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Calibration of Grain Moisture Content Measurement Devices for Wheat

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Abstract. Four different moisture content meters were calibrated by using the air oven as a reference for calibration and using wheat. The brand names of these devices are Tecator (Sinar moisture system), Dole 400 (moisture tester), Protimeter (Moisture meters for cereals), and Infratec (Grain Analyzer). Samples of wheat (Yecora Rojo) were run in every moisture meter and in the oven. Moisture content (m.c.) range was from 7 to 22%.

Calibration curves were constructed for these meters. For each meter, an equation for calculation of corresponding oven moisture content at any moisture level was established. According to the statistical analysis using LSD test, it was found that there is no significant difference between the oven and Sinar moisture system, Infratec grain analyzer, and Dole 400 moisture tester while there was highly significant difference between Protimeter, moisture meter for cereals and the oven.

Introduction

Calibration of a moisture meter involves matching its moisture measurements with a reference – method moisture value on the same sample. The simplest calibration method is manual look-up charts. The meter displays the value of grain moisture content. The operator consults a chart or an equation to determine percent moisture in the oven.

Users object to chart machines on the basis of the extra effort and the time required. Grain buyers and sellers prefer to measure the grain moisture values directly.

The use of these meters has become a common practice in the last 40 years. The Motomco 919 meter was accepted as the official meter of the USDA in 1962 [1].

In regard to the accuracy of moisture meters, there is a limit to their accuracy. Almost all inaccuracies or random errors arise because of the variability in the grain, not weaknesses in the meters. Hurburgh [2] calibrated four trade-type meters with respect to the oven. At 15.5% wet basis m.c. in corn, for example, he expected random variations of up to ± 0.8 points of moisture content in a single test. Hurburgh mentioned that averaging test results are across several samples a big help in reducing a random error. He also found that random errors in soybean testing are about half of those in corn at the same moisture content. Portable meters, like those used on farms, are about 1.5-2.0 times as variable as trade-type meters, at the same moisture content [2].

Reference method for calibrating moisture meters

Because a moisture meter measures a property affected by water content, it requires calibration to a reference method capable of extracting water from samples. The meter is an indirect method of moisture measurements as opposed to the reference method which measures moisture directly.

The American Society of Agricultural Engineers (ASAE) – physical properties of agricultural product committee approved the measurement of moisture for grain and seeds in 1972 and revised it in 1982. For unground whole wheat moisture measurement, the committee stated oven method for 19 h period at 130°C, [3].

Objectives

The specific objectives of this study are:

1) To determine the variability between the recent developed moisture meters and the oven.
2) To construct calibration curves and equations for these meters to simplify their use in determining wheat (Yocora Rojo) moisture content.

Experimental Methods

The experiment was conducted in 1994 in the grain quality laboratory which belongs to the Agricultural Engineering Department, College of Agriculture and Veterinary Medicine in Al-Qassim. Four moisture meters were purchased, namely,

Tecator (Sinar moisture system), Dole 400 (moisture tester), Protimeter (moisture meters for cereals), and Infratec (grain analyzer). Procedures of using these meters were followed as described in their corresponding operating manuals.

Oven method

Moisture in oven is removed when grain is exposed to hot dry air. In any oven method, it is assumed that, at the end of the drying period, the entire mass of water present initially has been removed. It is also assumed that no other constituents of the grain have been driven off. As mentioned before, ASAE standard of unground whole wheat moisture measurement in the oven is at 130°C for 19 h.

Wet basis moisture percentage in the oven, MC(%), is calculated using the following form*:

$$\text{Oven, MC}(\%) = \frac{W_1 - W_2}{W_1 - W_T} \times 100 \qquad (1)$$

where

W_1 = initial weight of sample.
W_2 = final weight of sample after 19 h.
W_T = tare weight of dish.

* All moisture contents used in this study are expressed as a per cent of wet basis.

Procedures

Thirty-six kilograms of hard wheat (Yecora Rojo) sample (7% moisture) were brought to the lab from the wheat production of 1993. The amount was divided into 36 subsamples, each weighing 1 kg. These samples were split into 12 groups, each group having three replicates. Different moisture content in each group was obtained by spraying the grain with water to the required moisture level. Procedures of equilibration are as follow:

1) Determination of initial grain moisture content by oven
2) Calculation of water content to be added in order to reach to the required moisture level

3) Adding the required water to the sample interval
4) After adding the whole amount of water, sample was put in plastic bag and left for 24h with shaking to make sure of a good mixing and to obtain the required moisture level inside the grain; thus the moisture will not be only on the outer surface but uniformly distributed throughout the particles of grain.

The average of moisture content measured by the oven for three replicats in each group, was 7.27, 8.17, 10.62, 12, 15.91, 16.09, 16.7, 17.14, 17.7, 18, 21.64, and 22.16% and standard deviation for each was 0.05, 0.06, 0.04, 0.53, 0.07, 0.04, 0.05, 0.04, 0.02, 0.09, 0.08, and 0.04, respectively. In each group, samples were divided into five parts. Three replicats were taken for each part. These parts were put at the same time in the different moisture measurement methods; one in the oven (15 g.), one in the Tecator model (300 g.), one in the Dole 400 model (150 g.), one in the protimeter model (10 g.), and one in the Infratec grain analyzer (500 g.) Grain moisture content was then obtained from each replicate in each group and each method. Statistical analysis system (SAS) software was used to analyze the data of this experiment. Least Significant Test (LSD) statistical test was applied to compare the means of moisture content in each meter.

Results and Discussion

Average experimental moisture content and standard deviation in each moisture measurement method are shown in Table 1. According to this table, variability in the meters ranged from .003 to .524. In moisture meter for cereals, variability was the highest compared with other meters. The average standard deviation in moisture meter for cereals was 0.25 while the average standard deviations in Sinar moisture system, Infratec grain analyzer, and moisture tester were 0.15, 0.16, and 0.13, respectively. According to the statistical analysis using LSD test (Table 2), it was found that there is no significant difference between the oven and Sinar moisture system, Infratec grain analyzer, and Dole 400 moisture tester while there was highly significant difference between Protimeter, moisture meter for cereals and the oven.

Calibration curves were constructed for these meters. With each meter, linear and nonlinear equations with respect to the oven were tested in order to find out the best of line fit. Equations were developed as follow:

1) Raw data of moisture content from the devices and oven were inserted into Grapher program. The program can determine R^2 and more than one mathematical relationship such as:

Table 1. Average moisture content of oven vs. experimental and predicted moisture content[a] and standard deviation for different moisture content testers

Instrument name		Oven data											
		7.3	**8.2**	**10.6**	**12.0**	**15.9**	**16.1**	**16.7**	**17.1**	**18.0**	**18.0**	**21.6**	**22.2**
Sinar moisture system	Experimental	7.7	8.1	10.1	*	12.2	14.2	14.0	14.2	15.4	15.4	15.3	21.4
	Predicted	7.0	7.7	11.0	*	16.2	15.9	16.2	16.9	17.3	17.3	21.6	22.4
	SD[b]	0.12	0.26	0.19	*	0.15	0.08	0.25	0.12	0.35	0.35	0.04	0.10
Infratec grain analyer	Experimental	6.7	7.4	10.8	13.0	17.0	17.1	17.2	17.3	18.1	18.1	*	21.2
	Predicted	7.5	7.9	10.3	12.1	16.5	16.6	16.7	16.9	18.0	18.0	*	22.7
	SD	0.13	0.13	0.15	0.07	0.29	0.27	0:02	0.12	.013	0.01	*	0.26
Moisture meters for cereals	Experimental	*	*	13.3	15.5	17.0	16.7	16.7	17.1	17.7	17.7	*	22.3
	Predicted	*	*	10.4	13.2	16.2	15.6	15.7	16.5	17.7	17.7	*	21.9
	SD	*	*	0.06	0.52	0.15	0.49	0.49	0.21	0.12	0.12	*	0.37
Moisture tester	Experimental	*	8.0	*	12.4	*	14.5	*	16.7	16.4	16.4	*	21.9
	Predicted	*	8.1	*	12.3	*	15.4	*	17.6	18.0	18.0	*	21.1
	SD	*	0.02	*	0.17	*	0.36	*	0.20	.003	.003	*	.009

*: Date were not taken

[a]: Moisture content, wet basis

[b]: Standard deviation of the moisture content from the instrument

Table 2. Statistical analysis for the instruments of measuring moisture content

Instrument	Moisture content means	Standard deviation
Oven	15.28	4.81
Dole 400, moisture tester	14.89 n.s	4.63
Sinar moisture system	13.92 n.s	4.19
Moisture meter for cereals	17.29**	2.39
Infratec grain analyzer	12.07 n.s	2.95

n.s No significant comparison with the oven

** Highly significant comparison with the oven

a) Linear b) Logarithmic c) Exponential
d) Power e) Plynomial f) Cubic spine

2) Model which gave higher R^2 value was selected.

3) New data from the above model was transfered into the Quattro program. Regression equation from the new data and the data of the oven was established. This equation was combined with the equation which was shown in the figure. This equation was considered as the best fit.

Figure 1 shows the calibration curve for Dole 400, the moisture tester. The equation for this curve was:

$$\text{Oven, MC(\%)} = 20.33 - 4.01\,X + 0.38\,X^2 - 0.01\,X^3 \qquad (2)$$

where X represents the moisture measurement in the meter, wet basis. Correlation coefficient, R^2, was 99.3 which indicates a very good agreement with the oven method. Figure 2 shows the calibration curve of sinar moisture system. The equation for this curve was:

$$\text{Oven, MC(\%)} = 14.87\,\text{Ln}\,X - 23.13 \qquad (3)$$

Correlation coefficient was 99.5 which also indicates a very good agreement with the oven method. Figure 3 shows the calibration curve of Infratec grain analyzer. The equation for this curve was:

$$\text{Oven, MC(\%)} = 0.38 + 3.07\, e^{0.12\,X} \quad (4)$$

Correlation coefficient was 99.5 which indicates a very good relationship with the oven method. Figure 4 shows the calibration curve of moisture meter for cereals. The equation for this curve was:

$$\text{Oven, MC(\%)} = 175.89 - 32.6\,X + 2.05\,X^2 - 0.04\,X^3 \quad (5)$$

Correlation coefficient was 96.8.

From the previous curves, it should be now very easy to predict the moisture content in the oven by measuring the moisture content of wheat in any device by either using the plot or the equation. This calibration will save a lot of time and at the same time you will get very accurate results. As mentioned previously, the oven method requires 19 hours while in these meters the measurement will take only few seconds.

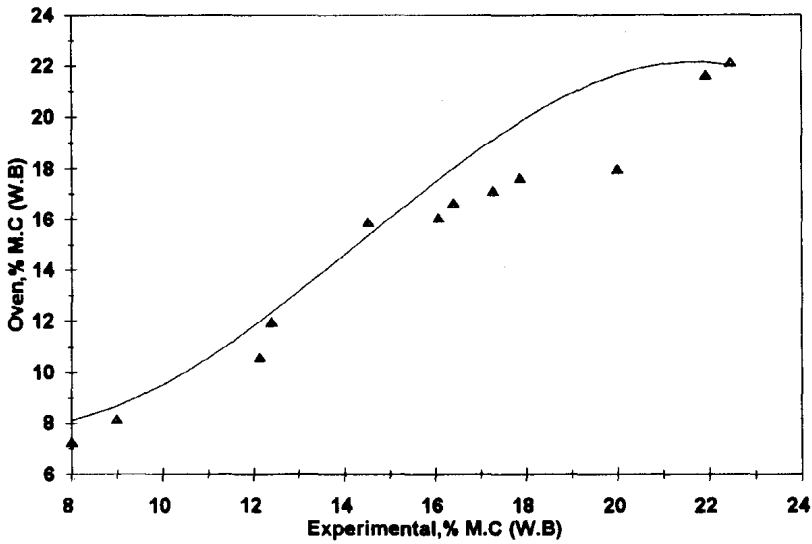

Fig. 1. Calibration curve for Dole 400, moisture tester.

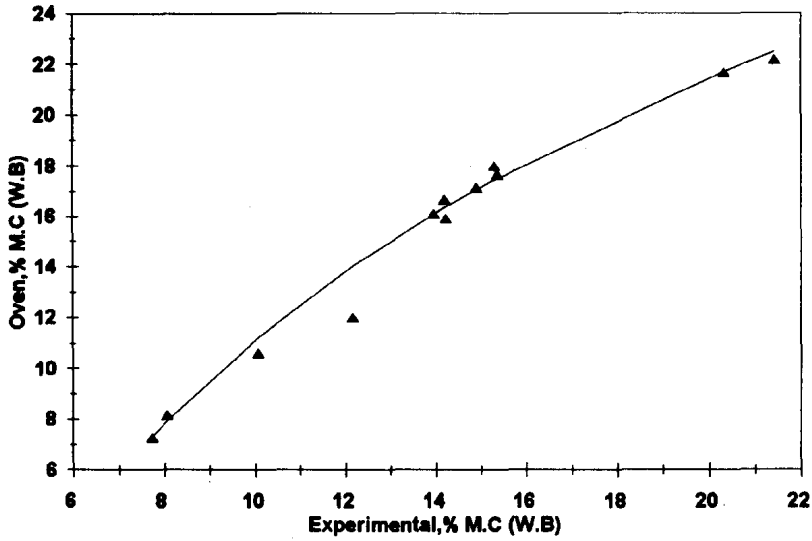

Fig. 2. Calibration curve for Sinar moisture system.

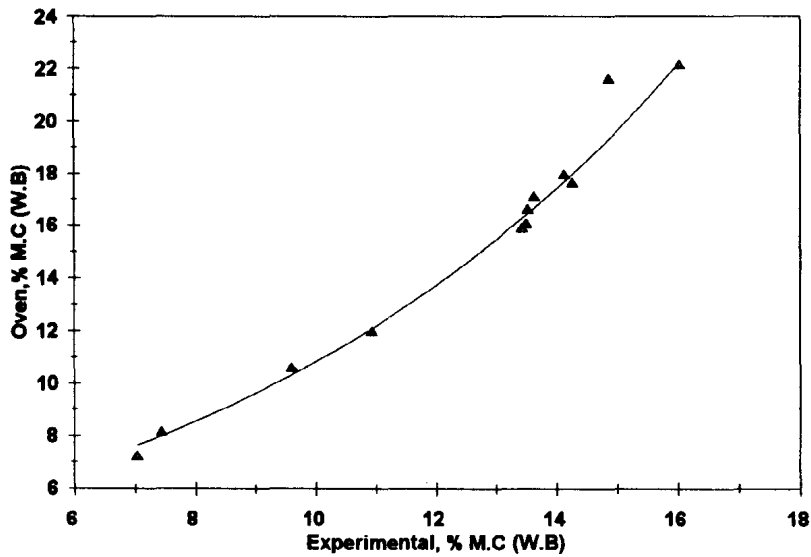

Fig. 3. Calibration curve for infratec grain analyzer.

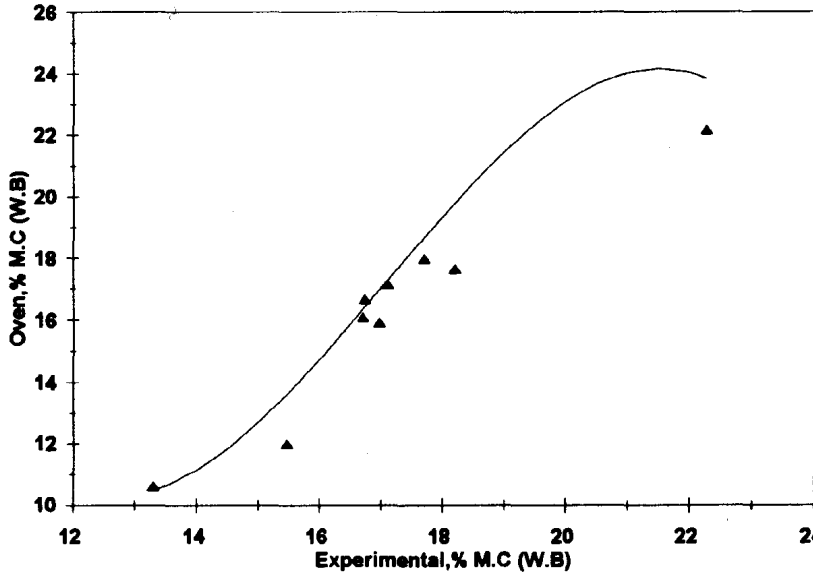

Fig. 4. Calibration curve for moisture meter for cereals.

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معايرة أجهزة قياس المحتوى الرطوبي للقمح

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ملخص البحث. تم معايرة أربع أجهزة مختلفة لقياس المحتوى الرطوبي باستخدام الفرن الحراري كمرجع للمعايرة واستخدام القمح. الأسماء التجارية لهذه الأجهزة هي كالتالي: تيكيتور (Sinar moisture system) ، دول ٤٠٠ (Moisture tester) ، بروتيميتر (Moisture meter for cereals) ، وإنفراتيك (Infratec grain analyzer) . في كل جهاز، تم قياس المحتوى الرطوبي للعينات المختلفة من القمح صنف يوكراروخو والذي يحتوي على نسبة شوائب ٧-١٠٪ ومن ثم تم قياس هذه العينات بواسطة الفرن الحراري. المحتوى الرطوبي للحبوب الذي تم قياسه يقع في المدى من ٧ حتى ٢٢٪.

تم إنشاء منحنيات المعايرة لكل هؤلاء الأجهزة. في كل جهاز، تم الحصول على معادلة خاصة به والتي عن طريقها يمكننا حساب وتوقع المحتوى الرطوبي للحبوب الذي ينتج من الفرن الحراري. إحصائيًا، لم يوجد فروقات معنوية بين استخدام الفرن لقياس المحتوى الرطوبي وجهاز تيكيتور وإنفراتيك ودول ٤٠٠، ولكنه وجد أن هناك فروقًا معنوية كبيرة في قياس المحتوى الحراري بين الفرن الحراري وجهاز البروتوميتر.