A Method for Detecting Mixtures of Artificially Dried Corn with High-Moisture Corn

JOE R. HART, Market Quality Research Division, ARS, USDA, Beltsville, Maryland

ABSTRACT

Artificial drying of corn harvested at high moisture levels often results in overdrying and heat damage. When overdried corn is mixed with undried corn, to produce a mean moisure content of 15.5%, the mixture is more likely to become moldy than unmixed samples at the same moisture level. Hysteresis effects were found to be increased greatly in mixtures containing heat-damaged kernels. In all mixtures hysteresis produced a greater range of moisture contents in individual kernels than that found in unmixed corn. This range was found by determining the moisture contents of 120 individual kernels in a sample and calculating the variance (square of the standard deviation from the mean moisture content). Unmixed samples had a variance lower than 0.2392 at 15.5% moisture level. The variance of mixtures was higher than 0.2392 and the variance of mixtures containing heat-damage was usually higher than the variance of mixtures without heat-damage.

The use of picker-shellers in harvesting corn is now well established. Moisture content at harvest is considerably above safe storage levels (1), and the artificial drying required is often the bottleneck that hampers the harvesting operation. A dryer with a capacity of 100 bu./hr. cannot keep pace with a machine harvesting 200 to 300 bu./hr. The tendency is to speed drying by using higher temperatures. Too rapid drying at high temperatures often results in overdrying and a moisture content much lower than the 15.5% limit set for the No. 2 grade (2). High-moisture corn may then be mixed with the overdried corn to obtain the desired mean moisture content of 15.5%.

Such mixing does not reduce damage that may already have occurred in the dried corn (1,3,4,5,6) but introduces possibilities for additional damage. At 15.5% moisture, corn is slightly above the critical level above which molds can grow. Respiration at 25°C. increases by about 400% between 15 and 17% moisture, and cracked and broken kernels respire more vigorously than sound normal kernels (7). The respiration increase is due, in part, to mold growth (8). A safe storage level below which molds will not normally grow has been found by some workers to be 14.8% (9); others have reported mold growths at moisture contents as low as 13.5% (10). At 25°C., corn at 15.5% moisture has an equilibrium relative humidity which is higher than 75%, the value usually given as the limit below which mold will not grow (11). During the period in which equilibrium conditions are being reached, the high-moisture portion of a corn mixture will be well above the level where moldiness and fermentation develop rapidly. If the overdried portion is heat-damaged, its ability to absorb water will be decreased (12) and the relative humidity of the entire mixture, even at equilibrium, may be sufficiently high to promote rapid growth of molds and yeasts. Even if the dried portion is not heat-damaged, hysteresis effects will cause the moisture content of the originally wet portion of the mixture to be at a higher level at equilibrium than the dried portion (13). Imperfect mixing may produce "pockets" of high-moisture corn where slow diffusion will delay equilibrium and cause heat to increase, and thus increase the probability of damage.

A method is described herein for detecting mixtures of wet and dry corn. This method is based on the fact that there is a wider range of moisture contents of individual kernels in a mixture than in an unmixed sample. Data were collected to evaluate the accuracy of the method and to anticipate the use of an electronic instrument for rapid determination of moisture contents of single kernels[1]. This instrument has undergone preliminary trials and is now being improved further.

MATERIALS AND METHODS

Source of Samples

Part of the high-moisture corn used was obtained immediately after harvest and contained 25–28% moisture. Other high-moisture samples were prepared by placing commercial samples of yellow corn (about 500 g.) in a humidity cabinet at 26.7°–29.4°C. and 90–95% r.h. until the moisture contents were 20–25%. No differences were found in the behavior in mixtures containing these two types of samples. All samples were stored at 2°–5°C.

The low-moisture samples were commercial samples of yellow corn obtained from the Grain Division, Consumer and Marketing Service, U.S. Department of Agriculture. Before use, many of these samples were heated in a temperature-controlled oven at 60°, 71°, 82°, or 93°C. to lower moisture content or to produce heat-damage. No attempt was made to reproduce actual conditions in a commercial dryer. The mere fact that a sample had been heated was not taken as proof that it was damaged.

The mixtures were prepared by blending in a Boerner divider different proportions of high- and low-moisture corn. The ratios of high-moisture to low-moisture corn in the different mixtures varied from 8.5:91.5 to 90.0:10.0. The moisture contents of the low-moisture samples ranged from 7 to 15% and the high-moisture samples from 16 to 28%. All moisture determinations were made on the wet basis.

Testing for Heat Damage

Ten samples, known not to have been dried by heat, were used in establishing a regression line of log resistance *vs.* capacitance for undamaged corn (Holaday, 14). Figure 1 shows the regression line and the points corresponding to capacitance-resistance measurements for all samples, both damaged and undamaged. The degree of damage was determined by measuring the negative displacement along the capacitance axis of the point representing the capacitance-resistance measurement. Displacement was measured in capacitance units. Many of the samples, as received, were found to be heat-damaged.

The percentage of kernels having stress cracks was also determined for

[1]The instrument is being developed by Instrumentation Research Laboratories, Market Quality Research Division, Agricultural Research Service, U.S. Department of Agriculture.

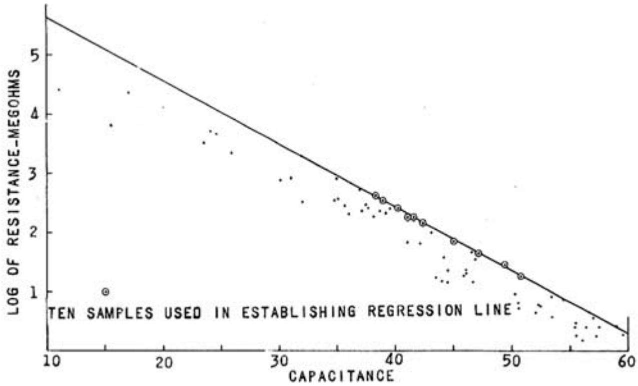

Fig. 1. Regression line of undamaged corn samples and scatter diagram of damaged samples.

most of the samples. Examination of the kernels by strong transmitted light revealed the presence of cracks (15).

Hysteresis Effects in Mixtures

The method described by Hart (13) for determining hysteresis effects in wheat was applied to corn. Samples of known moisture content were used. Dried corn which had been colored by a dye was added to undyed corn in such proportions as to produce a mixture calculated to have a moisture content of approximately 15.5%. The mixtures (about 600 g.) were put through a Boerner divider to ensure uniform mixing and held in sealed Mason jars at 25°C. Other mixtures were held at 32°C. At intervals portions were withdrawn from the jars, and the dyed kernels were separated from the undyed by hand picking. Moisture was determined on the dyed and undyed portions by the official air-oven method of the USDA (16). This procedure was continued until successive determinations showed no further change in moisture contents.

Determining the Range of Moisture Contents of Individual Kernels in Mixed and Unmixed Samples

Circular plates, approximately 10 in. in diameter and made of thin-gage aluminum, were used to hold the kernels during moisture determinations. Kernels from a sample were weighed individually and placed in the small numbered depressions in the plates. The kernels were then heated in a forced-draft oven for 72 hr. at 103°C. At first 144 kernels were taken from a sample; later 120 kernels were found to give results not appreciably different. Plates were cooled in a desiccator and kernels were removed, six at a time, for weighing. Moisture contents were calculated from weight losses.

The variance (square of the standard deviation from the mean moisture content) was used to indicate the range of moisture contents in a sample.

RESULTS

In Fig. 2 the percentage of kernels having stress cracks is plotted against the degree of damage as determined by the Holaday method. The coefficient

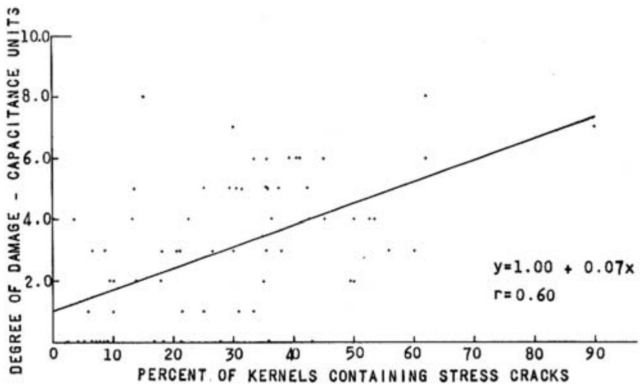

Fig. 2. Relation between percent of corn kernels containing stress cracks and degree of damage as determined by the Holaday method.

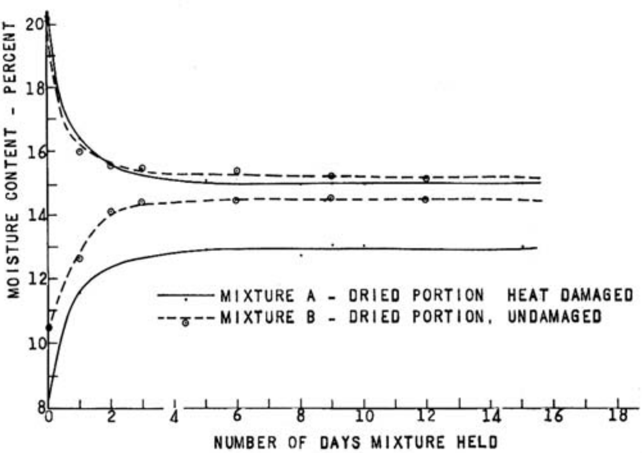

Fig. 3. Change in moisture contents of high- and low-moisture components of a mixture of corn with length of storage time.

of correlation is 0.60. Apparently, in some instances, heating may produce cracks but not the other types of damage associated with heat.

The manner in which the moisture contents of the two components of a mixture held at 25°C. change with length of storage time is shown in Fig. 3. When the graphs for the high- and low-moisture portions have become parallel, the distance between them indicates the extent of the hysteresis effect. The dried portion of mixture A had been badly heat-damaged, and the hysteresis effect was exceptionally high, 2.0%. Six other mixtures in which the dried portions had been heat-damaged showed hysteresis effects of 1.0, 1.1, 1.2, 1.0, 1.3, and 1.8%, respectively. The dry portion of mixture B, where the effect was 0.65%, had not been damaged. In 27 other mixtures with undamaged dry portions, which had been held at 25°C. for 15 days or longer, the hysteresis effects ranged from 0.36 to 0.93% with an average of 0.66%. Mixtures held at 32°C. showed essentially the same pattern of change, except that the two components of a mixture were somewhat closer in moisture content at equilibrium. One mixture in which the dried portion had been heat-damaged showed a hysteresis effect of 0.75%. Hysteresis effects for 11 mixtures ranged from 0.31 to 0.75% with an average of 0.48%. The range of moisture contents in a mixture will be greater than the hysteresis effect, since it is produced by hysteresis plus the range normally found in unmixed samples.

The relation between the mean moisture content for a sample and the variance of moisture contents is shown in Fig. 4. The regression line for

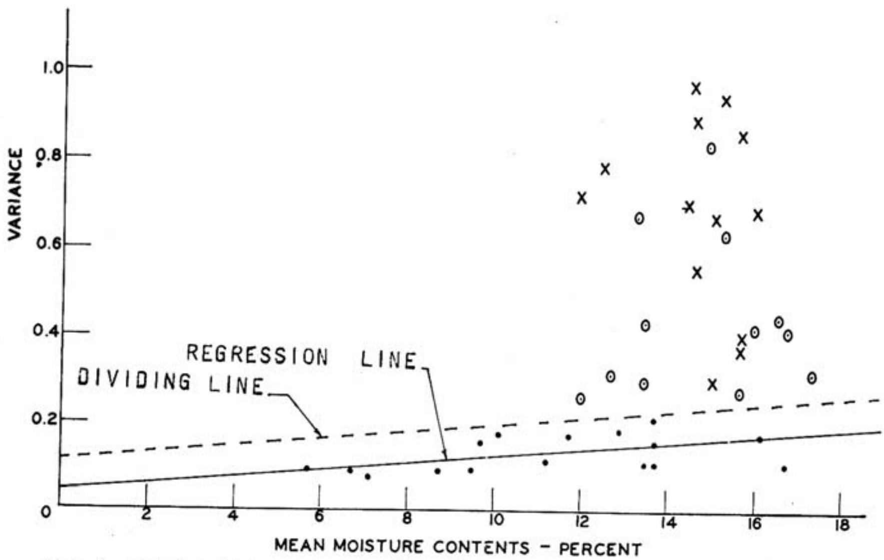

Fig. 4. Relation between mean of moisture contents of individual kernels in a sample and the variance. Legend: ●, unmixed samples; ⊙, mixtures in which the originally low-moisture portion had not been heat-damaged; X, mixtures in which the originally low-moisture portion had been heat-damaged.

the unmixed samples is given. Points for mixed samples all fall above this line, and points for mixtures containing heat-damaged corn are almost always farther away from this line than points for mixtures having no damaged corn. The broken line, above the regression line and parallel to it, is the boundary between points corresponding to mixtures and points representing unmixed samples. At 15.5% moisture, samples having a variance of moisture contents greater than 0.2392 would be mixtures.

In samples whose mean moisture contents are higher than 16.5% the relationships of Fig. 4 do not always apply. Nonmixtures at these moisture levels often show very wide variations in moisture contents of individual kernels. This is possibly due to the fact that they are at positions on their sorption isotherms where relatively large changes in their moisture contents produce very little change in their equilibrium relative humidities.

DISCUSSION

A mixture of high- and low-moisture corn can be detected by determining the variance and the mean of the moisture contents of its individual kernels. If the variance exceeds the value shown by the boundary line of Fig. 4 (0.2392 at 15.5% mean moisture content), the sample is a mixture. An advantage of the method lies in the fact that mixtures containing heat-damaged corn are most easily detected because of their wider range of moisture contents. Detection of such mixtures is most important, because they are more likely to become moldy during storage or shipment than mixtures containing no heat-damaged corn. In all mixtures, because of the higher range of moisture contents, detection is easier before than after equilibrium conditions are reached.

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