STRUCTURE OF THE RICE GRAIN SHOWN BY SCANNING ELECTRON MICROSCOPY[1,2]

C. A. WATSON and E. DIKEMAN[3]

Cereal Chem. 54(1): 120-130

ABSTRACT

Detailed structures of the endosperm, aleurone, germ, and hull of paddy and parboiled rice were studied with a scanning electron microscope. Similarities and differences between the ultrastructure of the rice grain and other cereal grains are discussed.

Rice, together with wheat, comprises most of the world population's nourishment. However, less is known about the chemistry and structure of rice than about other cereal grains—primarily because there has been less research on rice than on wheat and corn.

Recently, rice research was extensively reviewed (1,2). Del Rosario *et al.* (3) investigated the structure of the developing rice grain and Kennedy and Schelstraete (4) reported chemical, physical, and nutritional properties of rice and their distribution in the rice grain. Watson *et al.* (5) showed by scanning electron microscopy the relation between milling loss and the amount of pericarp and aleurone removed. The research reported here includes scanning electron microscope (SEM) observations of the endosperm, aleurone, germ, and hull of the rice grain with the objective of obtaining a better understanding of its ultrastructure.

MATERIALS AND METHODS

Varieties Labelle, Vista, and Caloro representing long, medium, and short grain types, respectively, were used. Labelle and Vista were obtained from Beaumont, Tex., and Caloro from Sacramento, Calif. Scanning electron photomicrographs were taken with an ETEC SEM at an accelerating voltage of 20 kV. A razor blade was used to fracture the grains. Kernel segments and hull fragments were mounted on aluminum stubs with Duco cement and coated with approximately 150 Å-thick gold-palladium alloy before observation with the SEM.

---

[1]Cooperative investigation between the U.S. Grain Marketing Research Center, Agricultural Research Service, U.S. Department of Agriculture; and the Kansas Agricultural Experiment Station, Manhattan. Contribution No. 896, Department of Grain Science and Industry.

[2]Mention of a trademark name or proprietary product does not constitute a guarantee or warranty of the product by the U.S. Department of Agriculture, and does not imply its approval to the exclusion of other products that may also be suitable.

[3]Respectively: Research Chemist, U.S. Grain Marketing Research Center, Agricultural Research Service, U.S. Department of Agriculture, Manhattan, KS 66502 (present address, Hard Red Spring and Durum Wheat Quality Laboratory, ARS, USDA, Department of Cereal Chemistry and Technology, North Dakota State University, Fargo 58102); and Research Assistant, Department of Grain Science and Industry, Kansas State University, Manhattan, KS 66506.

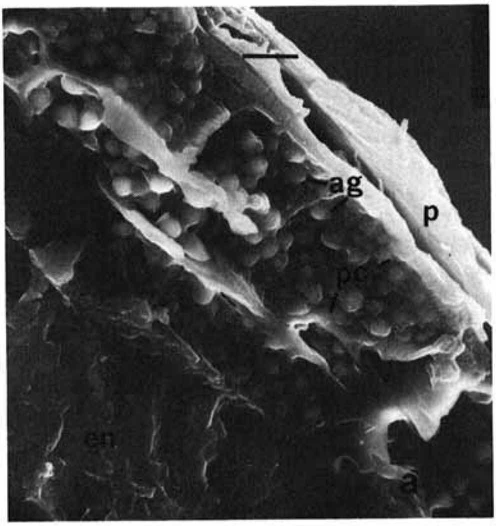

Fig. 1a. SEM micrograph of outer layer of the rice kernel; medium grain, ventral side. pc = parenchyma cell, ag = aleurone grain, en = endosperm, p = pericarp. Scale bar = 6.5 μm.

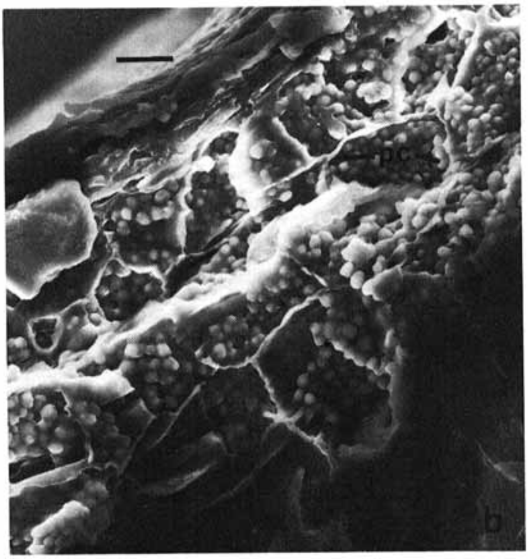

Fig. 1b. SEM micrograph of outer layer of the rice kernel; long grain, dorsal side. pc = parenchyma cell. Scale bar = 12.5 μm.

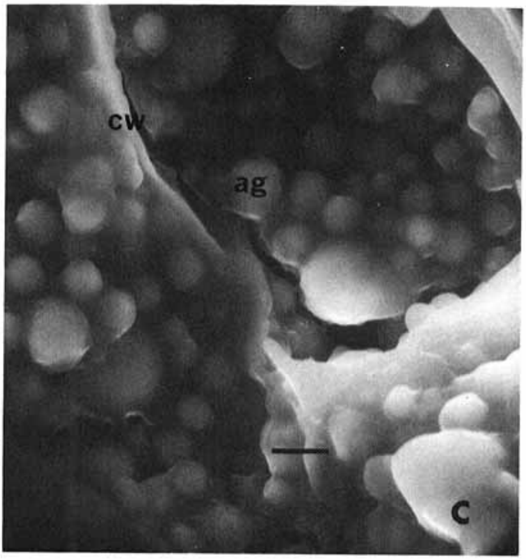

Fig. 1c. SEM micrograph of outer layer of the rice kernel; long grain, parenchyma cells and aleurone granules. ag = aleurone grain, cw = parenchyma cell wall. Scale bar = 2.5 μm.

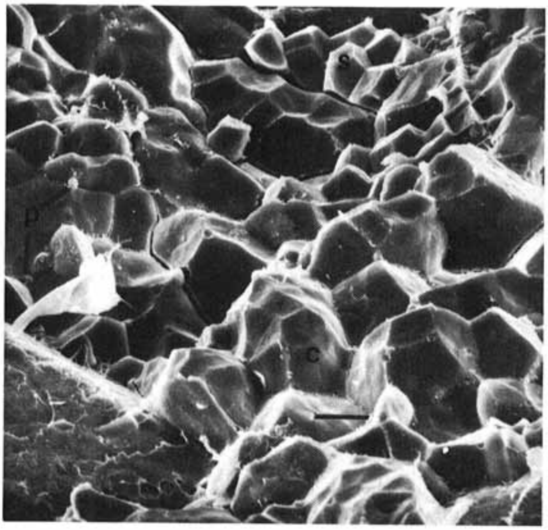

Fig. 2. SEM micrograph of inner endosperm of long grain rice kernel, showing the hard, polygonal-form starch: c = compound starch granules, s = starch bodies, p = protein granules. Scale bar = 6.7 μm.

RESULTS AND DISCUSSION

The ultrastructures observed in the three types of rice did not differ discernibly, and therefore they are not reported separately. The micrographs presented are of the long grain variety unless otherwise noted.

Figure 1 shows the aleurone layer of a rice grain composed of parenchyma cells (pc). The thickness of the aleurone layer varied with the number of parenchyma cells. There were 2–3 cells on the ventral side and 4–6 cells on the dorsal side (Figs. 1a and 1b). As many as 7 cells have been shown to be present (2). The parenchyma cells are composed of protein-rich aleurone grains (ag) surrounded by a fat-staining substance (2,6). However, Greenwood (7) reported that the aleurone granules of wheat were composed of phytin and not protein. Research is required to determine if the same is true for rice. The diameters of the aleurone grains were 0.25–3.5 μm (Fig. 1c), and comparable to the diameter of aleurone grains of wheat, about 2.0 μm (8). High magnification of the parenchyma cell wall (cw) and aleurone grain (ag) is shown in Fig. 1c.

In the endosperm (Fig. 2), the compound nature of rice starch bodies is evident. The polygonal shapes are compound starch granules (c) composed of several smaller starch bodies (s) shown where the compound granules have been fractured. The polygonal shapes are similar to those reported for other cereal grains (9–11). Juliano (2), reviewing earlier work of others, reported that rice starch granules are polygonal and compound with the structure of a pentagonal dodecahedron, and suggested that the polyhedral form might be caused by the compression of starch granules during development. Figure 3d shows an intact compound starch granule (c) and one with a subgranule missing (m). α-Amylase activity is evident by the pitting of the starch granules (s). Little and Dawson (6)

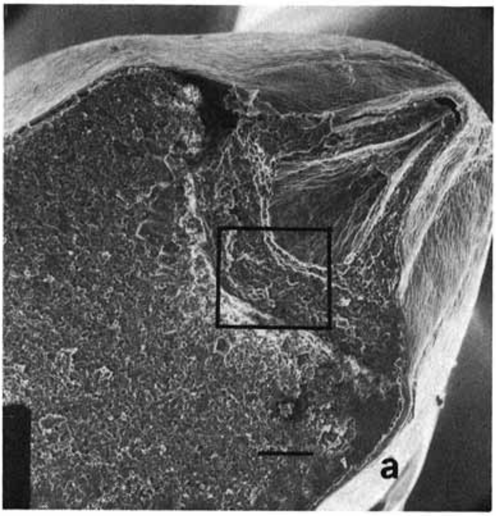

Fig. 3a. SEM micrograph of germ end of rice kernel; general view of germ end. Scale bar = 147 μm.

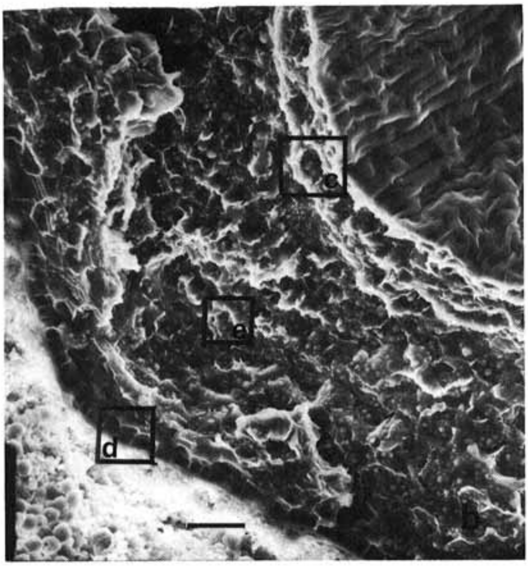

Fig. 3b. SEM micrograph of germ end of rice kernel; higher magnification of area outlined by square in 3a. Scale bar = 29 μm.

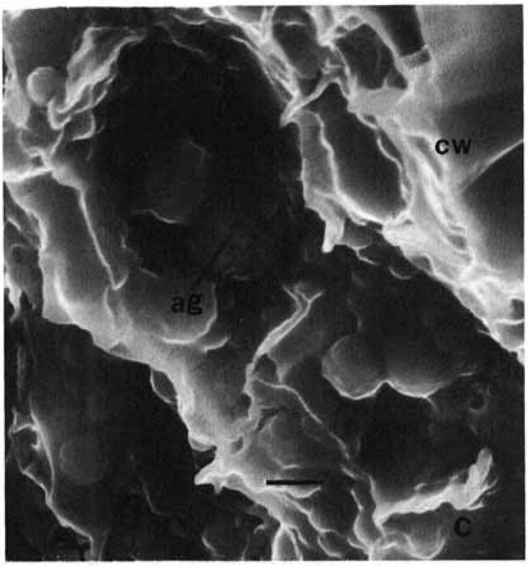

Fig. 3c. SEM micrograph of germ end of rice kernel; area labeled "c" in 3b. ag = aleurone grain, cw = cell wall. Scale bar = 3.7 μm.

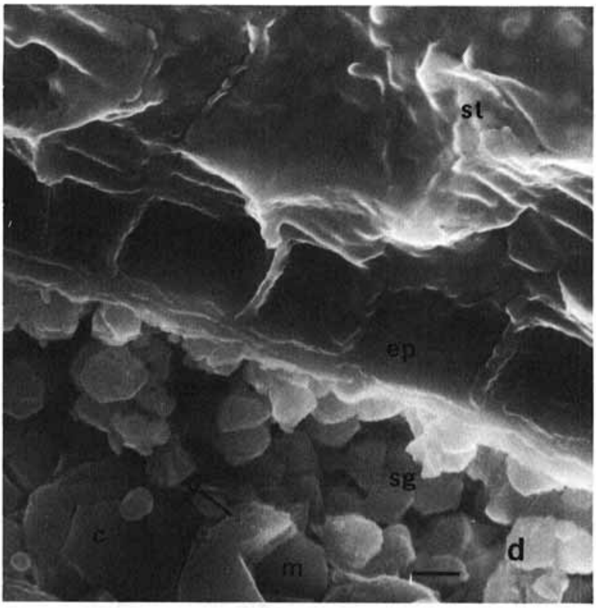

Fig. 3d. SEM micrograph of germ end of rice kernel; area labeled "d" in 3b. sg = starch granules, ep = epithelium, st = scutellum, c = compound starch granule, m = compound starch granule showing a subgranule missing, o = pit holes due to α-amylase activity. Scale bar = 5.0 μm.

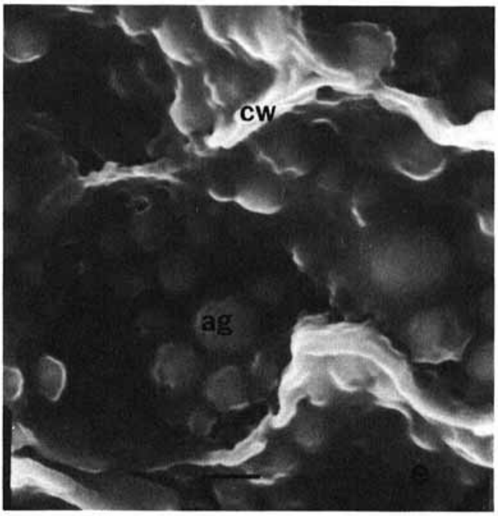

Fig. 3e. SEM micrograph of germ end of rice kernel; area labeled "e" in 3b. ag = aleurone grain, cw = cell wall. Scale bar = 2.4 μm.

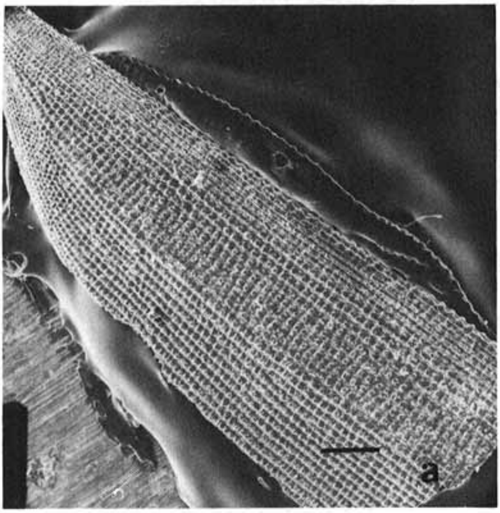

Fig. 4a. SEM micrograph of rice hull; outside of hull. Scale bar = 370 μm.

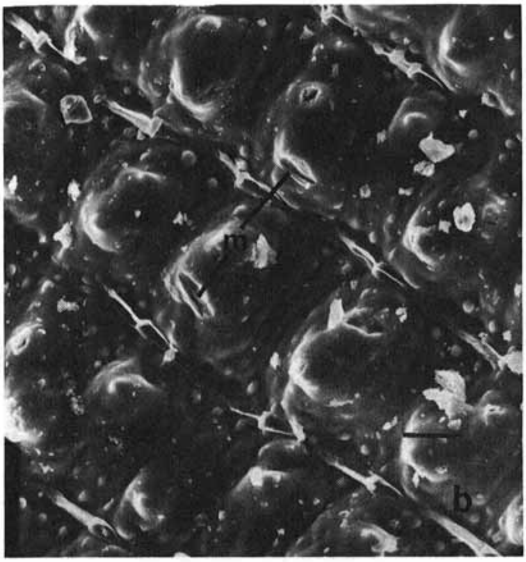

Fig. 4b. SEM micrograph of rice hull; outside of hull showing mechanical indentations (m). Scale bar = 28 μm.

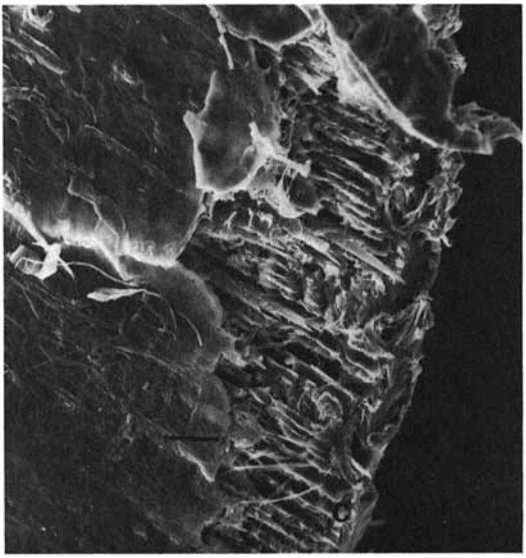

Fig. 4c. SEM micrograph of rice hull; cross section of hull. Scale bar = 38.5 μm.

Fig. 5a. SEM micrograph of parboiled rice kernel and hull; pericarp and aleurone layer. Scale bar = 16 μm.

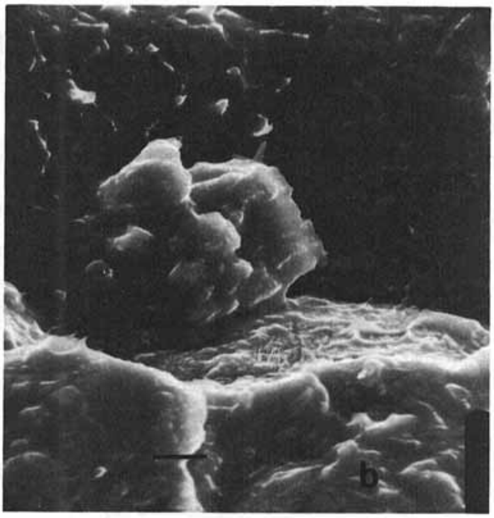

Fig. 5b. SEM micrograph of parboiled rice kernel and hull; endosperm. Scale bar = 6.8 μm.

Fig. 5c. SEM micrograph of parboiled rice kernel and hull; outside of hull. Scale bar = 12.5 μm.

reported that starch granules in the peripheral cells of the endosperm are smaller than those in the major, central portion. They observed that the granules in the peripheral cells form tiny clusters separated by a surrounding dense proteinaceous material, whereas those in the central portion of the kernel occur in closely packed, compound groups with several groups in each cell. Protein granules (p) can be seen in Fig. 2 at various intervals, but apparently they are not as numerous as in grain sorghum (9).

A view of a longitudinal section of the germ end of a rice grain is shown in Fig. 3a; 3b is the portion of Fig. 3a outlined in the square. Figures 3c through 3e show various points indicated on Fig. 3b, at higher magnification. Figure 3c shows the substructure of the parenchyma cells which make up the scutellum and the cell walls (cw) of the outer layer of the scutellum. The aleurone grains (ag) in the parenchyma cells appear to have a substructure. Figure 3d shows starch granules (sg) and a rectangular cell structure (ep) between the starch granules and the scutellum (st). This layer (the epithelium) is the outermost layer of the scutellum, and is composed of rectangular parenchyma cells (2). Figure 3e shows the parenchyma cells, aleurone granules (ag), and parenchyma cell wall (cw) that make up the scutellum between the areas labeled c and d in Fig. 3b.

Views of the exterior of the hull are shown in Figs. 4a and 4b. Unlike the hull of other cereal grains, the exterior surface of the hull of rice is composed of dentate rectangular elements. Mechanical indentations (m) can be seen on some of these in Fig. 4b. Thomas and Jones (12) and Thomas *et al.* (13) state that silica is highly concentrated in the outer dentate crust. The inner region of the hull (Fig. 4c) is fibrous and striated, and is composed of elongated hypodermal fibers. Thomas *et al.* (13) showed that the midregion contains little silica.

Several SEM micrographs of commercial parboiled rice grain were obtained and representative photographs are shown in Fig. 5. All portions of the grain underwent marked changes during parboiling. Evidence of the aleurone layer is present in Fig. 5a, but it is impossible to distinguish the aleurone grains or the parenchyma cells. The starch cells of the endosperm have been gelatinized (Fig. 5b). The hull (Fig. 5c) shows the same dentate structure as the paddy hull; however, material was dissolved during the parboiling process, creating holes in the surface, and the mechanical indentations seen in the paddy hull are not readily observable.

Acknowledgments

We thank R. C. Hoseney, Department of Grain Science and Industry, Kansas State University, Manhattan, for help in interpretation of the microphotographs, and Pam Tuillez, Technician, Department of Entomology, Kansas State University, Manhattan, for preparing the photomicrographs.

Literature Cited

1. HOUSTON, D. F. (ed.). Rice: Chemistry and technology. Amer. Ass. Cereal Chem.: St. Paul, Minn. (1972).
2. JULIANO, B. V. The rice caryopsis and its composition. In: Rice: Chemistry and technology, ed. by D. F. Houston, Chap. 2, p. 16. Amer. Ass. Cereal Chem.: St. Paul, Minn. (1972).
3. DEL ROSARIO, A. R., BRIONES, V. P., VIDAL, A. J., and JULIANO, B. O. Composition and endosperm structure of developing and mature rice. Cereal Chem. 45: 225 (1968).
4. KENNEDY, B. M., and SCHELSTRAETE, M. Chemical, physical, and nutritional properties of high-protein flours and residual kernel from the overmilling of uncoated milled rice. III.

Iron, calcium, magnesium, phosphorus, sodium, potassium, and phytic acid. Cereal Chem. 52: 173 (1975).

5. WATSON, C. A., DIKEMAN, E., and STERMER, R. A. A note on surface lipid content and scanning electron microscopy of milled rice as related to degree of milling. Cereal Chem. 52: 742 (1975).
6. LITTLE, R. R., and DAWSON, E. H. Histology and histochemistry of raw and cooked rice kernels. Food Res. 25: 611 (1960).
7. GREENWOOD, C. T. Cereal science in the UK—Achievements and prospects. Cereal Sci. Today 20: 23 (1975).
8. STEVENS, D. J. The aleurone layer of wheat. III. Isolation and scanning electron microscopic examination of the layer and of its component parts. J. Sci. Food Agr. 24: 307 (1973).
9. HOSENEY, R. C., DAVIS, A. B., and HARBERS, L. H. Pericarp and endosperm structure of sorghum grain shown by scanning electron microscopy. Cereal Chem. 51: 552 (1974).
10. POMERANZ, Y., and SACHS, I. B. Scanning electron microscopy of the buckwheat kernel. Cereal Chem. 49: 23 (1972).
11. ROBUTTI, J. L., HOSENEY, R. C., and WASSOM, C. E. Modified opaque-2 corn endosperms. II. Structure viewed with a scanning electron microscope. Cereal Chem. 51: 173 (1974).
12. THOMAS, R. S., and JONES, F. T. Microincineration and scanning electron microscopy: Silica in rice hulls, p. 276. Proc. 28th Annual Meeting Electron Microscopy Society of America. Claitor's Publishing Division: Baton Rouge, La. (1970).
13. THOMAS, R. S., BASU, P. K., and JONES, F. T. Silicon tetrachloride synthesis from rice hulls: Transmission and scanning electron microscope study, p. 236. Proc. 30th Annual Meeting Electron Microscopy Society of America. Claitor's Publishing Division: Baton Rouge, La. (1972).

[Received March 2, 1976. Accepted May 13, 1976]