Scanning Electron Microscope Views of Material from Various Stages in the Milling of Hard Red Winter, Soft Red Winter, and Durum Wheat[1]

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ABSTRACT

The scanning electron microscope provides an interesting perspective in the examination of wheat milling. Initial fracture patterns following passage of mill stock through the break rolls show which portions of the endosperm will become middling stocks. Continued attrition in the milling flow results in the removal of most of the endosperm until the final layer of endosperm cells often adheres to the aleurone layer and the remainder of the bran. Major differences in the attrition patterns of hard red winter, soft red winter, and durum wheats are verified by this method of observation.

The scanning electron microscope (SEM) has been used widely for viewing and comparing structures of cereal grains (Hoseney and Seib 1973, Simmonds 1974, Moss et al 1980). Work to date has emphasized laboratory dissection of grain as the mode of preparation for viewing. Although they provide an excellent view of the structure of various grains, these dissections do not tell much about the disruption of grain structure that occurs during normal milling processes.

The large differences in the milling characteristics of different classes of wheat are widely known. The differences are demonstrated by the differing particle size ranges and sifting requirements of flour for hard and soft varieties of wheat. Our purpose in this study was to use the SEM to provide visual confirmation of the accepted theory of differences in structural disruption patterns for normally milled wheats of different classes.

MATERIALS AND METHODS

Samples of hard red winter, soft red winter, and durum wheats were collected from mills processing each class of wheat. The hard red winter wheat samples were obtained from the pilot-scale mill at the Department of Grain Science and Industry at Kansas State University. Soft red winter wheat samples were collected through the courtesy of Cereal Food Processors, Inc., during normal operations at their mill in Kansas City. Durum samples from normal milling operations were collected and sent to us by the Peavey Company.

In each case, samples were collected above each set of rolls throughout the mill flow. Collecting samples at these points in the mill provides an identifiable portion of the wheat kernel, as the majority of material broken free from the kernel is removed through sifting and purification. Additional samples were collected from material entering and leaving the bran dusters, as well as from various flour streams and tailings.

Samples were mounted on aluminum stubs with conductive glue and coated with a layer of gold-palladium. Additionally, we dusted each sample with a blast of compressed air before coating. This was to remove small bits of material that were not firmly attached and that would have resulted in "charging," an image defect, during viewing.

Prepared samples were observed in an ETEC U-1 scanning electron microscope. Accelerating voltages of either 2.5 or 5.0 kV were used throughout the study.

RESULTS AND DISCUSSION

The most interesting observations of the disruption of wheat kernels were obtained early in the milling process. Samples

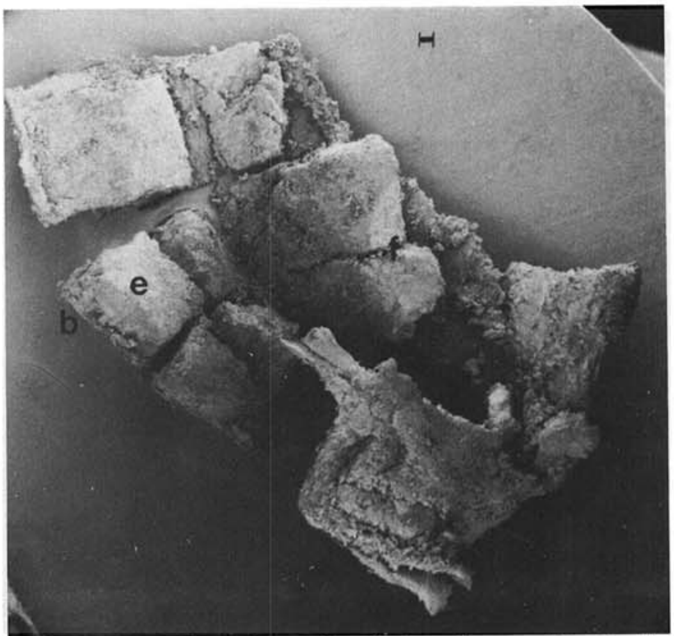

Fig. 1. Hard red winter wheat collected above the second break rolls. b = bran, e = endosperm. Bar = 100 μm.

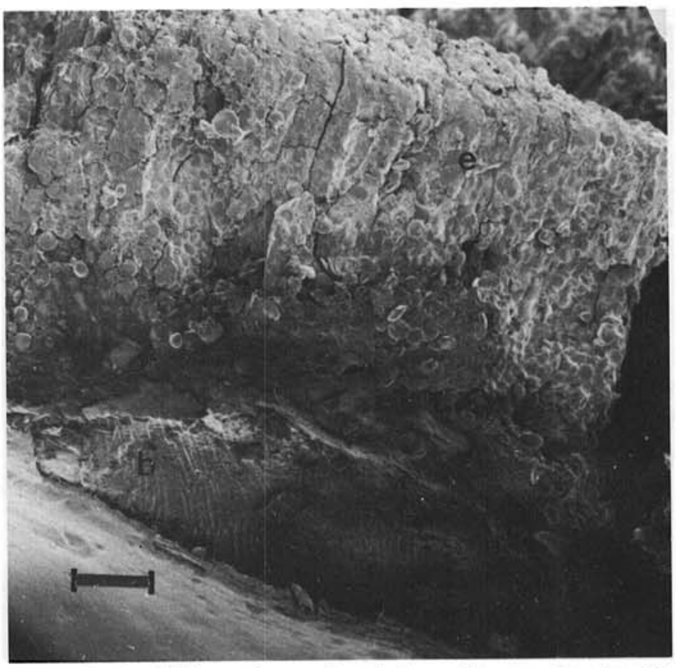

Fig. 2. Hard red winter wheat collected above the second break rolls. b = bran, e = endosperm. Bar = 100 μm.

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collected above the first three break rolls remained sufficiently intact to enable determination of the major portions of the kernel, such as bran, aleurone, and endosperm. In durum wheat, an extremely hard type, samples taken above the fifth break rolls maintained sufficient integrity to enable identification of structure.

Samples collected further down the mill flow, such as middlings streams, were distinguishable from flour only by their greater particle size. For purposes of determining kernel disruption patterns, samples taken beyond the break rolls in the reduction streams were visually unexciting.

Hard red winter wheat samples taken above the second break rolls are shown in Figs. 1 and 2. Figure 1 shows an entire wheat kernel that has been opened up by the action of the first break rolls. Major fractures divide the endosperm into large chunks that remain attached to the bran. Figure 2 is a closer view of one of the major chunks shown in Fig. 1. In addition to the large fractures visible in Fig. 1, numerous smaller cracks often delineate endosperm cells. Figure 3 is a sample taken above the third break rolls. The sample is somewhat similar to that of Fig. 1, but the number of chunks is greater and their size is smaller. Figure 4 is a side view (90° to that of Fig. 3) of material taken above the third break rolls. This view clearly shows how endosperm particles are fractured cleanly from the bran for later reduction to flour. By the third break stage, some areas of the bran are nearly stripped of endosperm, as shown in Fig. 5. The structures resembling honeycombs are cell walls that remain after their contents have been freed. These are the outermost layer of endosperm cells, which

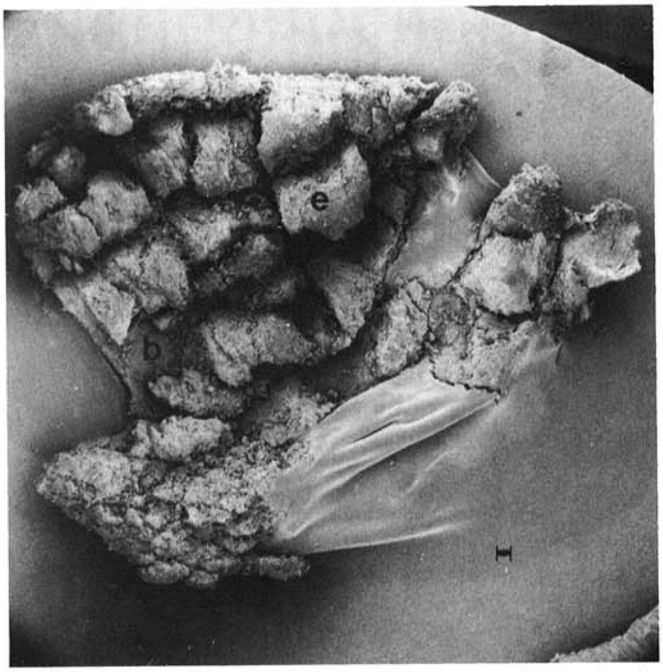

Fig. 3. Hard red winter wheat collected above the third break rolls. b = bran, e = endosperm. Bar = 100 μm.

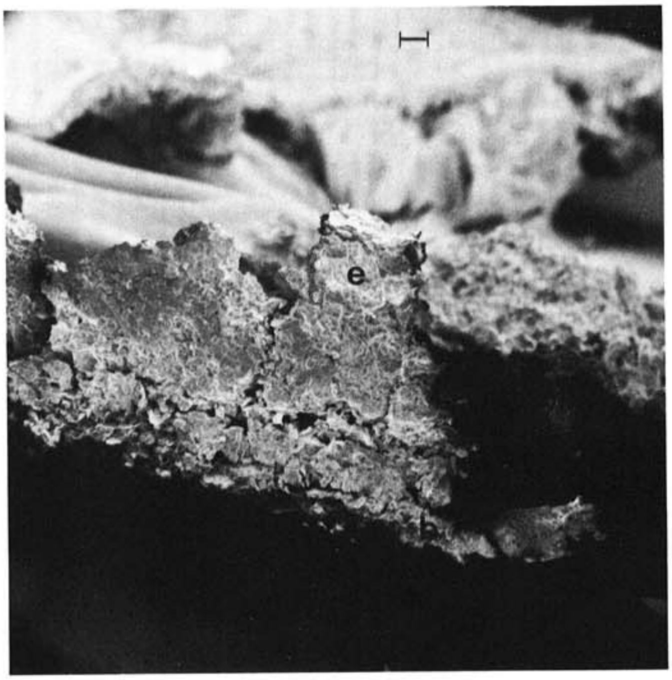

Fig. 4. Hard red winter wheat collected above the third break rolls. b = bran, e = endosperm. Bar = 100 μm.

Fig. 5. Hard red winter wheat collected above the third break rolls. c = empty cell. Bar = 100 μm.

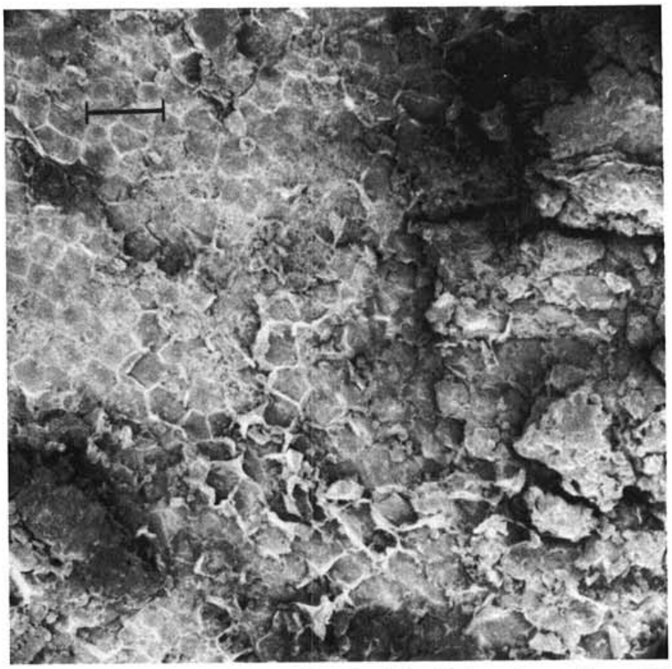

Fig. 6. Hard red winter wheat collected exiting the bran duster. Bar = 100 μm.

have the aleurone layer as their base.

Figures 6, 7, and 8 are samples taken from the material exiting the bran duster, a device used to polish the last bits of endosperm from wheat bran. Figure 6 shows areas of bran in which the cell walls are nearly totally removed, leaving only an outline of their attachment to the aleurone layer. Other parts of the bran have small amounts of endosperm that adhere after processing through the bran duster. Figure 7 is a lateral view of a bran sample in which the aleurone layer can be seen just below what remains of the cell walls. The bran duster did an efficient job of endosperm removal in this area. Figure 8 is a view of an area where the bran duster was less efficient but still demonstrates the effect of the process on cell walls, which are bent over and flattened.

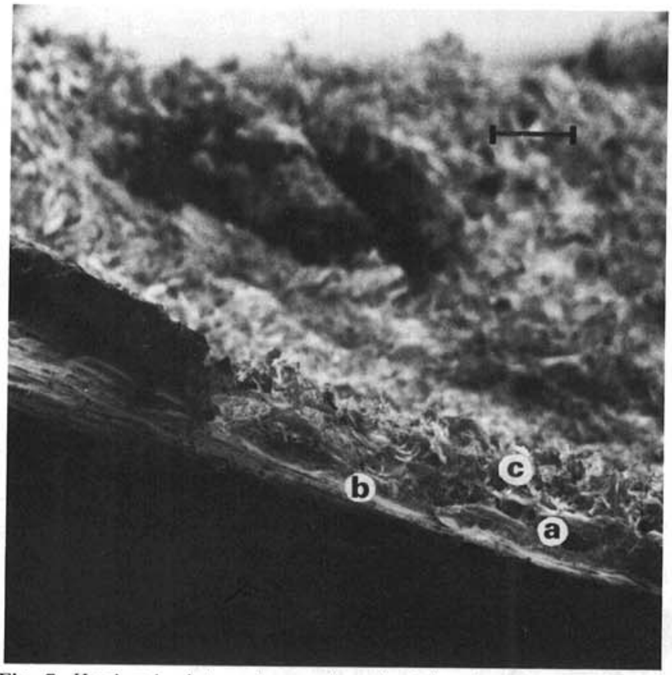

Fig. 7. Hard red winter wheat collected exiting the bran duster. a = aleurone, b = bran, c = cell wall remnants. Bar = 100 μm.

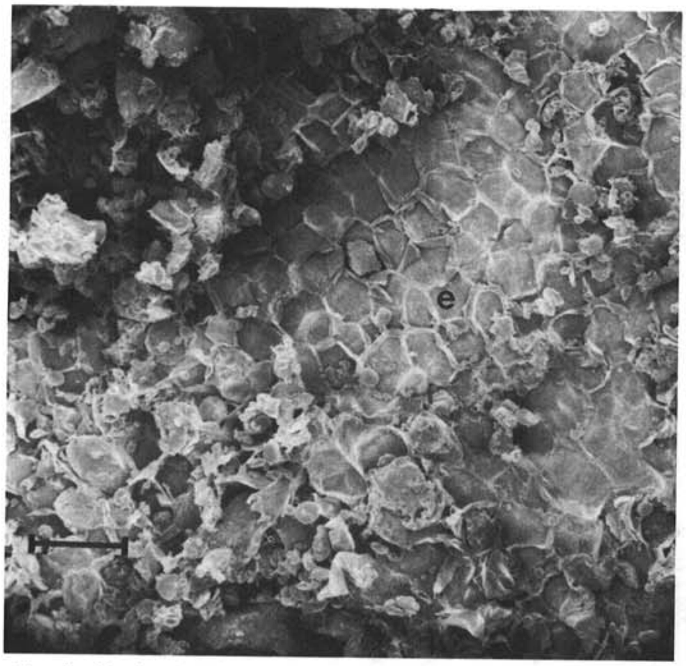

Fig. 8. Hard red winter wheat collected exiting the bran duster. e = endosperm cells emptied and collapsed. Bar = 100 μm.

Figures 9, 10, and 11 are of soft red winter wheat samples taken above the second break rolls. In contrast to hard red winter wheat samples from the same stage of milling (Figs. 1 and 2), these show much greater disruption of the endosperm. Some fracturing into chunks occurred, but this involves a much smaller portion of the endosperm, and the margins of the fractures are not as clean as those in the hard red winter wheat samples. A closer look at the larger endosperm chunks of soft red winter wheat (Fig. 10) shows some smaller cracks in addition to the major fractures. These smaller cracks are more random than those in hard red winter wheat and do not clearly outline endosperm cells. Figure 11 allows very close examination of one of the major fractures shown in Figs. 9 and 10. It is not clear whether this fracture follows any particular

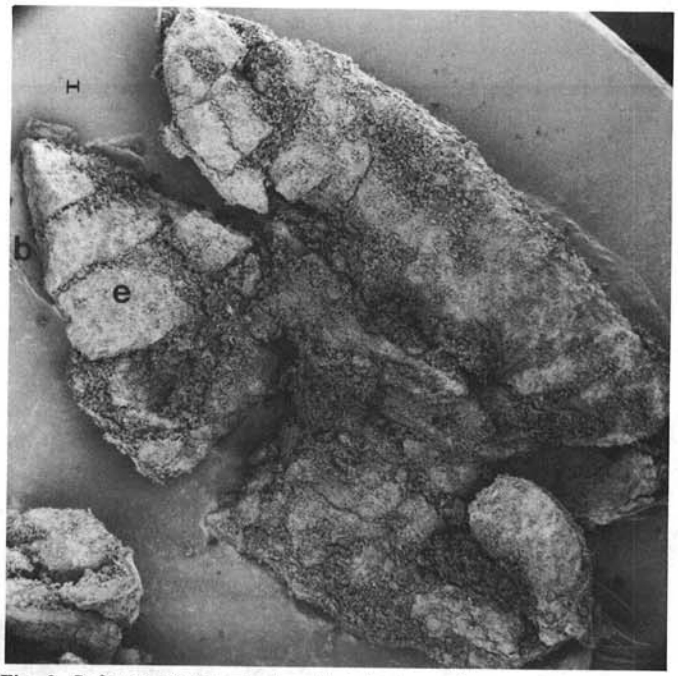

Fig. 9. Soft red winter wheat collected above the second break rolls. b = bran, e = endosperm. Bar = 100 μm.

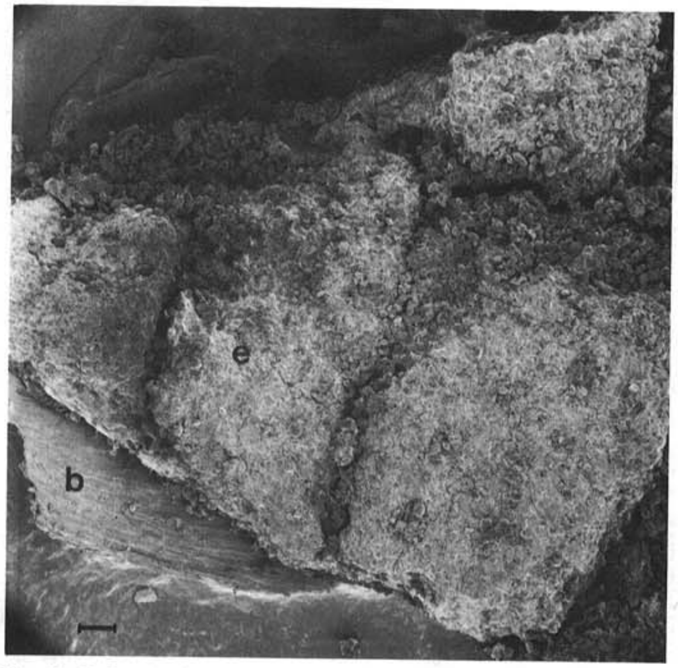

Fig. 10. Soft red winter wheat collected above the second break rolls. b = bran, e = endosperm. Bar = 100 μm.

endosperm structural feature such as a cell wall. Additionally, very few starch granules, if any, are fractured. Figure 12 is soft red winter wheat from above the third break rolls. The majority of the endosperm has been removed by this point. In contrast with hard red winter wheat samples, the cell wall structures adhering to the aleurone layer are barely visible; the bran is cleaner once the endosperm starch-protein matrix has been removed.

Figures 13 and 14 are durum wheat samples from above the second break rolls. Figure 13 shows that durum wheat has an initial fracture pattern much different from that of either hard red winter or soft red winter wheat. Durum does not appear to flatten out to the same extent, nor does it fracture into roughly cubical chunks of endosperm. Instead, durum retains a three-dimensional shape with long, deep fractures, leaving elongated rather than cubical chunks of endosperm attached to the bran. As with the other two classes of wheat, durum has some secondary cracking of the endosperm in addition to the major fractures that occur during pre-break processing and first-break processing. Figure 14 is an example of this secondary cracking. These secondary cracks do not follow cell walls as did those in hard red winter wheat, but the fracture margins are much more distinct than are those in soft wheat. Occasional examples of fracture along cell walls were found in durum samples, as shown in Figure 15. This material was collected above the second sizing rolls and clearly shows an area of intact cells. Possibly because of the thickness of cell walls in the durum sample, starch granules within cells are difficult to see. Because the SEM cannot

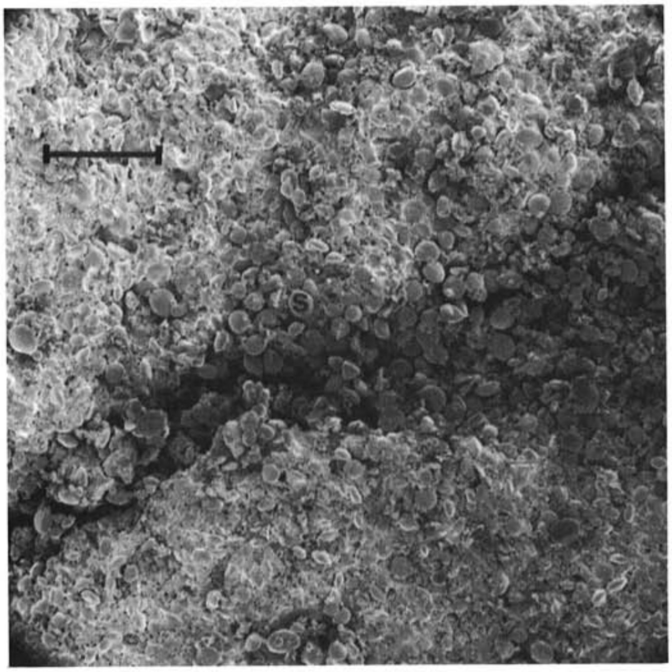

Fig. 11. Soft red winter wheat collected above the second break rolls. s = starch granules. Bar = 100 μm.

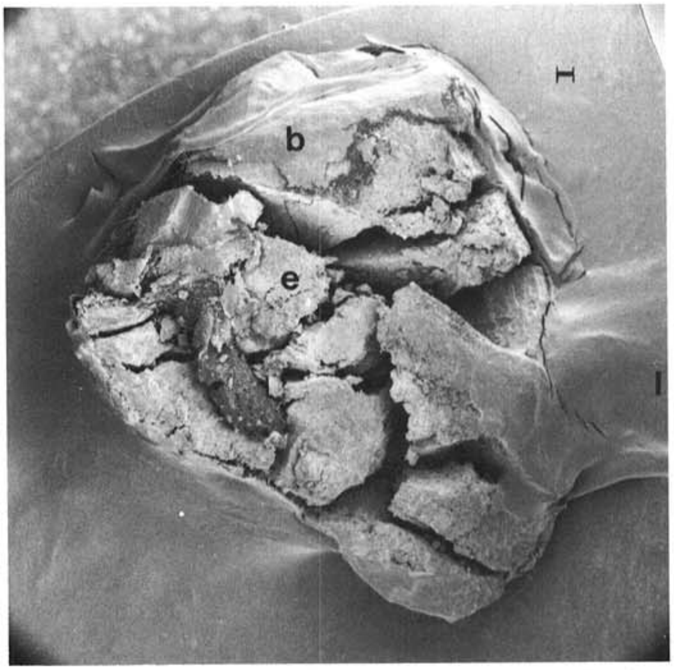

Fig. 13. Durum wheat collected above the second break rolls. b = bran, e = endosperm. Bar = 100 μm.

Fig. 12. Soft red winter wheat collected above the third break rolls. e = endosperm. Bar = 100 μm.

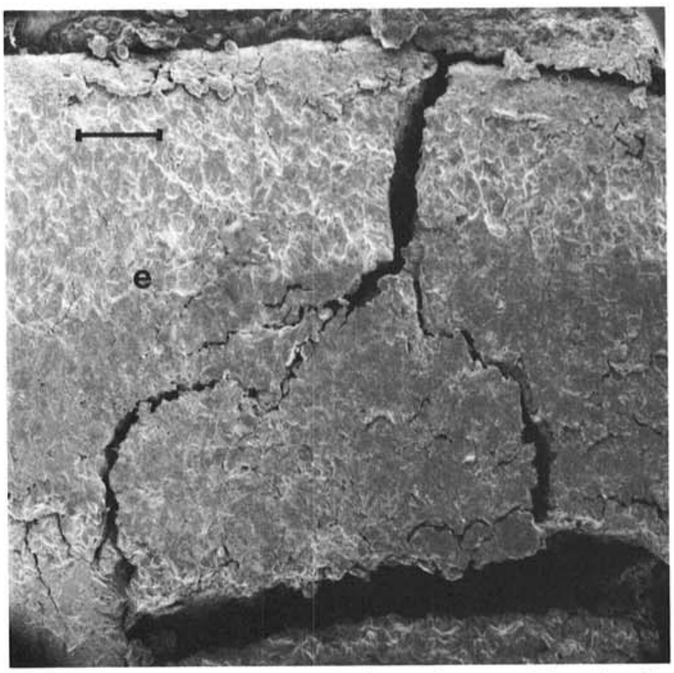

Fig. 14. Durum wheat collected above the second break rolls. e = endosperm. Bar = 100 μm.

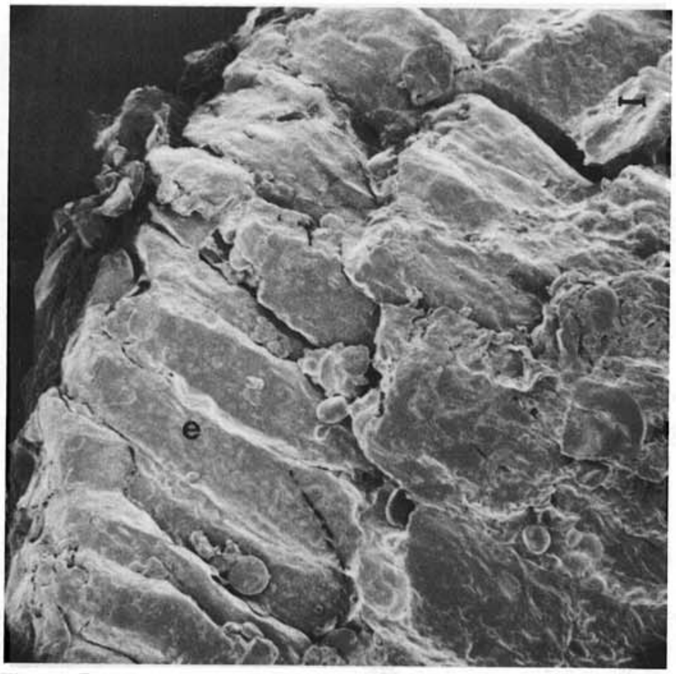

Fig. 15. Durum collected above the second sizing rolls. e = endosperm. Bar = 100 μm.

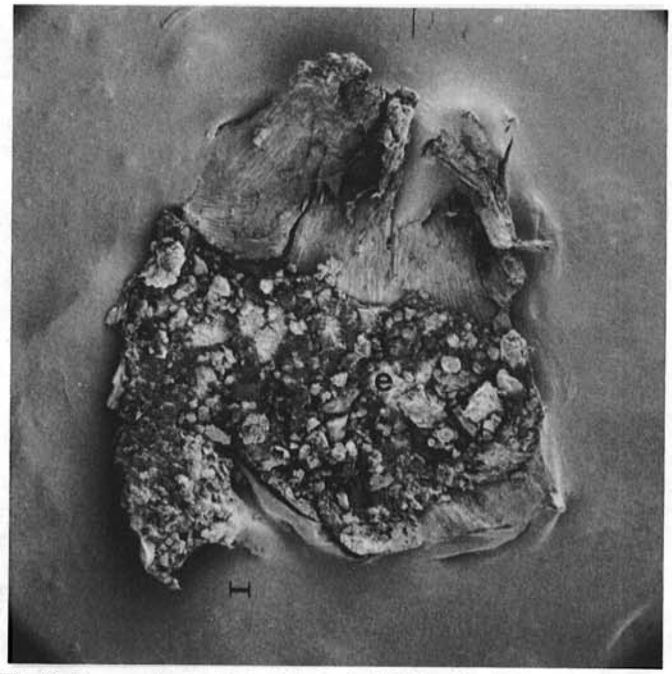

Fig. 16. Durum wheat collected above the fifth break rolls. e = endosperm. Bar = 100 μm.

penetrate the cells, the samples in which starch is visible "within" the cell are those that have a thin, pliable cell wall that can mold itself around the cell contents and thus have a surface contour while remaining intact.

Figure 16 is a sample of durum wheat taken above the fifth, and final, break rolls. A large amount of endosperm remains attached to the bran even this far down the break system, reflecting the extreme hardness of this type of wheat.

This study provides visual evidence of the great variability in milling properties of three different classes of wheat under commercial milling conditions. This visual evidence supports laboratory-scale studies that previously indicated that hard wheat endosperm and soft wheat endosperm have quite different patterns of disintegration. These photographs suggest that soft wheat endosperm is more readily removed from its bran than is endosperm from hard wheat. Disintegration of the soft wheat endosperm also is more quickly accomplished, a fact confirmed by the requirement of soft wheat mills for increased amounts of sifting surface early in the mill flow.

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