô quality in a sorghum breeding program. Proc. Intl. Symp. Sorghum Grain Quality, L. W. Rooney and D. S. Murty, eds. ICRISAT, Patancheru, India.

GLUECK, J. A., and ROONEY, L. W. 1978. Chemistry and structure of grain in relation to mold resistance. Page 119 in: Sorghum Diseases: A World Review. Intl. Crops. Res. Inst. for the Semi-Arid Tropics, Hyderabad, India.

MAXSON, E. D., FRYAR, W. B., ROONEY, L. W., and KRISHNAPRASAD, M. N. 1971. Milling properties of sorghum grain with different proportions of corneous to floury endosperm. Cereal Chem. 48:478.

ROONEY, L. W., and KIRLEIS, A. W. 1980. Trip Report of Mali and Upper Volta. INTSORMIL. 25 pp.

SCHEURING, J. F., SULLINS, R. D., ROONEY, L. W., and MILLER, F. R. 1977. Flaky pericarp: A new easy pearling character in grain sorghum. Agron. Abstr. 1977:120.

SHEPHERD, A. D. 1979. Laboratory abrasive decorticating mill for small grains. Cereal Chem. 56:517.

SHEPHERD, A. D. 1981. How a typical sorghum peels. Cereal Chem. 58(4):303.

SWANSON, A. F. 1928. Seed coat structure and inheritance of seed color in sorghums. J. Agric. Res. 37:577.

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