NOTE

Time-Dependent Moisture Gradients in Conditioned Wheat, Determined by Electrical Methods[1,2]

Y. POMERANZ and L. C. BOLTE, U.S. Grain Marketing Research Laboratory, U.S. Department of Agriculture, Agricultural Research Service, Manhattan, KS 66502; and S. AFEWORK, Department of Chemical Engineering, Kansas State University, Manhattan 66502

ABSTRACT

Water penetration during wheat conditioning and subsequent moisture content changes were determined. Four electrical moisture meters were used to determine moisture contents in grain on the basis of dielectric, capacitance, impedance, and conductance properties. The differences between actual moisture content and moisture determined by each of the electrical methods decreased as the time after water addition increased. The differences were largest for the conductance and smallest for the capacitance method. The differences were attributable to moisture gradients in the wheat. The rate of water penetration, according to moisture determined by the conductance method, was rapid in soft red winter wheat, slow in durum wheat, and intermediate in hard red winter wheat. Water distribution in the wheat kernel, as determined by conductance, was stabilized in 2–4 hr after water addition, depending on the kernel hardness.

Cereal Chem. 61(6): 559–561

The main objective of conditioning wheat is to improve its physical state for milling by making the bran and germ tougher and the starchy endosperm more mellow (Swanson 1933, Pence and Swanson 1930). Bradbury et al (1960) published a survey of the literature on conditioning wheat for milling, which covered studies on entrance of water into the wheat kernels, including place, rate, factors affecting, and methods of following entrance and movement. The chief methods were: 1) water-absorption by weight increase in parts of the kernel, 2) absorption by protected (ie, shellac-coated) and unprotected portions of the kernel, and 3) water movement determined by special staining procedures.

More recently, Moss (1973) studied varietal differences in grain morphology as they affected water penetration, conditioning, and milling. Varietal differences were governed by kernel size and shape, thickness and composition of the outer cuticle and testa, extent to which the outer epidermal and inner parenchymal cells had been compressed, and number and size of protein masses in the subaleurone endosperm cells. Butcher and Stenvert (1973) determined by an autoradiographic technique that the rate of water penetration into the kernel differed among Australian wheat cultivars. Moss (1977) used an improved labeling technique applicable directly to whole sections, which enabled a more precise study of the conditioning water than was previously achieved using halves of labeled wheat grains. Within 1 hr, labeled water penetrated into the aleurone cells and in many cases into the starchy endosperm to a depth of 50–60 μm. The embryo and scutellum also rapidly absorbed water. Subsequent penetration into the endosperm was delayed for several hours. The relation between levels for moisture optimum conditioning and grain hardness based on these findings, was reported recently (Anonymous 1977). Initial moisture and protein contents also affected the rate of water penetration. Increasing the initial moisture reduced the water binding potential of grain components and allowed more rapid movement of water. Increasing the protein content retarded the rate of moisture movement, because of the proteins' water binding capacity and because proteins contribute to a more ordered endosperm structure.

[1]Cooperative investigations between USDA-ARS and the Kansas Agricultural Experiment Station, Kansas State University.

[2]Mention of firm names or trade products does not constitute endorsement by the U.S. Department of Agriculture over others not mentioned.

The objective of this research was to determine the rate of water penetration into wheat by following changes in apparent moisture content, as determined by several electrical methods. The study was based on the observation that conductance is greatly affected by the extent of moisture penetration into and moisture distribution in the conditioned wheat kernel. This moisture gradient in freshly conditioned wheat makes it impossible to determine the true moisture content by some electrical methods. A comparison of moisture contents in conditioned wheat, as determined by the conductance method and the capacitance method, was useful, however, in following the rate of water penetration.

MATERIALS AND METHODS

Four hard red winter, two soft red winter, and two durum wheats were used. Their partial characterization is given in Table I. The wheats were conditioned to contain 15% moisture at 21.1°C (70°F) in the apparatus described by Bequette and Barmore (1963). Three-kg samples were conditioned and blended, and duplicate subsamples were drawn at appropriate intervals and analyzed. Moisture (by the air-oven drying method) and protein (by the Kjeldahl method) were determined, according to AACC approved methods (1976) on material ground on a laboratory Hobart mill, and wheat hardness was measured by the NIR reflectance method (Bruinsma and Rubenthaler 1978, Miller et al 1982) on material ground on a Udy mill.

The rapid electric meters used to follow moisture penetration and principles of their operation were: DICKEY-john GAC II-

TABLE I
Characterization of Wheats Used in This Study

Class and Variety	Test Weight (lb/bu)	Average Kernel Weight (mg)	Moisture (%)	Hardness (NIR at 1,680 nm)	Protein ($N \times 5.7$, 14% mb)
Soft red winter					
Hart	56.8	32.3	10.6	131	14.4
Pike	56.5	29.0	10.9	111	12.7
Hard red winter					
Newton	58.4	25.2	11.8	200	12.3
Scout 66 (A)	57.4	26.6	12.3	208	13.3
Scout 66 (B)	58.5	26.4	10.6	211	13.8
Larned	59.6	32.2	10.5	192	13.4
Durum					
Cando	58.2	29.5	9.5	251	13.6
Vic	58.7	58.1	12.5	290	13.4

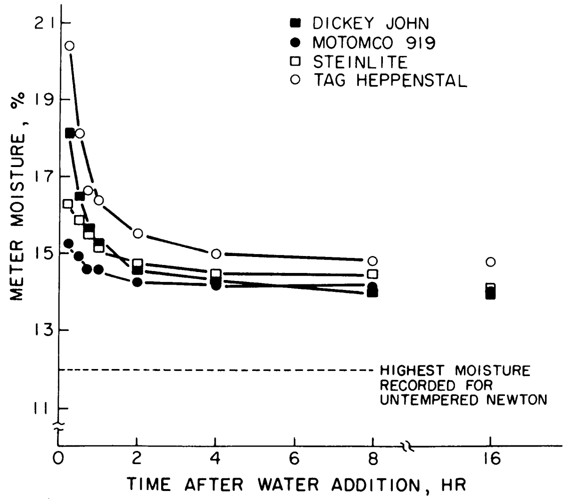

Fig. 1. Water contents of conditioned hard red winter wheat, cultivar Newton, as determined by four electrical moisture meters at various times after tempering. (DICKEY-john dielectric, Motomco capacitance, Steinlite impedance, Tag-Heppenstal conductance).

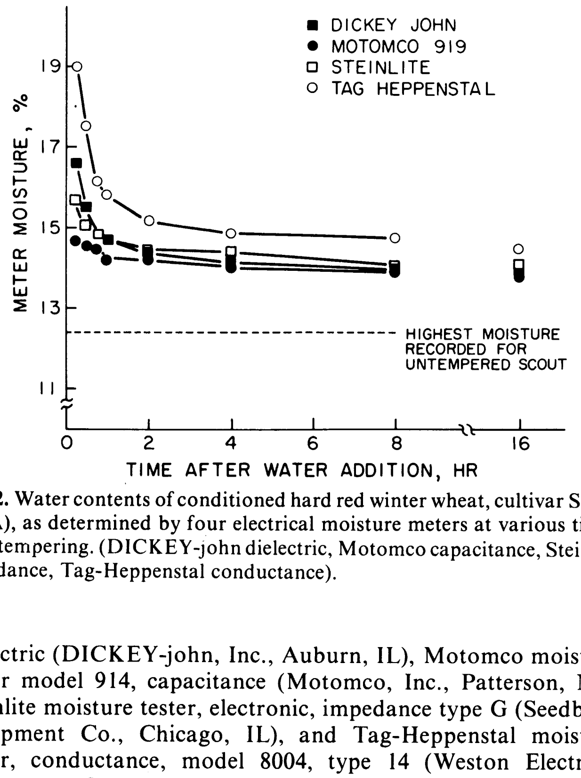

Fig. 2. Water contents of conditioned hard red winter wheat, cultivar Scout 66 (A), as determined by four electrical moisture meters at various times after tempering. (DICKEY-john dielectric, Motomco capacitance, Steinlite impedance, Tag-Heppenstal conductance).

dielectric (DICKEY-john, Inc., Auburn, IL), Motomco moisture meter model 914, capacitance (Motomco, Inc., Patterson, NJ), Steinlite moisture tester, electronic, impedance type G (Seedburo Equipment Co., Chicago, IL), and Tag-Heppenstal moisture meter, conductance, model 8004, type 14 (Weston Electrical Instruments Corp., Newark, NJ).

All results are averages of determinations made on duplicate subsamples.

RESULTS AND DISCUSSION

Moisture was determined by four electrical methods in two hard winter wheat cultivars, Newton and Scout 66, 15 min to 16 hr after tempering to 15% moisture. Averages of analyzing duplicate subsamples are shown in Figs. 1 and 2. Differences between the moisture contents determined by any of the electrical methods and the actual, 15%, moisture content of conditioned wheat decreased as the time after tempering increased and presumably, as water was distributed more evenly throughout the kernel. This difference was largest for the conductance method and decreased in order for the dielectric, impedance, and capacitance methods. These results are consistent with the finding that capacitance methods are least affected and conductance methods are most affected by nonuniform moisture distribution in the wheat kernel.

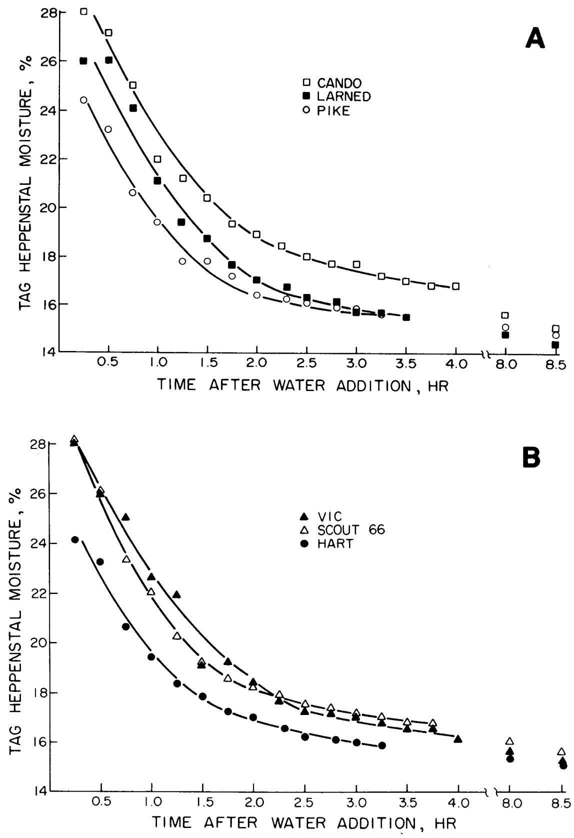

Fig. 3. Water contents of six conditioned wheats, as determined by the conductance method at various times after tempering. Cando and Vic = durum, Larned and Scout 66 (B) = hard red winter, and Pike and Hart = soft red winter.

Effects of grain hardness on the rate of water penetration in durum, hard red winter, and soft red winter wheats are shown in Fig. 3A and B. Water penetration was fastest in the two soft red winter wheat cultivars, Hart and Pike; intermediate in the two hard red winter wheats, Scout 66 and Larned; and slowest in the two durum wheats, Vic and Cando. Water distribution in the wheat kernel, as determined by conductance, was stabilized in 2–4 hr after water addition, depending on wheat hardness. More extensive studies are required to determine to what extent kernel size, original moisture, and protein contents affect the rate of water penetration. No consistent effects were recorded for the samples used in this study.

The value of determining the rate of water penetration into the wheat kernel is primarily as an index of conditioning time required for wheat in the milling process. The results of such a study have been published elsewhere (Pomeranz et al 1984).

LITERATURE CITED

AMERICAN ASSOCIATION OF CEREAL CHEMISTS. 1976. Approved Methods of AACC. 7th ed. Method 44-15A, approved April 1967, and Method 46-11, approved April 1961. The Association, St. Paul, MN.

ANONYMOUS. 1977. The importance of conditioning Australian wheat for milling. Wheat Australia 10(5):2.

BEQUETTE, R. K., and BARMORE, M. A. 1963. Tips worth noting in experimental milling. Cereal Sci. Today 8:339.

BRADBURY, D., HUBBARD, J. E., MACMASTER, M. M., and SENTI, F. R. 1960. Conditioning wheat for milling. A survey of the literature. Misc. publ. no. 824, Agric. Res. Serv., U.S. Department of Agriculture, Washington, DC.

BRUINSMA, B. L., and RUBENTHALER, G. L. 1978. Estimation of

lysine and texture in cereals by NIR. Page X-BR-1 in: Proceedings of the 8th Technical International Congress. 1978. Technicon Instruments Co., Ltd., London, England.
BUTCHER, J., and STENVERT, N. L. 1973. Conditioning studies on Australian wheat. III. The role of the rate of water penetration into the wheat grain. J. Sci. Food Agric. 24:1,077.
MILLER, B. S., AFEWORK, S., POMERANZ, Y., BRUINSMA, B. L., and BOOTH, G. D. 1982. Measuring the hardness of wheat. Cereal Foods World 27:61.
MOSS, R. 1973. Conditioning studies on Australian wheat. II. Morphology of wheat and its relationship to conditioning. J. Sci. Food Agric. 24:1,067.
MOSS, R. 1977. The autoradiographic technique for the location of conditioning water in wheat at the cellular level. J. Sci. Food Agric. 28:23.
PENCE, R. O., and SWANSON, C. O. 1930. Rate of water penetration in wheat during tempering. Assoc. Oper. Millers Bull. 1:110.
POMERANZ, Y., BOLTE, L. C., FINNEY, K. F., and SHOGREN, M. D. 1984. Experimental micromilling of hard winter wheat. Cereal Chem. In press.
SWANSON, C. O. 1933. What have we learned about wheat tempering? Assoc. Oper. Millers Bull. 1:203.

[Received May 14, 1984. Accepted September 17, 1984]