Effect of Corn Cultivar and Sample Variance on the Performance of Three Electronic Moisture Meters[1]

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ABSTRACT

Six varieties of corn commonly grown in Missouri were used to evaluate the effect of variety on the performance of three electronic moisture meters. The variety of the corn was found to be of little importance in affecting the moisture determinations. Field data on one variety of corn harvested at different stages of drying were used to estimate within-variety variance among meters, field samples, and subsamples. There was greater variation among duplicate readings from a meter than among 250-g subsamples or 1,000-g field samples, which indicated that most of the inaccuracy of the meters stems from the individual moisture determinations. Meter inaccuracy increased for corn with higher moisture content, particularly that having about 25% moisture.

Electrical moisture meters are well established in the grain trade because they are relatively inexpensive and yet provide rapid test results needed in commerce with a generally acceptable degree of reliability (Nelson 1981). The reliability of the dielectric type of grain moisture meter, however, deteriorates at grain moisture levels above 25%, and this has caused concern because much grain, especially corn, is harvested at high moisture levels (Nelson 1981). Hurburgh et al (1980) found that the accuracy of electronic moisture meters was dependent on the moisture level of the corn and that the precision of electronic moisture meters decreased for corn with higher moisture content.

Hemeda et al (1982) found that increased harvest damage lowered meter readings in dry corn and increased meter readings in wet corn, relative to the official USDA air-oven method. They also found that neither the drying air temperature (20–82°C) nor the corn variety affects the precision of the oven method or the precision of the meters. Paulsen (1982) found a significant difference in meter performance between hand-shelled and combined-shelled corn samples.

Grains from different parts of the country frequently do not show the same electrical properties and give different moisture content results when measured with electronic moisture meters (Hunt and Neustadt 1966). Several grain characteristics affect the relationship between dielectric properties and moisture content, including electrical frequency, temperature, bulk density, and chemical composition (Nelson 1977).

The purpose of this study was to determine whether cultivar differences in corn grown at the same location could affect the performance of three electronic moisture meters as compared to the official USDA air-oven moisture determination (USDA 1976).

A second study, using a single variety, was done to estimate the within-variety variance among meters, field samples, and subsamples.

MATERIALS AND METHODS

Variety Data

Six varieties of corn commonly grown in Missouri (1981 harvest) were hand-harvested from adjacent experimental plots at the University of Missouri-Bradford Farms, Columbia. The varieties were PAG SX-98, DeKalb XL-72B, DeKalb XL-72AA, DeKalb XL-372, Missouri Farmers Association 5802, and Golden Harvest H-2500. The corn was harvested and shelled by hand to minimize the number of cracked or broken grains that could result from mechanical harvesting. Approximately 2 kg of shelled corn of each variety was obtained. Cracked and broken grains were removed. Four random 250-g subsamples were taken from each variety, and the initial moisture content determined with three moisture meters for each subsample. The initial moisture determinations were made immediately after harvesting. Three electronic moisture meters used to measure the moisture contents of the grains were Steinlite RCT (Stein Laboratories, Inc., Atchison, KS), the Motomco 919 (Motomco Electronics, Inc., Paterson, NJ), and the Dickey-john GAC-II (Dickey-john, Inc., Auburn, IL). All moisture meters were calibrated and used in accordance with the manufacturer's instructions and conversion charts. With the Motomco 919, chart numbers C-1-C and C-2-D (Motomco 1978) were used, and with the Steinlite RCt, the conversion chart for corn supplied with the instrument was used (Stein Laboratories, Inc., 1978). The Dickey-john GAC II did not require a conversion chart. The same 250 g of corn weighed on a Mettler P5N balance to ± 0.1 g was used in each of the three meters. Approximately 15 g of corn was removed from each 250-g subsample following the electronic moisture meter measurements, weighed to the nearest milligram, and placed into predried and desiccated aluminum dishes as described for the air-oven method (USDA 1976). The samples were dried in a Blue M model Poweromatic 70 forced convection oven (Blue Island, IL) at 103 ± 1°C for 72 hr. The samples were cooled to room temperature in a desiccator after removal from the oven.

The rest of the subsamples were then mixed with the remaining original sample of the same variety. Each of the six varieties was evenly spread on aluminum cookie sheets to dry in the laboratory at room temperature. At various intervals (0, 4, 8, 16, and 24 days after harvest), four random 250-g subsamples were taken from each variety for meter moisture readings and air-oven moisture determinations as before.

Field Data

One variety of corn (Pioneer 3182) was hand-harvested at various stages of drying in the field from a plot at the University of Missouri-South Farms, Columbia. The corn was harvested from the field six times. The corn was harvested and shelled by hand to minimize the number of cracked or broken grains that might have resulted from mechanical harvesting. Cracked and broken grains were removed. On each harvest date, two separate but random 1-kg samples of shelled corn were harvested to get an estimate on sampling variability. Each 1-kg sample was entirely divided into four 250-g subsamples. Duplicate meter moisture readings were taken with the three moisture meters and two 15-g subsamples by the air-oven method, using the same meters and procedures as before.

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Statistical Analysis

Analysis of variance procedures were used to analyze each study (Steel and Torrie 1960). Variety and meter effects in all linear models were considered fixed. The following linear models were used:

variety experiment (all varieties)

$$X_{ijhl} = \mu + V_i + M_j + VM_{ij} + T_h + VT_{ih} + MT_{jh} + VMT_{ijh} + e_{ijhl}$$

variety experiment (by variety)

$$X_{ijh} = \mu + M_i + T_j + MT_{ij} + e_{ijh}$$

field experiment

$$X_{ijh} = \mu + M_i + H_j + MH_{ij} + S_{ijh} + SS_{ijh}$$

where X_{ijhl}, X_{ijk} represent moisture contents of grain, μ = overall population mean, V_i = effect of variety i, M_i or M_j = effect of meter i or j on moisture determination, T_h = postharvest time for a particular sample, and H_i = harvest date for a sample. MV_{ij}, MT_{ih}, VT_{ih}, and MVT_{ijh} represent first- and second-order interaction effects.

Estimates of means and variances were calculated using usual procedures discussed in Steel and Torrie (1960). Means were separated using the Protected Least Significant Difference Rule (Steel and Torrie 1960).

RESULTS AND DISCUSSION

Cultivar Experiment

The analysis of variance indicated a significant ($P<0.001$) meter × drying interval and significant ($P<0.001$) meter × drying interval × variety interaction effects. The mean moisture content of corn samples drying in the laboratory as measured by the air-oven method (USDA 1976) and by three electronic moisture meters is given in Table I. Similar tables for each variety were examined for departures from results shown in Table I but are not presented because there were few differences between the individual varieties and the overall results.

TABLE I
Mean Moisture Content of Six Corn Varieties Drying in the Laboratory as Measured by the Air-Oven Method and by Three Electronic Moisture Meters

	Mean Moisture Content Measured (%)[a]			
Days after Harvest	Air Oven	Dickey-john GAC-II	Motomco 919	Steinlite RCT
0	28.12 a	25.58 b	24.79 c	25.57 b
4	25.01 a	23.73 b	22.97 c	24.16 d
8	15.53 a	16.30 b	15.98 a	16.77 b
16	10.42 b	11.90 a	11.46 c	12.01 a
24	10.16 ab	11.74 a	11.08 c	11.71 a

[a]Means within a row not followed by common letters are significantly different ($P<0.05$). N = 16.

TABLE II
Mean Moisture Content of One Corn Variety Harvested at Various Stages of Drying in the Field

	Mean Moisture Content Measured (%)[a]			
Sample	Air Oven	Dickey-john GAC-II	Motomco 919	Steinlite RCT
1	27.83 a	26.67 b	24.95 c	26.62 b
2	26.81 a	26.96 a	24.33 b	25.77 c
3	21.36 b	22.32 a	21.60 b	22.54 a
4	21.31 b	21.95 a	21.14 b	22.08 a
5	18.44 c	19.58 a	18.85 b	19.66 a
6	19.48 b	20.70 a	19.55 b	20.56 a

[a]Means within a row followed by common letters are not significantly different ($P<0.05$). N = 16.

By allowing the samples to dry in the laboratory, we were then able to obtain a range of moisture measurements from the same lot of corn.

At higher moisture levels, moisture meter readings were significantly lower ($P<0.05$) than those by the air-oven method (Table I); however, at low moisture levels, meter readings were significantly higher ($P<0.05$) than the air-oven method. Individual varieties tended to follow the same pattern seen in the overall means, except for cultivar PAG SX-98 when the Motomco moisture reading on the third sampling date was significantly higher ($P<0.05$) than the air-oven method.

Overall, the Motomco 919 meter gave lower moisture readings than either the Steinlite or Dickey-john meters. This indicated greater inaccuracy in measuring high-moisture corn but better accuracy with low-moisture corn.

The data show that no meter is as accurate as the air-oven method and that as the moisture content increases into the high moisture range, the meters become more inaccurate. This supports findings by Hurburgh et al (1980) and Nelson (1981).

Cultivar effects, among those tested, are of little importance in affecting moisture determinations. Bias or failure of an electronic meter to reflect the air-dry moisture content were virtually identical for each variety.

Variance Experiment

A second study using a single variety (Pioneer 3183) was done to estimate the within-variety variance among meters, field samples, and subsamples. The mean moisture content as determined by the air-oven method and by the three moisture meters of the corn samples harvested at various stages of drying in the field are given in Table II.

An analysis of variance was calculated and variance components estimated for the following: σ^2_{SA} = variance among sample days; σ^2_S = variance among field samples, same date; σ^2_{SS} = variance among 250-g subsamples, same field sample and date and; σ^2_D = variance among duplicate readings (or among sub-subsamples in the case of the air-dry method). These estimates are reported in Table III.

The total variance in a grain moisture determination is

$$\sigma^2_T + \sigma^2_{SA} + \sigma^2_S + \sigma^2_{SS} + \sigma^2_D$$

The variation among "duplicate" determinations or variance introduced by moisture meters is represented by σ^2_D.

Estimated variance among determinations, $\hat{\sigma}^2_D$, is greater than the variance among grain samples, $\hat{\sigma}^2_{SS}$, and the variance among field samples, $\hat{\sigma}^2_S$, for all meters (Table III). The ratio $\hat{\sigma}^2_D/\hat{\sigma}^2_T$ represents an estimate of the fraction of variance due to the device. This ratio was estimated to be 0.025, 0.021, and 0.029 for the Dickey-john, Steinlite, and Motomco, respectively. This fraction was about twice the ratio $\hat{\sigma}^2_{SS}/\hat{\sigma}^2_T$, the ratio variance among duplicate grain samples to total variance. This ratio was 0.015, 0.010, and 0.015 for the Dickey-john, Steinlite, and Motomco, respectively.

Also, the ratio $\hat{\sigma}^2_S/\hat{\sigma}^2_T$, that of the variance among 250-g subsamples to total variance, was .016, 0.14, and 0.18 for the Dickey-john, Steinlite, and Motomco, respectively.

TABLE III
Estimated Variance Components by Type of Moisture Determination

Variance Component	Air Oven	Dickey-john GAC-II	Motomco 919	Steinlite RCT
Among sample days, $\hat{\sigma}^2_{SA}$	14.4136	8.0345	6.0134	7.6882
Among field samples same day, $\hat{\sigma}^2_S$	0.3634	0.1379	0.1171	0.1107
Among 250 gram subsamples, same field, $\hat{\sigma}^2_{SS}$	0.1649	0.1271	0.933	0.802
Among duplicate readings, same subsample, $\hat{\sigma}^2_D$	0.2732	0.2158	0.1826	0.1710
Total variance $\hat{\sigma}^2_T$	15.2151	8.5153	6.4064	8.0501

These results indicate greater variation among duplicate readings from a meter than among 250-g subsamples or 1,000-g field samples, which indicates that most of the inaccuracy of the meters stems from the individual moisture determinations of the corn samples. This indicates that, even if we have a good sampling technique, to obtain a representative sample from a lot of corn we will still have variation between representative samples.

The variance among sample days estimated by moisture meter ($\hat{\sigma}_{SA}^2$) reflects the inability of each meter to estimate the extremes. The σ_{SA}^2 meter estimates were about half the air-oven estimates, indicating that the moisture meters are not able to estimate the higher moisture values well.

Meter inaccuracy increased as moisture content increased, particularly above 25% moisture.

LITERATURE CITED

HEMEDA, M. A., HURBURGH, C. R., Jr., and BERN, C. J. 1982. Effects of corn variety, mechanical damage, and drying temperature on electronic moisture meters. ASAE Paper No. 82-3547. Am. Soc. Agric. Eng., St. Joseph, MI.

HUNT, W. H., and NEUSTADT, M. H. 1966. Factors affecting the precision of moisture measurement in grain and related crops. J. Assoc. Off. Anal. Chem. 49:757.

HURBURGH, C. R., BERN, C. J., and SITZMANN, C. D. 1980. Performance of electronic moisture meters in corn. ASAE Paper No. 80-3057. Am. Soc. Agric. Eng., St. Joseph, MI.

MOTOMCO. 1978. Motomco model 919 moisture meter operating instructions. Motomco, Inc., Paterson, NJ.

NELSON, S. O. 1977. Use of electrical properties for grain-moisture measurement. J. Microwave Power 12:67.

NELSON, S. O. 1981. Review of factors influencing the dielectric properties of cereal grains. Cereal Chem. 58:487.

PAULSEN, M. R., HILL, L. D., and DIXON, B. L. 1982. Moisture meter-to-oven comparisons for fall—1981 corn. ASAE Paper No. 82-3548. Am. Soc. Agric. Eng., St. Joseph, MI.

STEEL, R. G. D., and TORRIE, J. H. 1960. Principles and Procedures of Statistics. McGraw-Hill Book Co., Inc., NY.

STEIN LABORATORIES, INC. 1978. Calibration and temperature correction chart for the Steinlite RCT for corn. Stein Laboratories, Inc., Atchison, KS.

UNITED STATES DEPARTMENT OF AGRICULTURE. 1976. Grain Equipment Manual GR 916-6. Federal Grain Inspection Service, Standardization Division, Richards-Gebauer AFB, Grandview, MO.

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