Determination of Moisture Content of Maize Seed: Comparison of Two Moisture Meters with the Oven Method

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Abstract

Accurate estimate of seed moisture content is important in the determination of the harvest date of seed crops, the physiological quality of seeds as well as grain price. Therefore, an accurate determination of this parameter is important. Usually, secondary methods of seed moisture determination like seed moisture meters are calibrated against the ground oven method. However, the oven method is cumbersome and time-consuming. Faster methods involving moisture meters are now available commercially. The performance of moisture meters relative to the oven method in the determination of harvest moisture in maize (*Zea mays* L.) has not been investigated in sub-Saharan Africa. The objectives of this study were to (i) investigate the accuracy of two moisture meters; HE 90 and the multi-grain (ii) establish prediction equations for maize kernel moisture from the reading of the two meters. The overall and group mean values for each method were significantly different ($P<0.05$). Seed moisture content as determined by oven method was the highest ($P<.0.05$) and the multi-grain gave the least ($P<.0.05$). Both meters underestimated the overall mean seed moisture content by 2 and 52%, respectively. Multi-grain consistently underestimated seed moisture content by 20-62% of the oven method value and the degree of underestimation increased with increase in seed moisture content. Similarly HE 90 underestimated samples in the range 12.51-15.00 and >15.00 were by 2%. The prediction equations obtained from the regression analyses had no practical and physiological relevance. The margin of loss of precision associated with the determination of seed moisture content using multi-grain far outweighed the gain associated with the non-destructiveness, rapidity and simplicity of the method. The HE 90 will be useful for a rapid estimation of the moisture content of maize seed samples that had been determined *a priori* to fall in the range 12.5-15%.

Key words: Seed testing, Statistics, Prediction equation, Oven

INTRODUCTION

Seed moisture content is an important indicator of seed maturity and a major determinant of seed longevity in grain crops. Regardless of whether a crop is for seed (plant propagule) or grain (food, feed, and industrial raw material), harvest decisions are conditional upon the determination of kernel moisture content because of the cost implications for post-harvest drying of high moisture kernels. Moisture content determination is also important in plant breeding.

Comparative yields of grain crops subjected to different treatments (such as varieties) in carefully conducted yield trials can be measured only after plot-yield weights have been corrected to a constant moisture basis, usually 15%. Moisture content is used in commerce because of its contribution to grain weight and its implications for seed or grain storage. A small change in seed moisture content has a large effect on the storage life of the seeds. It is therefore important to determine the moisture content in order to make a reasonably accurate prediction of the possible storage life of a seed lot.

Methods of determining seed moisture content are broadly categorized as primary (direct) or secondary (indirect) (Benjamin, 1984; Tang *et al.*, 2000). Primary methods such as air oven, distillation and solvent extraction are generally accepted as the standard in that they measure seed moisture directly, precisely, more accurately and require no calibration against any other method. The oven-ground or ISTA method (International Seed Testing Association, 1999) is the internationally accepted standard method of determining seed moisture content for research and commercial seed testing purposes. It involves the removal of water by heating whole (small-seeded) or milled (large-seeded) grains at specific temperatures for a specified period of time. Moisture content is then expressed as a percentage of the mass of water per unit mass of the wet material (wet weight basis, %) or as a percentage of the mass of water per unit mass of the dry material (dry weight basis, g g^{-1} dry weight) (*http://www.III-Seed Moisture Content.htm)*. The secondary or indirect methods of determining moisture content involve the measurement of a property of the material including mechanical, electrical or thermal property that is related to the moisture content which is then expressed on a wet weight basis.

Although direct methods of seed moisture determination are the most reliable, they are destructive, laborious and time-consuming than indirect methods. (International Seed Testing Association, 1999). As noted by Peter *et al.* (2001), direct methods are not useful under field conditions and production environment. This has therefore necessitated the use of quick and practical (indirect) methods of determining seed or grain moisture under production conditions in spite of the relatively lower accuracy than the time-consuming direct methods. The objectives of this study were to (i) investigate the accuracy of two moisture meters entering the Nigerian seed industry for estimating seed moisture content, (ii) establish prediction equations for maize kernel moisture from the reading of the two meters.

MATERIALS AND METHODS

One hundred and seventy-six (176) maize seed lots from genetically divergent experimental cultivars evaluated at the Teaching and Research Farm, Obafemi Awolowo University, Ile-Ife between 2004 and 2006 were used for the study. A primary reference method, the oven method (International Seed Testing Association, 1999) was used to compare the indirect or secondary method involving the use of two moisture meters, the Multi-grain (DICKEY-John Corporation, Auburn, IL 62615) and HE 90 (Pfeuffer GmbH, D-97318 Kitzingen).The HE 90 is the standard moisture meter of grain acceptance in Germany. The two meters were calibrated following the manufacturer's recommendations.

The moisture content of each of the 176 seed lots was determined in four replications as follows: intact seeds were added into the sample cell of DICKEY-John meter and the percent moisture was then recorded as displayed on the meter screen. The seeds were then milled with a laboratory mill, Labomill, (Pfeuffer GmbH, D-97318 Kitzingen). The mill was specifically designed for and sold with the HE 90 moisture meter. The HE 90 measuring cell was filled with the milled material screwed and then placed on the HE 90 for the determination of the moisture content of the material. The moisture meter for the material was displayed after about 30 seconds and this was recorded for each replication of a sample. The milled material was also used for the oven method. Sample fresh (FWT) and dry (DWT) weights were obtained by weighing the sample before and after drying in a forced-air Memmert oven (Memmert GmbH + Co. KG, D-91107 Schwabach) for 24 hours at 105°C. Prior to the determination of the dry weight after drying, the sample containers were allowed to cool down for about 30 min in desiccators with self-indicating silica gel. The moisture content was then calculated by expressing the difference between FWT and DWT as a percentage of FWT.

Statistical Analyses

Using data from the oven method, the samples were grouped into four as follows:

a. Samples with <10.00 % oven seed moisture content
b. Samples with 10.00-12.50 % oven seed moisture content
c. Samples with 12.51-15.00 % oven seed moisture content
d. Samples with >15.00 % oven seed moisture content.

Combined and group analyses of variance were also performed on the basis of the above groupings. The contribution of each source of variation to the total observed variability in seed moisture content was calculated by expressing the sum of squares due to each source as a percentage of the total sum of squares. Correlation analyses among the three methods and regression analyses of the two secondary methods on the oven method were carried out to estimate the strength of the relationships. All analyses were done using SAS version 8.1 (SAS Institute, 1999a, b).

RESULTS

Means squares value from the analysis of variance showed highly significant effect of sample, method of determination and the method × sample interaction on the seed moisture content, with method of determination accounting for 70% of total sums of squares (Table 1).

The overall and group mean values for each method were significantly different ($P<0.05$), the oven method was the highest and the multi-grain was the least (Table 2).

Relative to the oven method, the HE 90 and the multi-grain underestimated the overall mean seed moisture content by 2 and 52%, respectively. Also, multi-grain meter consistently underestimated seed moisture content of the groups by 20-62% of the oven method value and the degree of underestimation increased with increase in seed moisture content. Both the lower and upper limits of the range of seed moisture content as determined by multi-grain were consistently lower than similar values for oven method. Contrariwise, for samples with moisture content in the ranges

Table 1: Means squares from the analysis of variance of moisture content of maize seeds

Source of variation	DF	Means squares	% Contribution to variability
Replication	3	1.469*	0.0001
Sample	175	17.824***	9.844
Method	2	11041.067***	69.688
Sample × Method	350	16.316***	18.022
Error	1581	0.48735	2.432
CV		6.33	
Mean		11.03	
R^2		97.57***	

*, *** Significant at 0.05 and 0.001 level of probability.

<10% and 10.00 - 12.50% (oven method), HE 90 overestimated by 11 and 46% respectively. On the other hand samples in the range 12.51-15.00 and >15.00 were underestimated by 2 and 23%, respectively. Similarly, the range for HE 90 was larger than the value for oven method when moisture content was ≤12.50% and smaller when it was above 12.50%. However, the coefficients of variability (CVs) for the seed moisture content as determined by HE 90 were the least variable for the overall analysis as well as across the four groupings.

The results of the correlation analysis revealed a highly significant ($P<0.01$) r-value between oven method and HE 90, although the coefficient of determination (r^2) was less than 25% (Table 3).

Within the four groupings, the r-values were significant between oven method and the two moisture meter methods (HE 90 and Multi-grain) only for the 12.51-15.00% group. At the <10% moisture group for which the two moisture meters were highly correlated, the r values between oven method and the two other methods were not significant. The r^2 attributable to the prediction equations developed from the data were less than 10% for all samples with moisture content below 12.51% and above 15% (Table 4). When seed moisture content is in the range 12.51 to 15.00%, HE 90 would predict oven seed moisture content but with only a moderate degree of reliability because only about 25-30% of observable variability would have been accounted for by the relationship.

DISCUSSION

An accurate determination of seed moisture content is crucial in the production, research, and marketing of seeds and grains. The over- and under-estimation of seed moisture content can cause significant loss of seed quality for researchers and seed companies, financial losses for seed and grain merchants and yield losses for farmers. However, the accuracy of the results of any seed moisture determination is highly dependent on the accuracy of the method and equipment used. Hence, reliability and repeatability are two factors that must not be compromised when determining the method or equipment to use.

Standard calibration and the knowledge of the range of accuracy of any equipment for the indirect measurement of seed moisture will minimize errors often associated with the indirect methods. In comparison with the standard (oven ground) method, multi-grain and HE 90 are far less accurate for determining moisture content of maize seed. It appeared that the two

Table 2: Means, ranges and coefficient of variability (cv) of seed moisture content for individual groups of samples and the overall sample (n=176) as determined by three methods

Statistic	Group	Oven	HE 90	Multi-grain
Mean	Overall	13.51a	13.12b (2%)†	6.46c (52%)†
	<10.00%	8.68a	12.71b (-46%)	6.92c (20%)
	10.00-12.50%	11.65a	12.89b (-11%)	6.74c (42%)
	12.51-15.00%	13.67a	13.37b (2%)	5.91c (57%)
	>15.00%	17.37a	13.35b (23%)	6.58c (62%)
Range	Overall	7.17-21.04	11.80-14.15	3.15-9.78
	<10.00%	7.17 - 9.90	11.80 – 13.30	5.18 - 9.40
	10.00-12.5%	10.01 – 12.50	11.85 - 14.05	3.60 – 9.48
	12.51-15.00%	12.57 – 14.92	12.60 -14.13	3.15 – 9.23
	>15.00%	15.39 – 21.04	12.38 -14.15	3.60 – 9.78
CV (%)	Overall	23.24	3.66	24.46
	<10.00%	8.11	2.94	19.12
	10.00-12.5%	6.81	3.55	23.63
	12.51-15.00%	5.44	2.91	29.91
	>15.00%	8.64	3.35	21.67

Means in the same column with different letters are significantly different at $P < 0.05$
† indicate the degree of underestimation (+ sign) or overestimation (- sign) of seed moisture content relative to oven method seed moisture content.

Table 3: Pearson Correlation Coefficients (r) for the three methods of four groups of maize samples with oven moisture content: <10.00%, 10.00-12.50%, 12.51-15.00% and > 15.00%.

Group	Method	Method	
		Multi-grain	HE 90
Overall (n=176)	HE 90	0.107	-
	Oven	0.090	0.489**
<10.00% (n=27)	HE 90	0.700**	-
	Oven	-0.089	0.031
10.00-12.5% (n=43)	HE 90	0.169	-
	Oven	-0.234	0.255
12.51-15.00% (n=54)	HE 90	0.055	-
	Oven	0.308*	0.505**
>15.00% (n=52)	HE 90	0.245	-
	Oven	-0.186	0.083

Table 4: Linear regression of moisture meters (Multi-grain and HE 90) on oven method seed moisture content

Range of moisture content (Oven method)	Moisture meter	Parameter Estimates		
		R^2 (%)	b_o	b_1
<10.00%	Multi-grain	0.8	9.03**	-0.05
	HE 90	0.1	7.90	0.06
10.00-12.5%	Multi-grain	5.5	2.43**	-0.12
	HE 90	6.5	5.95	0.44
12.51-15.00%	Multi-grain	9.5*	12.91**	0.13
	HE 90	25.5**	0.79	0.97**
>15.00%	Multi-grain	3.5	18.66	-0.20
	HE 90	0.8	13.39*	0.30

*, ** Significant at 0.05 and 0.01 levels of probability respectively

moisture meters were designed for a narrow range of seed moisture values above and below which they were incapable of giving accurate and reliable estimates irrespective of the number of times a sample is tested. The two moisture meters evaluated in this study underestimated seed moisture significantly and therefore have a narrow range of usefulness. They are of limited usefulness in seed research, genebank activities and other physiological purposes when accurate estimate of seed moisture content are required. This is clearly supported by the failure of the two methods to strongly and reliably predict the direct (oven) method. Unlike the multi-grain that underestimated seed moisture by more than 50% of the oven-method value, HE 90 gave estimates that were very close to the value from the oven method when seed moisture was in the range 12.5-15.0%. This is also the only range of seed moisture for which a significant predictive relationship was observed although the coefficients of determination were low. These observations explain the significant method × sample effect on the accuracy of seed moisture content obtained. It was not possible to ascertain the contributions of the genotype of each sample to the significant sample × method effect detected, the likelihood of which Tang *et al.* (2000) had suggested because the accuracy of the two meters relative to the standard (oven) method was the main objective of this investigation. Our results corroborate the findings of Benjamin (1984) that there was no significant genotype × method interaction when seed moisture content of 47 tropical maize genotypes from two different locations were determined by oven method and three other moisture testers including Dickey-John. Consequently a greater emphasis was placed on this at the expense of likelihood of any significant genotype by method interaction. Although, the samples were identified arbitrarily by number rather than pedigree, they comprised more than fifty genetically divergent maize varieties that had been subjected to different treatments.

The following conclusions could be reached from the results of this investigation. The margin of error associated with the determination of seed moisture content using multi-grain far outweighed the gain associated with the non-destructiveness, rapidity and simplicity of the method. The HE 90 will be useful for a rapid estimation of the moisture content of maize seed samples that had been *a priori* determined to fall in the range 12.5-15% above and below which they are less dependable. They could also be used under situations where a lesser degree of accuracy is required. Such situations may include seed drying, transportation, marketing or storage of maize seeds. The values obtained from the two moistures meters were positively correlated for moisture contents <10%, otherwise they are independent.

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