BREAKAGE OF ENDOSPERM CELL WALLS IN FLOUR MILLING[1]

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ABSTRACT

Particles of cell walls from the starchy endosperm occur with more or less of the cell contents, or with none, in hard red winter wheat flours. The cell-wall particles are always portions of walls of two adjacent cells, with the middle lamella which cements them. Breakage of the cell walls is invariably transverse, rather than along the middle lamella. This conclusion is compatible with known structure, composition, and physical properties of plant cell walls.

The purpose of flour milling is to separate the starchy endosperm of the wheat kernel from other parts and to reduce it into small particles which, in the aggregate, form flour. The size range of the flour particles depends on the type of wheat milled and the details of the milling process employed. Both are selected to produce flour of the desired characteristics. Other parts of the wheat kernel – bran, aleurone cell layer, brush, and germ – are unavoidably included in flour to a relatively small extent. In the present discussion, they will be ignored.

A number of investigators have reported on the types of starchy endosperm particles found in flours of hard and soft wheats (1,5,9,16). Both types of flours contain individual starch granules, particles of protein and of cell walls, and larger particles. The last are of greater size in hard than in soft wheat flour and may, indeed, represent intact contents of one or more entire cells, with or without some surrounding walls.

Some papers (9,15) and comments in open discussions (16) have indicated the possibility that a flour particle apparently composed of the entire cell contents with its surrounding wall may result from breakage of the wall along the middle lamella. This would be most surprising, for, in botanical studies, cells can be separated thus only by comparatively drastic treatment with chemicals (maceration).

There is a practical aspect to the question, in view of recent developments in the milling industry. Hess (6,7) showed the possibility of producing fractions of different protein contents from a flour. Whether effected by sedimentation, air elution, or other means,

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classification depends on differences in size, shape, and density of the flour particles. Density, in turn, is dependent upon composition.

Modern advances in milling technology include the production of several flours with specific properties from one flour produced from a conventional flow. Commonly, the original flour is subjected to fine grinding and classification. Considerable work, therefore, has been done on the nature of the particles which are separated to form the flour fractions (3,4,8,11,12,13,14). Major attention has been given to starch and protein components of the particles. Cell walls can have considerable influence on power required for both milling and fine grinding, and on the factors affecting classification. Inclusion or exclusion of cell walls would influence baking quality of flour fractions. It seems desirable, therefore, to define more clearly the manner in which cell walls are broken during flour production.

The purpose of the present work was to determine whether the cell walls of hard wheat are broken along the middle lamella during milling.

Materials and Methods

Flour was milled in the laboratory from a sample of No. 1 Ponca

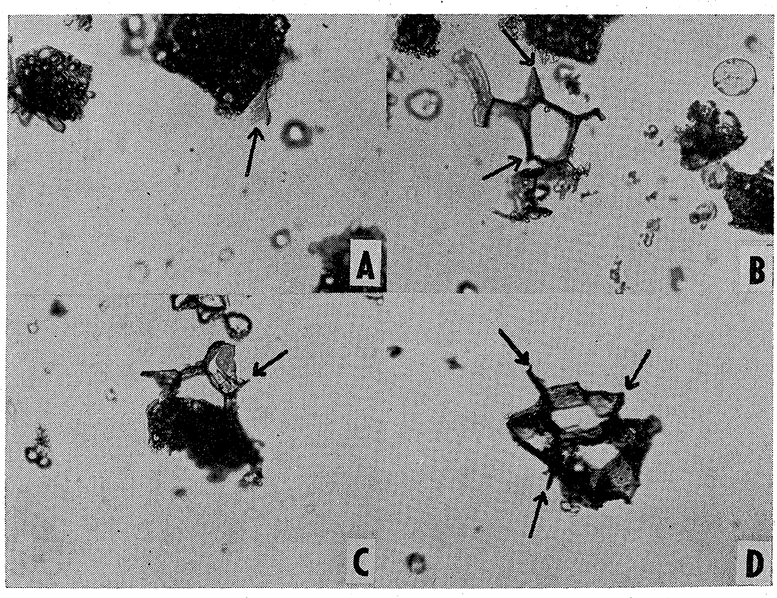

Fig. 1. Particles from Ponca hard red winter wheat flour: a, cell contents broken transversely, middle portion remaining intact; b, c, d, parts of walls of several cells from which contents have escaped during milling; all walls are double, with middle lamella cementing the walls of adjacent cells. Arrows point to stumps of broken walls of adjacent cells. Magnification 130×.

variety hard red winter wheat grown at Stillwater, Oklahoma, in 1960. The grain was dry-cleaned in a Carter dockage tester and a Forster dry scourer and was then cold-conditioned. Sufficient water was added, as the grain was tumbled in a drum, to raise the moisture content to 15%. When all water had been taken up by the wheat, it was allowed to rest for 24 hours in a closed can. The grain was then milled. A flow of four breaks and five reductions on Allis laboratory roller mills and a plane sifter with an 11xx flour cloth was used. Flour of 74.4% extraction was obtained.

Similarly milled flour from Bison hard red winter wheat grown at Hays, Kansas, in 1960 and a sample of commercially milled hard red winter wheat flour from wheat grown in 1960 were used to confirm observations. In addition, samples of flour which had been milled from warm- and hot-conditioned wheat for another research study were observed microscopically.

Colloidal molybdenum blue (Mo_3O_8), used for staining endosperm cell walls (5) in Fig. 1, d, was prepared as described by Mellor (10).

A 0.025% Congo red solution in pH 8 phosphate buffer was used to stain the middle lamella of the cell walls as shown in Fig. 2.

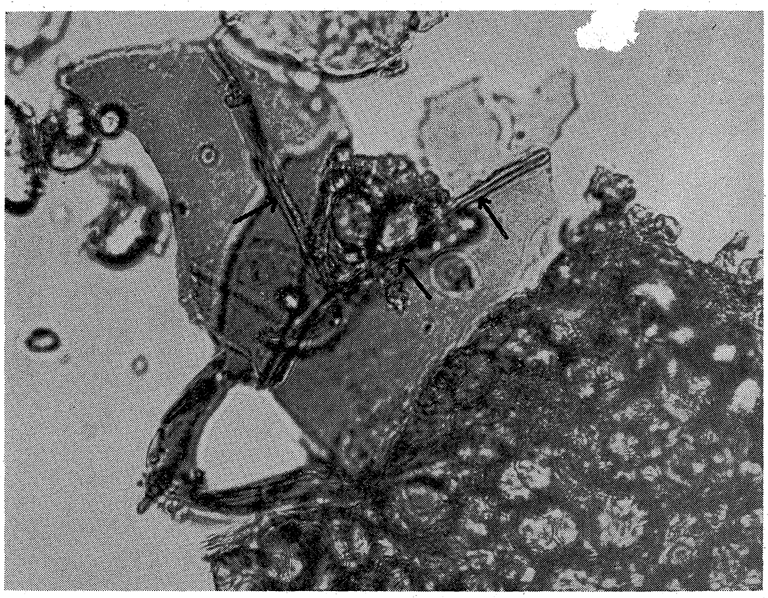

Fig. 2. A particle of Ponca hard red winter wheat flour composed of cell contents of several cells with some walls adhering, and with some attached walls free of cell contents. The arrows point to cell walls that are shown in cross-section and stained to make the middle lamella between walls of adjacent cells clearly visible. Other cell walls in this photomicrograph are at such angles that the middle lamella is not visible. Magnification 615×.

Microscopic mounts of flour particles were prepared by adding the particles to a drop of stain on a glass slide and covering the preparation with a glass cover slip.

Results and Discussion

In the higher plants, each cell is surrounded by a wall. Walls between adjacent cells are cemented together by a thin layer known as the "middle lamella". That this is the situation in the starchy endosperm of the wheat kernel is amply evident from prior publications (2, Figs. 21 and 23; 9, Fig. 5).

Particles of cell wall from the starchy endosperm are always present in flour. The most noticeable types are a loose "flap" attached to an endosperm cell particle, as in Fig. 2, and free particles that look like small sheets of material. Kent and Jones (9) published drawings to show the range in quantity of cell wall remaining on hard wheat flour particles. Cell wall closely attached to cell contents is more difficult to observe than the "flaps" and is easily overlooked (Fig. 1, a). Sometimes, however, the cell contents drop out and the once-surrounding walls become visible (Fig. 1, b,c,d). If not properly oriented in the mount, they too are easily overlooked. Cell-wall particles similar to those shown in Fig. 1, b and 1, d can, however, be obtained by partial maceration of flour particles in Jeffrey's fluid (10% aqueous chromic acid and 10% aqueous nitric acid solutions, 1:1).

All types of cell-wall particles, regardless of how the wheat was conditioned for milling, were found to be composed of two cell walls with the cementing middle lamella. A typical example is shown in Fig. 2, where the middle lamella is clearly evident in cross-section (because of proper staining) as a dark line between adjacent cell walls. Cell walls observed from the side appear as flat sheets and, of course, the individual cell walls and the middle lamella between them are not then evident.

In preliminary microscopic studies cell walls found on or among flour particles were found to be of the same order of thickness as those occurring between adjacent cells in the unground, sectioned endosperm. Splitting of cell walls along the middle lamella would halve the thickness.

Sometimes a flour particle is found which consists of entire cell contents surrounded by cell walls. The walls in the particle then include portions of the walls of adjacent cells that are cemented to the wall of the cell in question by the middle lamella. Thus there must be other particles in the flour, formed from the adjacent cells, that consist of parts of cell contents or entire cell contents with no covering, or partial covering by cell walls. That such particles do exist has been pointed out by Kent and Jones (9) and confirmed in the present study.

It is possible, therefore, to visualize how breakage occurs to form flour particles. Cell walls are broken transversely. Cell contents may be broken into two or more parts or may remain intact. In either case, none or part of the cell wall may remain with the particle. When the cell contents remain intact, the complete cell wall may also remain, but will then carry with it the adjacent cell walls of neighboring cells, with the middle lamella. The breaks in such a case occur close to the intact cell and their locations are often difficult to see. Each break leaves a more or less visible "stump," however; several are indicated by arrows in Fig. 1, d.

There is no evidence that there is any cleavage between cell walls, along the middle lamella. All that is known of plant cell-wall structure and properties supports these observations. Apparently the adhesiveness between cell walls and middle lamella is too strong to be broken during milling.

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