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Y. Pomeranz

Z. Czuchajowska

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STRUCTURE OF COARSE AND FINE FRACTIONS OF CORN SAMPLES GROUND ON THE STENVERT HARDNESS TESTER

Y. Pomeranz[1] and Z. Czuchajowska[2]

[1]U.S. Grain Marketing Research Laboratory, USDA, Agricultural Research Service
1515 College Avenue, Manhattan, Kansas 66502
[2]Dept. of Chemical Engineering, Kansas State University, Manhattan, Kansas 66506

Abstract

Kernels from a pair of isogenic lines (with regard to hardness) and two commercial hybrids of dent corn (that varied in hardness) were ground on the Stenvert Hardness Tester and separated by sieving into coarse (>0.710 mm) and fine (<0.500 mm) fractions. The corn samples differed little in oil contents. The coarse particles from the hard corn samples were angular and sharp-edged; those from the soft corn samples were rounded. The yield of coarse particles was higher and they contained less oil in hard than in soft corn. Fine particles from all four corn samples had higher oil content than the coarse particles. Visual examination, observation at low magnification under a light microscope, and use of a scanning electron microscope revealed consistent differences in the extent and mode of corn kernel breakdown during grinding. Particles in the coarse fraction from hard kernels were to a large extent intact with little exposure of their contents. In the soft kernels, particles in the coarse fraction were broken extensively and their contents exposed. It is postulated that differences in the extent of mechanical breakdown and oil content are related to differences in shelf life of corn grits.

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Direct inquiries to Y. Pomeranz
Telephone number: 913 776 2701

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Introduction

The production of corn grits of good shelf life is of great interest to the dry milling industry (Hopkins et al., 1903; Earle et al., 1946; Brekke, 1970; Brockington, 1970). Several methods of corn hardness determination were evaluated by Pomeranz et al. (1984) on corn varying widely in structure and composition as well as on pairs of isogenic lines with respect to hardness. We have reported on the use of the Stenvert tester to determine hardness of corn (Pomeranz et al. 1985a) and hardness of eight commercially dried corn hybrids equilibrated at two moisture levels (Pomeranz et al., 1985b). In a more recent study (Pomeranz et al., 1985c), kernels from seven classes separated according to size and shape from three hybrids were ground on the Stenvert Hardness Tester. The ground corn was sieved to obtain two main fractions: coarse (>0.710 mm in diameter) and fine (<0.500 mm in diameter). The oil contents of the coarse and fine fractions differed widely for the three hybrids. The effects of corn hardness on particle size and oil content of the coarse fraction were confirmed for corn hybrids dried under various commercial conditions. It was concluded that the Stenvert Hardness Tester has potential for predictive determination of corn properties in dry milling, both in terms of yields of products and of their particle size and composition. This report describes the effects of grinding corn with the Stenvert Hardness Tester on structure of the fine and coarse fractions. The structure was evaluated at low magnification by light-microscopy, and by scanning electron microscopy.

Materials and Methods

The two yellow dent corn hybrids (Stauffer 8500, relatively hard, and Bo Jac, relatively soft) were described previously (Pomeranz et al., 1985a). In addition, a pair of isogenic lines (dent and flint), from the breeding program of Cargill, Inc., Minneapolis, MN, was studied. The pair is considered to differ primarily, or only, in kernel hardness. The flint kernels were smaller and had higher density, larger particle size (when ground), and higher NIR (near infrared) reflectance values at 1680 nm than their dent corn isogenic counterparts (Pomeranz et al., 1984). The NIR reflectance value at 1680 nm is an index of particle size; the higher the value, the larger the average particle size. The corn kernels were ground with the Stenvert Hardness Tester and separated into coarse (>0.710 mm in diameter) and fine fractions (<0.500 mm in diameter). The gross composition of the kernels was described by Pomeranz et al. (1985a).

Light microscopic examinations of ground samples were made on the Tessovar photomicrographic zoom system (Carl Zeiss Co., Oberkochen, W. Germany). The ground and sieved samples were viewed before and after staining with a green dye (Fast Green FCF, Color Index No. 42053) according to Chowdury and Buchele (1976). For examination by scanning electron microscopy (SEM), the samples were placed on double-stick Scotch® tape mounted on 9-mm diameter aluminum specimen holders. The samples were coated with a 10-nm layer of graphite and a 15-nm layer of gold, and viewed and photographed in the ETEC autoscan electron microscope at an acceleration voltage of 5 kV.

Results and Discussion

Characteristics of corn samples ground into coarse and fine fractions on the Stenvert tester are compared in Table 1. The hard kernels were higher than the softer counterparts in density and yield and lower in oil content of the coarse fraction. The fine fractions contained substantially more oil than the coarse fractions, and the fine fraction from soft corn was lower in oil than the fine fraction from hard corn.

Light micrographs of the coarse fractions (>0.710 mm) are shown in Figures 1-2 before staining and in Figures 3-4 after staining with Fast Green FCF. The hard, flinty and angular particles are more numerous in Figures 1 and 3 (from Stauffer 8500) than in Figures 2 and 4 (from Bo Jac).

Coarse particles from flint and dent isogenic pairs, examined by SEM, are shown in Figures 5a-h. The top line (Figures 5a-d) shows relatively little breakdown of the structure and relatively little exposure of starch granules in the flint corn. This is accompanied by little germ oil in the coarse particles and may explain the relatively good shelf life of coarse grits from flint corn during storage. In addition, differences in the amounts of germ and aleurone particles in the coarse fractions from soft and hard corn can affect shelf life. The particles from the dent corn (Figures 5e-h) are broken open and the starch granules are exposed. Whereas the cleavage in the flint particles is along wall lines in a manner that retains to a large extent cell integrity, the cleavage in the dent particles is across cell walls (Fig. 5g and h). The starch granules in the flinty corn, to the extent that they are exposed, are mainly polygonal with a few spherical. The starch granules in the dent corn are mainly spherical with a substantial amount polygonal.

Fine particles (<0.500 mm) from flint and dent isogenic lines, examined by SEM, are shown in Figs. 6a-f. In each figure, particles identified by an arrow indicate the site of subsequent examination at higher magnification. The fine particles, sieved after grinding on the Stenvert mill, varied widely in size. The fine particles from flint corn (Figures 6a-c) show breakdown of cell contents and cell wall and a somewhat porous and mechanically damaged structure. The exposed starch granules are of various sizes and shapes. The fine particles from dent corn (Figures 6d-f) seem less disintegrated, which may explain (in part) their relatively lower retention of oil from the germ. The highly variable distribution (in particle size and extent of mechanical breakdown) of the fraction <0.500 mm in flint corn is illustrated in Figures 7a and b. The starch granules varied widely in size and shape and the cell wall and protein matrix are extensively disintegrated and exposed.

Visual observation indicated small variations in hardness and vitreosity within coarse particles from isogenic corn lines ground on the Stenvert tester. In the particles from the commercial hybrids, however, there were visible differences in texture. Thus for instance, in Stauffer 8500 both hard and relatively soft areas were identified both visually and after examination under the SEM. They are demonstrated for coarse particles in the relatively hard Stauffer 8500 in Figs. 8a-e. A relatively soft piece is identified in Fig. 8a (bottom left) and shown at intermediate and

Table 1
Yields and Some Characteristics of Coarse (>0.710 mm) and Fine (<0.500 mm) Fractions of Stenvert Ground Corn Samples

Yields and Characteristics	Isogenic Lines		Commercial Hybrids	
	Flint	Dent	Stauffer 8500	Bo Jac
1000 kernel weight (g)	256.5	313.6	251.0	247.6
Density (g/cc)	1.324	1.280	1.339	1.283
Yield				
Coarse (%)	53.5	45.6	49.2	42.3
Fine (%)	30.0	38.4	35.4	40.2
Oil*				
Whole kernel (%)	3.88	3.93	3.95	3.66
Coarse fraction (%)	1.17	1.73	1.51	2.39
Fine fraction (%)	9.76	6.79	7.62	4.87

*14% moisture basis.

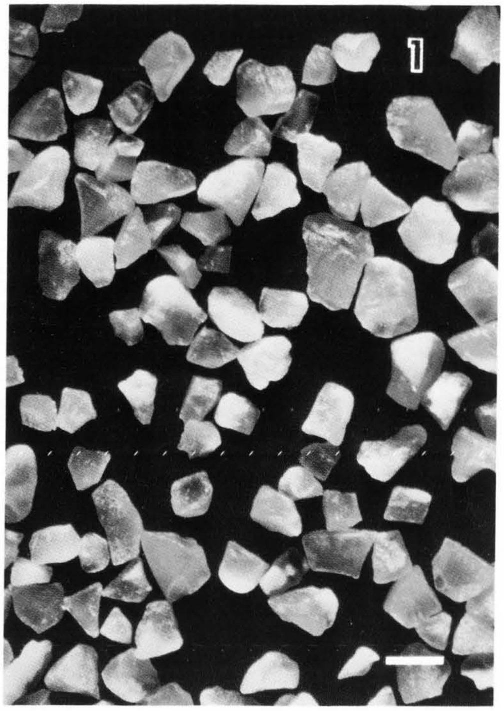

Fig. 1. Light micrograph of the coarse fraction (>0.710 mm) from Stenvert ground Stauffer 8500 corn; bar = 650 μm.

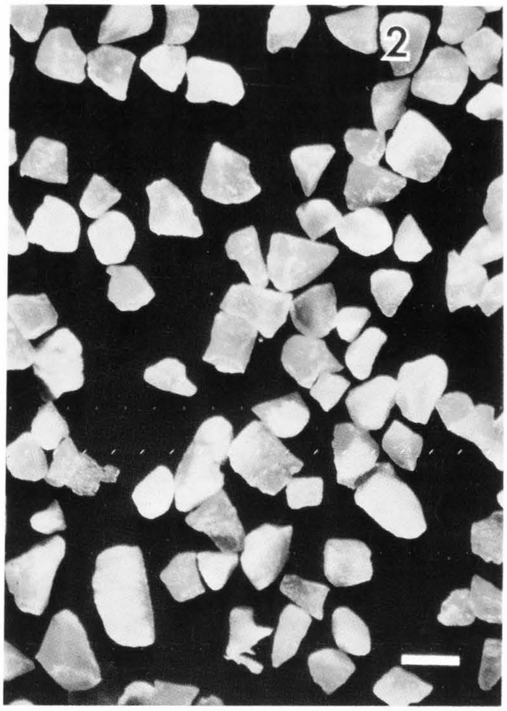

Fig. 2. Light micrograph of the coarse fraction (>0.710 mm) from Stenvert ground Bo Jac corn; bar = 650 μm.

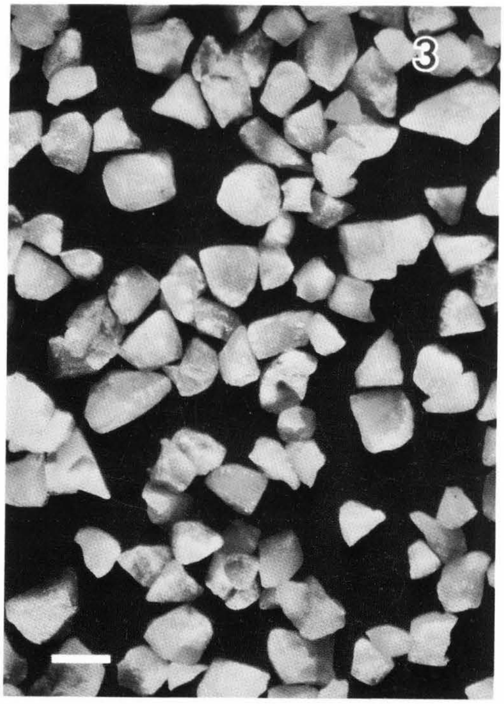

Fig. 3. Light micrograph of the coarse fraction (>0.710 mm) from Stenvert ground Stauffer 8500 corn after staining with Fast Green FCF; bar = 650 μm.

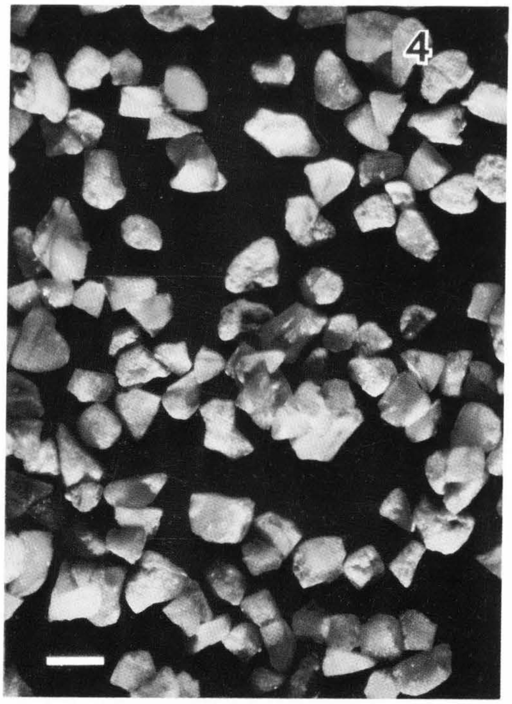

Fig. 4. Light micrograph of the coarse fraction (>0.710 mm) from Stenvert ground Bo Jac corn after staining with Fast Green FCF; bar = 650 μm.

Fig. 5a-h. SEM of the coarse fraction from flint (a-d) and dent (e-h) Stenvert ground corn (isogenic lines). a) Low magnifications of particles from flint corn. Arrow identifies the particle examined in Fig. b; bar = 700 µm. b) Intermediate magnification of particle from flint corn. Arrows identify particles examined at high magnification in Figs. c (low arrow) and d (top arrow); bar = 125 µm. c) High magnification of flint corn particle identified in Fig. b; bar = 10 µm. d) High magnification of flint corn particle identified in Fig. b; bar = 10 µm. e) Low magnification of particles from dent corn. Arrow identifies the particle examined in Fig. f; bar = 700 µm. f) Intermediate magnification of particle from dent corn. Arrow identifies particles examined at high magnification in Figs. g and h; bar = 125 µm. g) High magnification of dent corn particle identified in Fig. f. Note polygonal shape of starch granules and cleavage through cell wall; bar = 10 µm. h) High magnification of dent corn particle identified in Fig. f. Note spherical shape of starch granules and cleavage through cell wall; bar = 10 µm.

high magnification in Figs. 8b and 8c. A harder, more vitreous particle in Fig. 8a (bottom right) is shown at intermediate and high magnification in Figs. 8d and 8e. Again, whereas in the soft area there is much exposure of starch granules, in the hard area there is little exposure. Similar areas were selected for coarse particles of the relatively soft Bo Jac (Figs. 9a-c). The very soft piece (Fig. 9a, bottom right) is shown at high magnification in Fig. 9b and the somewhat harder piece (Fig. 9a, top middle) in Fig. 9c. Relative hardness is expressed by differences in appearance under low magnification (or even visually) and in the appearance under the SEM at high magnification.

Of particular interest is the fact that, whereas there was little difference in the oil contents between the pair of isogenic lines and the pair of hybrid corn samples (Table 1), the oil contents of the Stenvert ground coarse and fine fractions in the two pairs differed widely. The fine fractions were high in oil in all four samples; higher in the flint than in the dent isogenic line and higher in the relatively hard Stauffer than in the relatively soft Bo Jac. The high oil contents of the four fine fractions would reduce their shelf life by causing a rapid rise in rancidity. The coarse fractions, of value in food processing (breakfast cereals, hominy grits, brewers' grits, etc.), are relatively low in oil. Different relative amounts of germ oil were present in the coarse and fine particles from hard and soft corn.

In summary, the oil contents of the coarse and fine fractions from corn ground on the Stenvert mill were affected by corn hardness. Hardness governed the mode and extent of corn breakage, the texture of the broken particles, and their contents of germ oil. The distribution of oil in the coarse fractions of hard and soft corn is known to be related to shelf life of milled corn in food production.

It should be emphasized that the results of this study were obtained on corn equilibrated to a moisture content of about 12.3% as ground under the empirical conditions of the Stenvert Hardness Tester, a hammer/cutter mill that operates at 3600 rpm. The coarse fraction (>0.710 mm) in all samples contained some particles from outside the starchy endosperm (germ, pericarp, and aleurone). In addition, in the two commercial hybrids the coarse particles contained both flint and dent particles (and their mixtures). The flint particles in Stauffer 8500, however, were more numerous than in Bo Jac. The flint particles in the coarse fraction of all samples were consistently less broken open and showed less exposure of cell contents, and less oil than the coarse soft particles from the Stenvert ground corn.

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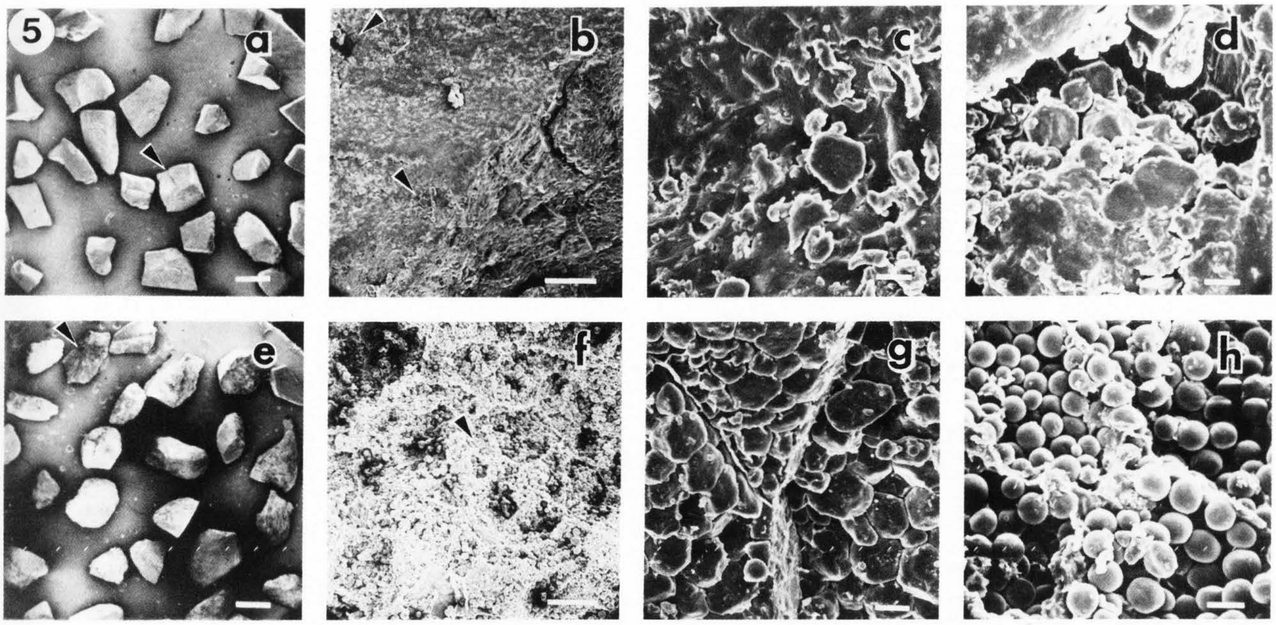


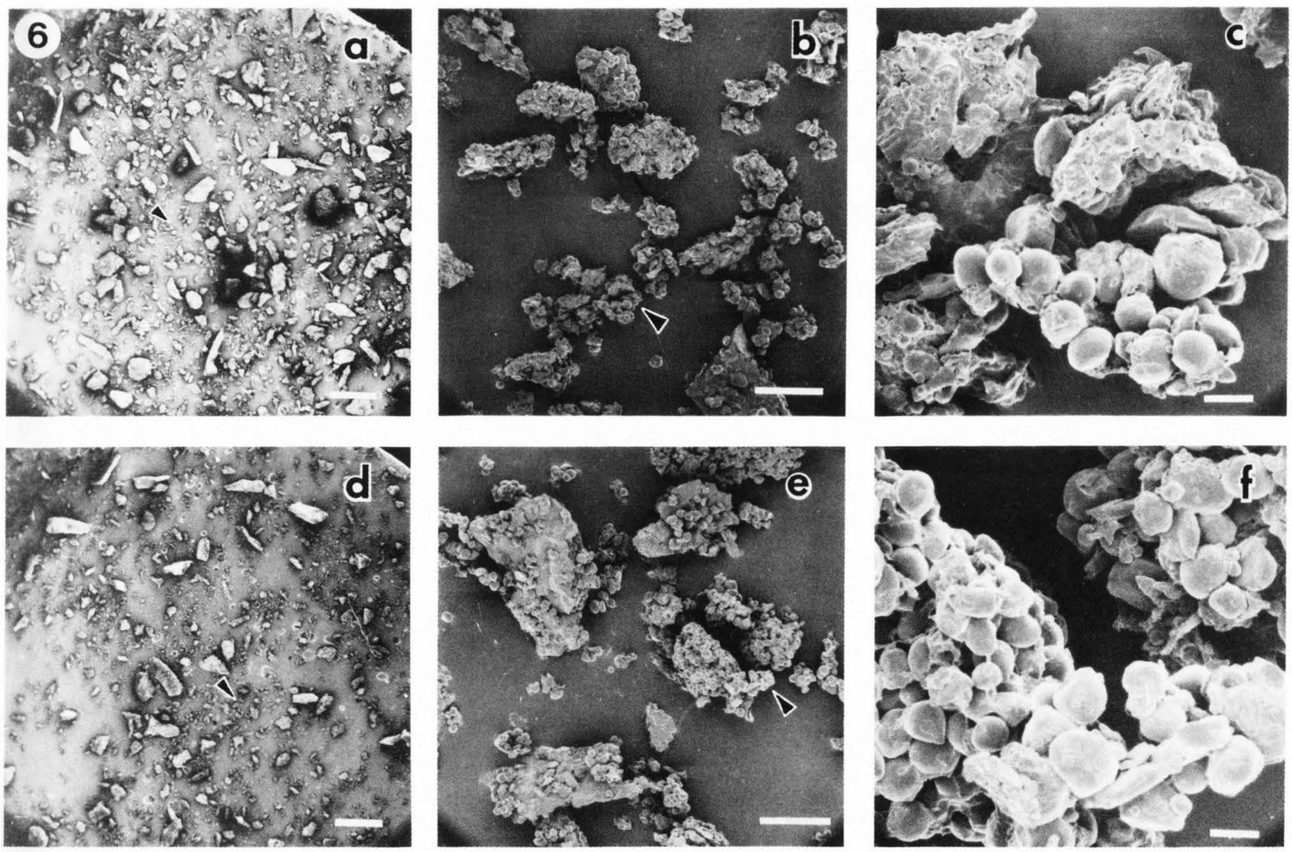


Fig. 6a-f. SEM of the fine fraction from flint (top line, a-c) and dent (bottom line, d-f) Stenvert ground corn (isogenic lines). Arrows identify particles examined at higher magnification in subsequent figures. Low (a), intermediate (b), and high magnification (c) of particles from flint corn. Low (d), intermediate (e), and high magnification (f) of particles from dent corn. The bar equals 800 µm in a and d; 100 µm in b and e; and 10 µm in c and f.

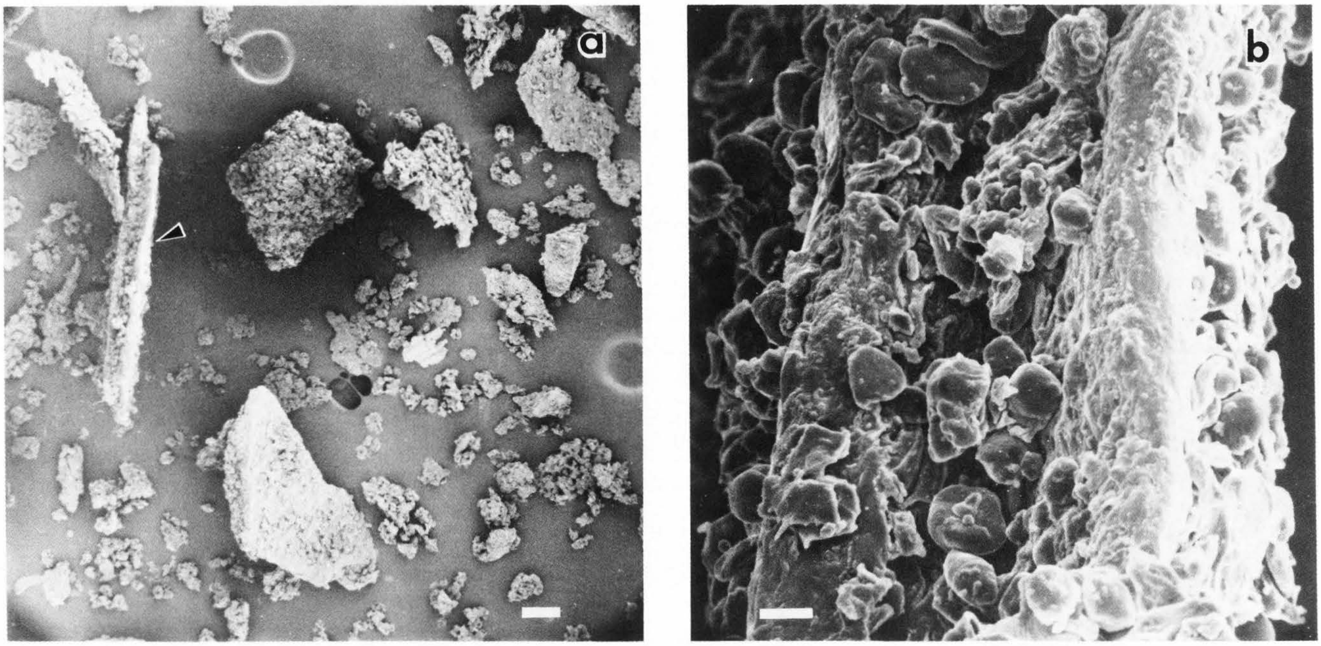
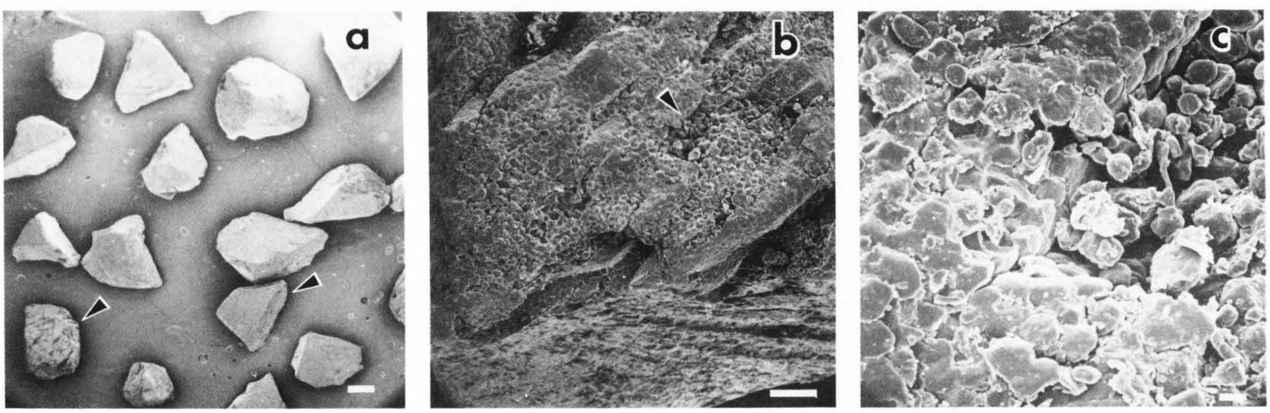


Fig. 7a-b. SEM of particles varying widely in size in the fine fraction (<0.500 mm) of Stenvert ground flint corn (isogenic line). Parts of the long particle identified by an arrow in a is shown at high magnification in b. The bar equals 100 μm in a and 10 μm in b.



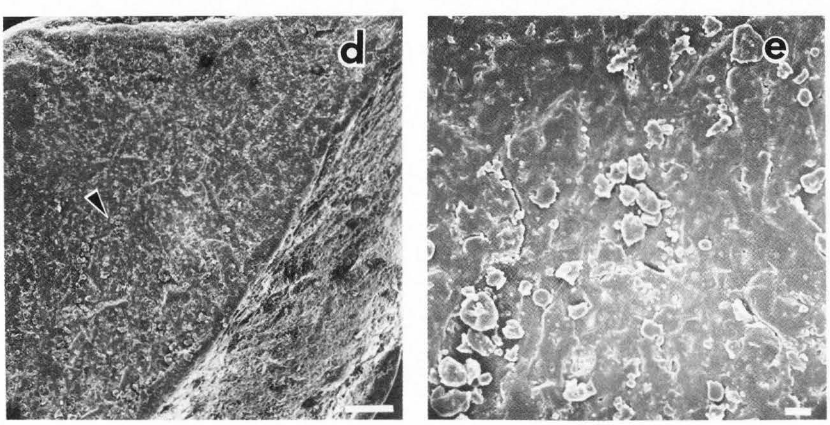


Fig. 8a-e. SEM of coarse particles from Stenvert ground Stauffer 8500 corn. Corn pieces identified in a are shown at intermediate (b and d) and high magnification (c and e). Figures b and c from a relatively soft area and Figures d and e from a relatively hard area in the pieces. The bar equals 450 μm in a; 100 μm in b and d; and 10 μm in c and e.

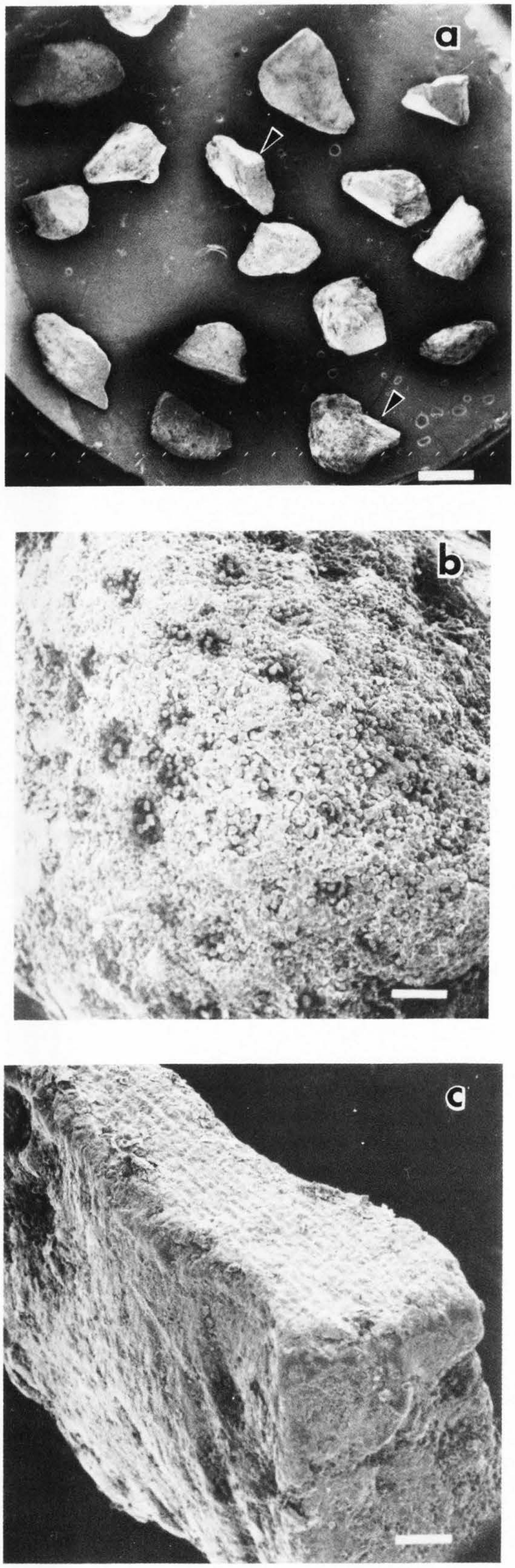


Fig. 9a-c. SEM of coarse particles from Stenvert ground Bo Jac corn. Corn pieces identified in Fig. a are shown at higher magnification in Fig. b (bottom right in a) and in Fig. c (middle top in Fig. a). The bar equals 700 µm in a and 100 µm in b and c.