Rapid Moisture Content Determination of Macadamia Nuts with an Electronic Moisture Meter

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Summary. *An electronic moisture meter (Dole Model 400) was calibrated for rapid determination of moisture content of macadamia (Macadamia integrifolia Maiden and Betche) nuts. The meter was found suitable to measure the moisture content (from 9.5% to 21.5% on a wet-weight basis) of macadamia nuts with sufficient accuracy for routine use by farmers and processors. On average, the meter readings were about 0.21% ± 0.08% SE lower compared to readings obtained from the standard forced-air oven technique. A moisture analysis with the meter required <5 minutes compared to 72 hours by conventional oven-drying.*

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Use of trade name in this paper does not imply endorsement by the Univ. of Hawaii of products names nor criticism of similar ones not mentioned.

Rapid assessment of moisture content is very important in maintaining quality standards of macadamia nuts during handling and processing. Storing macadamia nuts with a high moisture content favors postharvest fungal infestation, resulting in poor kernel quality, which, in turn, results in low value or rejection by processors. However, the high costs ofequipment used in the conventional forced-air oven method prohibit farmers in Hawaii to make accurate on-farm moisture content determination of macadamia nuts.

Electronic moisture meters are used widely for grain moisture measurement. Okwelogu (1971) reviewed several types of moisture meters and their principles of operation. The most common type of meters measure moisture by the integration of a dielectric constant. The dielectric constant is a function of moisture content. The principles of dielectric moisture measurement have been described previously (Breen and Monaghan, 1976; Nelson, 1965, 1982). Moisturemeters generally are factory-calibrated for agronomic crops such as corn, soybeans, rice, beans, coffee, oats, wheat, barley, and peanuts. However, macadamia nuts have not been calibrated and there is no literature available on the calibration of a moisture meter for determining their moisture content. The purpose of this study was to calibrate an electronic moisture meter (Dole Model 400, Eaton Corporation, Carol Stream, Ill.) for macadamia nuts and to compare its accuracy with the conventional forced-air oven drying method. The affordability, availability, simplicity of use, ruggedness, and portability were reasons for selecting this particular meter. In addition, the meter has a built-in weighing system, thus eliminating the need for a separate weighing scale. The Dole 400 electronic meter costs about $400 compared to more than $2000 for a convection forced-air oven and weighing scale using the standard oven method.

Materials and methods. Mature abscised 508 macadamia nuts were collected from the field and husked (exocarp removed). Initial moisture content of the whole nut (seedcoat with kernel) was determined by drying 100-g samples in a forced-air oven at 75C for 72 h. Moisture content within the batch ranged from 24% to 27% on a wet-weight basis [(original weight - oven dried weight)/original weight] x 100. To obtain nut samples of different moisture levels for calibrating the moisture meter, the moist nuts were dried in single layers at ambient temperature for different lengths of time. Nuts of different moisture levels were stored in separate, sealed, plastic containers and allowed to equilibrate for 72 h before use. The moisture contents of the whole nuts from each container were then determined in a forced-air oven as described previously. Moisture contents in the stored samples ranged from 9% to 22% (wet basis).

The moisture meter was operated using the procedures described in the Dole 400 operating manual. About 142 g of whole nuts was weighed using the meter s built-in weighing system. Due to the weight of individual nuts (7.83 ± 1.44 g at 13.5% moisture content), it was difficult to obtain an exact test weight of 142 g for every sample. Because the nuts were too large to fit into the meter test cell, they were cracked in a mechanical cracker (Hilo Steel Works, Hilo, Hawaii). The cracked sample (seedcoat and kernel) was collected and transferred into the test cell. The meter A scale was read to correspond to the moisture content of the nuts. The temperature of the test sample was recorded with a mercury thermometer immediately after the moisture reading was taken. The entire procedure required <5 min to perform per sample. A total of 250 samples were used to calibrate the moisture meter.

Calibration curve. Linear regression analysis of the forced-air oven moisture data and the corresponding meter scale readings produced the equation (Y = 0.0885X + 6.885, R^2 = 0.965), in which the percentage of

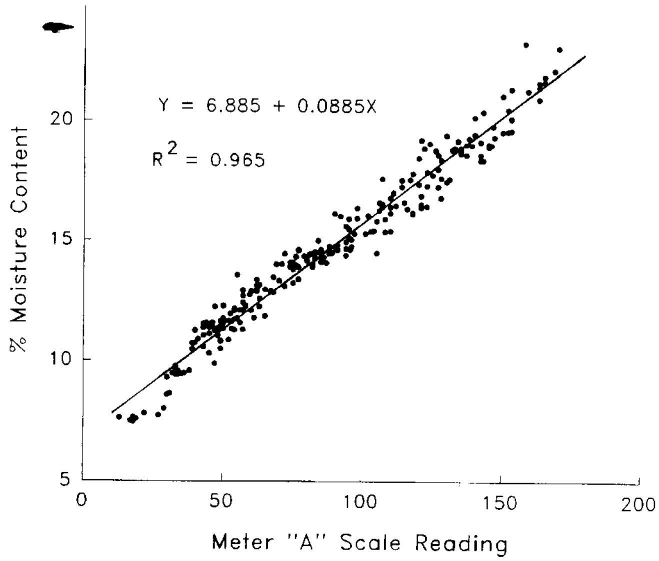

Fig. 1. ***Relationship between macadamia nut moisture content and moisture meter A scale readings***

moisture determined by forced-air oven (Y) is expressed as a function of the meter scale reading (Fig. 1). The equation can be used to construct the typical calibration tables supplied by equipment manufacturers for any intervals of instrument readings. A segment of such a table developed from the above equation is illustrated in Table 1. We recommend applying the equation to an applicable moisture range of 9.5% to 21.5%. The dielectric constant of a material, and hence the meter reading, are influenced by temperature at any given moisture content. Our moisture analyses and calibration equation were obtained at 22C. For moisture tests performed at other temperatures and where higher accuracy is required, a temperature correction chart is provided in the operating manual.

Table 1. ***Calibrated moisture content conversion chart for macadamia nuts (seedcoat with kernel).***

Dole 400 scale "A" readings	Moisture content (%, wet basis)
30	9.54
31	9.63
32	9.72
33	9.80
90	14.85
91	14.94
92	15.03
93	15.11
160	21.04
161	21.13
162	21.22
163	21.31

Testing the accuracy of the calibration curve. Percent moisture content of 33 macadamia nut samples was determined using the forced-air oven and the Dole 400 moisture meter to test the accuracy of the calibration equation. The moisture meter scale readings were converted to moisture contents using the calibration equation derived above. Table 2 compares the values derived from the forced-air oven method and electronic moisture meter. The average difference between the oven and electronic meter moisture reading was 0.21% ± 0.08% SE ($P < 0.05$ by paired t test). Therefore, the instrument is sufficiently accurate for field and quality control use.

Factors that may have contributed to the meter bias are sample-to-sample variation, sample test weight, variation in setting the null meter needle exactly on its mechanical zero, and packing density in the test cell. Variations in sample test weights and in sizes of the nuts after cracking affected the packing density in the test cell. Since the dielectric properties of agricultural products are affected by bulk density (Nelson, 1973, 1982), the packing density in the test cell contributed to meter error. To reduce meter error, we recommend that moisture measurements be made on several samples within a batch and that at least three meter readings be taken per sample. An average moisture content then can be computed.

Table 2. ***Comparison of moisture content (percentage) of macadamia nuts by the forced-air oven and the Dole 400 moisture meter.***[z]

Oven	Dole 400	Difference (Oven – Dole)
9.59	10.01	–0.42
9.88	9.63	0.25
9.94	9.80	0.14
9.96	9.63	0.33
10.21	10.18	0.03
10.30	9.96	0.34
10.39	10.18	0.21
10.47	10.28	0.19
10.70	10.60	0.10
10.94	10.74	0.20
11.82	11.78	0.04
11.93	11.87	0.06
12.11	11.87	0.24
12.29	11.66	0.63
12.64	11.57	1.07
12.66	12.76	–0.10
13.24	12.46	0.78
13.33	12.55	0.78
14.17	13.79	0.38
14.28	13.87	0.41
14.31	13.99	0.32
15.29	15.48	–0.19
16.62	16.40	0.22
16.97	17.24	–0.27
17.23	17.75	–0.52
17.33	16.17	1.16
18.12	17.97	0.15
18.19	18.51	–0.32
18.39	17.45	0.94
18.56	18.79	–0.23
19.54	20.27	–0.73
19.84	19.76	0.08
20.16	19.55	0.61

[z] $Y = 0.0885X + 6.885$, $R^2 = 0.965$.

Relationship between kernel and whole-nut moisture content. In drying macadamia nuts, an accurate determination of kernel moisture content is critical to the prevention of damage during kernel processing. Thus, the relationship between kernel and whole nut (kernel + seedcoat) moisture content was determined. Seventy 100-g samples of kernels were obtained from nuts with moisture levels of 7.5% to 20% and dried in a forced-air oven. The relationship between kernel and whole-nut moisture content is illustrated in Fig. 2. Percent moisture content of kernel can be estimated accurately from whole-nut moisture content using this relationship.

The results indicate that it is possible to use an electronic moisture meter (Dole Model 400) to rapidly

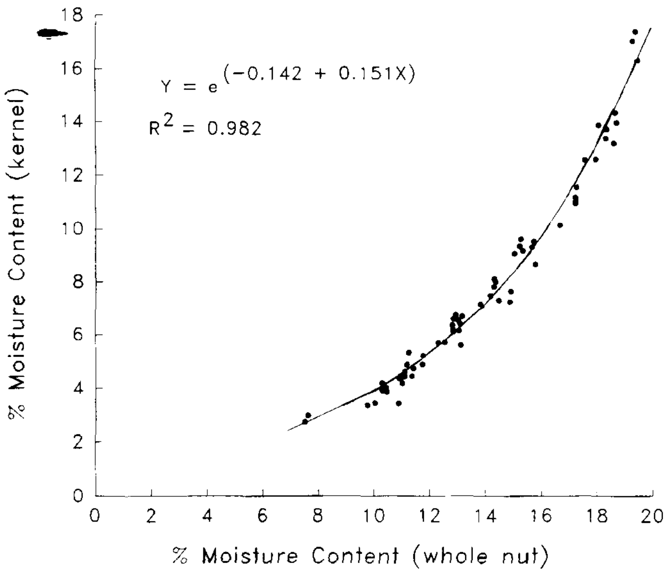

Fig. 2. ***Relationship between kernel and whole-nut moisture content.***

determine the moisture content of macadamia nuts (whole nut) with sufficient accuracy for routine use by farmers and processors. The effective range of the meter is 9.5% to 21.5% moisture content (Fig. 1). Because there may be differences in nut composition due to cultivar, dry matter accumulation and water tension in the nut, and environmental conditions, use of the moisture meter for other cultivars may require adjustment or modification to the equations provided.

Acknowledgements

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