

How A Typical Sorghum Peels

A. D. SHEPHERD, Western Regional Research Center, Science and Education Administration, Agricultural Research, U.S. Department of Agriculture,¹ Berkeley, CA 94710
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In an article describing a laboratory abrasive decortivating mill (Shepherd 1979), the statement was made that "wheat, rice, and most other grains decorticate to remove a fine material that easily passes a 1-mm round perforated plate. Sorghum, however, decorticates in quite large flakes, and very little of the material removed will pass a 1-mm round hole without further attrition."

The flaking phenomenon is seen and talked about frequently, but almost nothing seems to be written about it. Hubbard et al (1950) obviously were observing the basis of flaking without referring to it as such when they hand-separated their bran fraction from sorghum with a scalpel and reported, "... the bran separated within the starchy mesocarp. Accordingly, the bran consisted of the cuticle, epidermis, hypoderm, and the major portion of the mesocarp. The innermost fragments of the mesocarp, the nucellar layer, and aleurone remained with the endosperm fraction." Their method did not produce large flakes, but it did locate the fragile layer within the pericarp. Freeman and Watson (1969), by a wet peeling method on sorghum, also removed pericarps in flake form.

The uniformity in flake thickness must result because preferential breakage occurs in a fragile tissue somewhere in the pericarp. The flaking process, in contrast to a more random chipping away, speeds decortication and might even be energy sparing. Flaking could be likened to the extremely easy removal of the rind of a tangerine compared to the more difficult removal of an orange rind by grating or skinning. The work reported here is an attempt to elucidate the flaking phenomenon in an admittedly idealized situation.

Observation of the flaking phenomenon depends to some extent upon fortuitous circumstances. Grain sorghums differ in their ability to flake and in the strength of the flake. The designs of decortivating mills make them differ in their ability to produce flakes and to retain them as flakes as the removed surface material exits the mill and comes into view. For the present work, we chose a combination of sorghum variety and milling conditions that were well suited to produce and preserve flakes as we decorticated to provide a sequence of grains peeled to increasing degrees.

MATERIALS AND METHODS

Grain Sorghum

Funk G-766W sorghum was selected for its endosperm hardness, which provided good general milling and flaking characteristics; the absence of pigmented inner integument and a white pericarp permitted easy dyeing and identification of tissues. The sample was cleaned and sized in a dockage tester and further selected by handpicking (Shepherd 1979). This provided a uniform lot from which subsamples were obtained by use of a splitter.

Decortication

The mill used in these tests and its method of operation have been described (Shepherd 1979). The mill is capable of producing and preserving flakes and of controlling decortication at desired levels.

¹Reference to a company and/or product name is only for purposes of information and does not imply approval or recommendation of the product by the USDA to the exclusion of others that may also be suitable.

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In addition to flakes, fine and broken materials are generated. Total recovery is quantitative to about 98-99%; therefore, both the peeled grain and the material removed are available for use.

Experiments

Fractionation of Removed Material. A single 20-g portion of sorghum was repetitively milled for 15-sec intervals using 150 grit, 1,500 rpm, six blades, and a 1-mm perforated screen. The contents of the first receiver was called fines. The second receiver contained much besides the polished grain because of the fine screen used, so the contents were further separated. First a 35-mesh screen (with 417- μ m openings) was used, and the throughs were combined with the fines in the first receiver. The overs were gently blown in a seed blower. The lights were called flakes. The heavies were handpicked to remove broken (less than 2/3 whole kernel), and the remainder was milled for a second 15-sec period followed by the separation

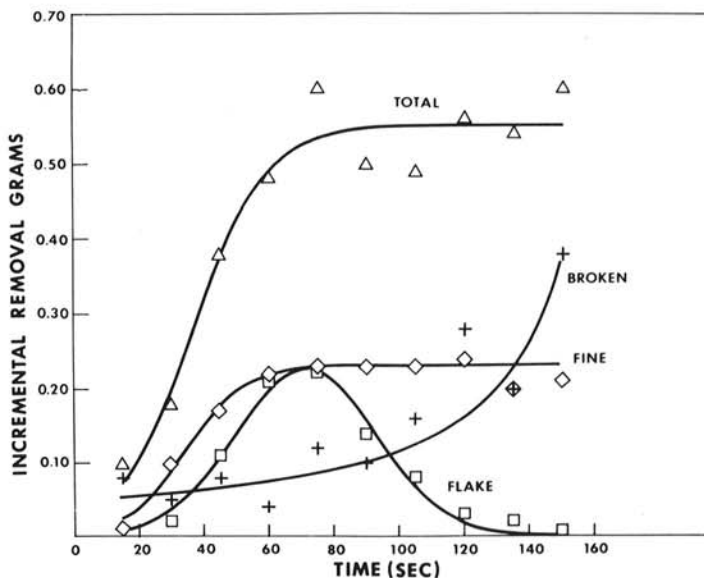


Fig. 1. Incremental removal of fine, broken, and flake and their sum as related to milling time.

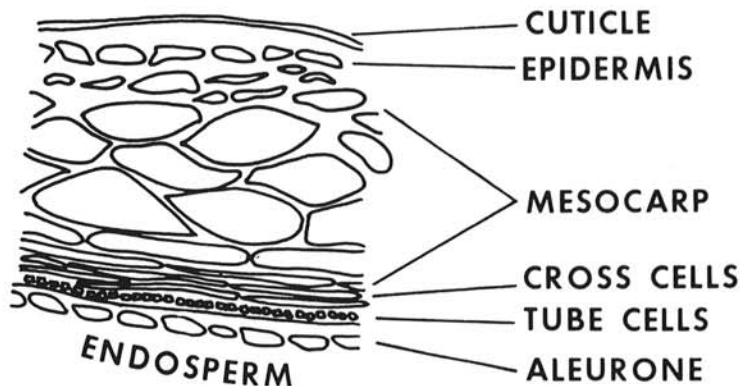


Fig. 2. Cross section of the exterior of a typical sorghum grain without an inner integument (adapted from Jowett 1965).

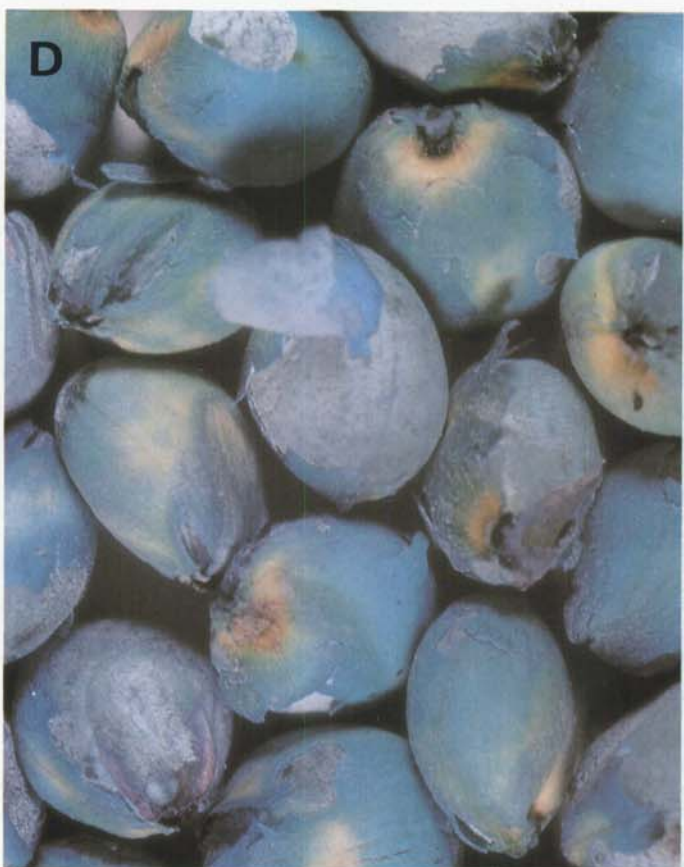
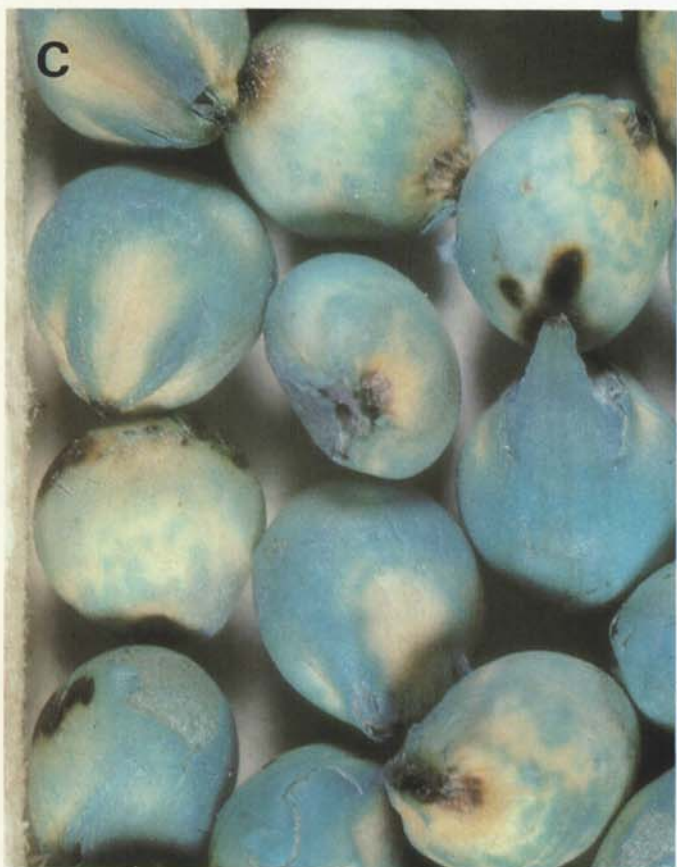


Fig. 3. Photomicrographs (about $\times 8$) of: **A**, dyed unmilled grain; **B**, dyed flakes; **C**, dyed grain with 1.8% removed; **D**, dyed grain with 3.4% removed.

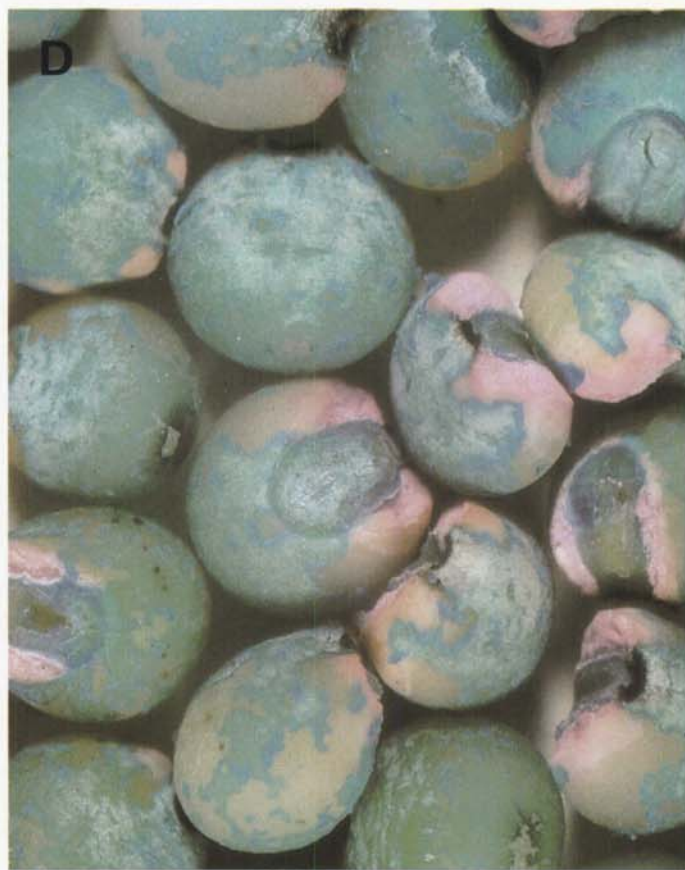
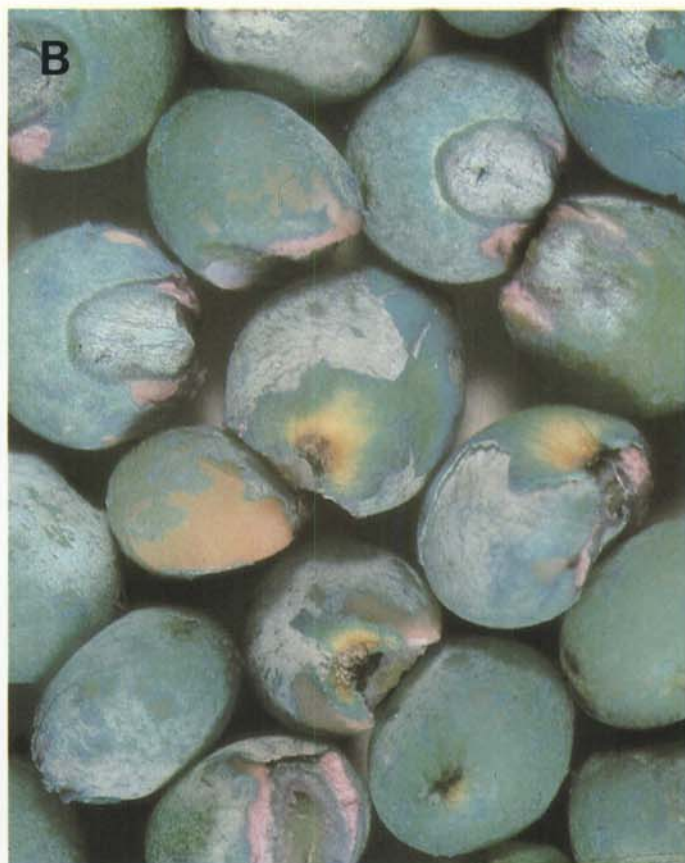
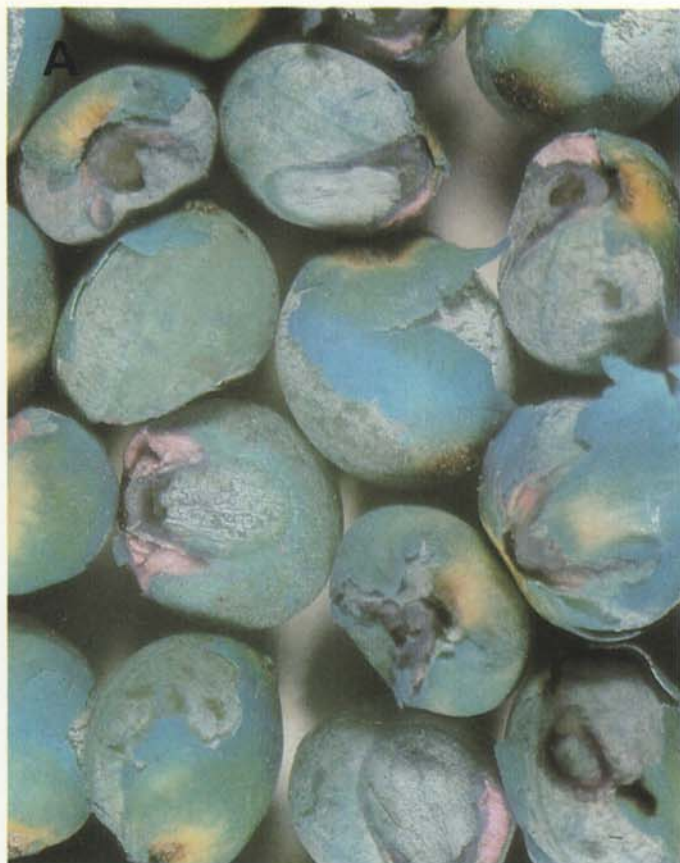


Fig. 4. Photomicrographs (about $\times 8$) of dyed partially milled grain. Percent removed: A, 5.7; B, 9.8, C, 11.4; D, 15.4.

process. This procedure was repeated 10 times, successively.

Sequentially Milled Samples. A second experiment was made using 10 samples (20-g) of Funk G-766W, each milled for a period ranging from 15 to 150 sec at 15-sec intervals. The same abrasive, rpm, blade count, and screen as in the first experiment were used. This time the brokens were not separated. Flakes were separated from the 150-sec sample only.

Two-gram portions of grain at each decortication time and half of the flakes separated from the last sample were dyed. The flakes and grain at each level of decortication and an unmilled sample were photographed in dyed and undyed form.

Dyeing

The method was that of Scheuring and Rooney (1979), using 0.05% methylene blue and 0.15% eosin-Y in 70% ethanol.

Photograph

A 2-g sample of grain contained in a slide mount was photographed using a single lens reflex camera with a 55-mm macrolens and extension tubes to give double magnification on the film. Illumination was provided by two strobe flash units symmetrically placed. Small apertures were used to provide good depth of field.

RESULTS AND DISCUSSION

Fractions Removed

Data for each fraction—fine, flake, and broken—and for the total are presented in Fig. 1. The curves show that total, fine, and flake have a short induction period. Curves for total and fine move through a straight line period of increase and then level off. The curve for flake reaches a maximum and forms a Gaussian curve. In the last 15-sec period almost no flakes were produced. The curve for brokens shows a much longer induction period but accelerates during the last third of the milling.

The Gaussian curve exhibited by the flakes is in keeping with the concept of flaking, in which a fragile layer of tissue exterior to the endosperm (Fig. 2) breaks preferentially and produces units consistent in thickness. Flake thickness uniformity was checked using a machinists' micrometer and found to be around 50–55 μm . Flakes are produced only once from a surface, and therefore the amount is more limited than that of the other fractions.

Sequential Milling

The amount removed ranged from 0.5 to 15.4%. The rate of decortication and other data differed between the two experiments, so direct comparison cannot be made.

Unmilled grain shows very little staining (Fig. 3A), probably because, where intact, the wax-coated cuticle prevents entry of the dye. Dyeing does occur to a limited extent on and around the pedicel of some grains, sometimes extending to outline the germ and spottily elsewhere, probably at lesions. Staining increases very early in the decortication (Fig. 3C) and is complete after a few percent decortication has occurred (Fig. 3D). The exterior surface of the pericarp stains blue after the dye penetrates. The flakes show this blue exterior and a white interior (Fig. 3B).

Decortication starts with breakage in the mechanically weak mesocarp and loosening of the pericarp exterior to that tissue (Fig. 2). By the time the flake is plucked off, it may be quite large. The largest flakes would appear to have covered about one quarter of

the kernel surface.

The white interior of the flake clearly was originally mated to the frosty white surface of the kernel, which appears as the flakes part. This is the mesocarp, the only white tissue that resists staining and remains white. The frosty white surface overlays the cross and tube cells, which stain a blue-green color different from the blue exterior of the flake.

After the flake has been peeled off, the remainder of the decortication proceeds much more slowly because much smaller units are removed. After the blue-green cross and tube cells are removed, the aleurone is exposed and identified by a pastel orange color (Fig. 4). Except where actual breakage occurs, endosperm appears as a pair of pink bands on either side of the germ. An area of fragility may be located here, or perhaps their appearance is related to the kernel shape, but this is commonly the first exposure of endosperm. However, total degerming usually does not result; the germ is simply worn down even with the surrounding endosperm.

The germ may appear to be dyed blue green as the flake peels from the surface above it, but in reality one is only viewing the outline of the germ in the cross and tube cell layers. As decortication progresses, these blue-green tissues are removed, exposing some or all of the germ. It appears in its natural pigmentation, a waxy orange-yellow. Because of this, the germ may at times have been identified as blue green when this dye mixture was used.

The yellow-orange-brown patches near the pedicel seem to be naturally pigmented. These appear also in undyed samples but are not as obvious as here where they are contrasted against the blue of the pericarp.

All conditions were selected to be as ideal as possible for observing peeling. This is desirable so that the pictures are simple and observations may be as certain as possible. We intend to report studies of several sorghums of other grain types. These studies are underway on grains with different combinations of features, such as pericarp pigmentation, inner integument, and thick and thin mesocarps. Pictures of these are much more difficult to analyze because of their complexities. In the all-sorghum types examined to date, flakes appear to result from cleavage in the mesocarp.

We have also observed flaking in pearl millet, rice, and wheat. Often flaking could have been easily overlooked because the flakes are so small. Flake size can be increased by using screens with larger perforations so that a flake may escape into the receiver before attrition can occur.

ACKNOWLEDGMENT

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LITERATURE CITED

- FREEMAN, J. E., and WATSON, S. A. 1969. Peeling sorghum grain for wet milling. *Cereal Sci. Today* 14(2):10–15.
- HUBBARD, J. E., HALL, H. N., and EARLE, F. R. 1950. Composition of the component parts of the sorghum kernel. *Cereal Chem.* 27:415–420.
- JOWETT, D. 1965. The grain structure of sorghum related to water uptake and germination. *East Afr. Agric. For. J.* 31(1):25–30.
- SCHEURING, J. T., and ROONEY, L. W. 1979. A staining procedure to determine the extent of bran removal in pearled sorghum. *Cereal Chem.* 56:545–548.
- SHEPHERD, A. D. 1979. Laboratory abrasive decortivating mill for small grains. *Cereal Chem.* 56:517–519.

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