A Microwave Oven Procedure for Soybean Moisture Content Determination

N. SHARMA and M. A. HANNA[1]

ABSTRACT

A simple microwave oven technique was developed for rapid determination of soybean moisture. Samples of whole soybeans in the moisture range of 9–33% (wb) were partially dried by exposing them for different time intervals in a microwave oven. Mathematical relationships were developed that accurately predicted the moisture of the soybeans based on partial moisture loss. This technique of using partial drying for rapidly predicting moisture of whole soybeans precluded burning of the samples.

Cereal Chem. 66(6):483–485

Moisture determination is a commonly employed technique in the field of food and agriculture. There are standard methods available for moisture determination in grains, forages, and foods (ASAE 1986, AOAC 1984, AACC 1983). These methods use air or vacuum ovens into which the sample is placed for a specified time at a specified temperature (different for different materials). The moisture content is then determined from the weight lost during that specified time. These methods are time-consuming, especially for food grains. Electronic moisture meters have been employed for quick moisture determination in grains, but Hurburgh et al (1980) concluded that the performance of moisture meters was erratic at higher moisture levels. Accuracy of the results given by the moisture meters also depended on how well the meters had been calibrated. Furthermore, calibration of these instruments was done against the standard oven methods, which were, again, time-consuming. Farmer and Brusewitz (1980), Noomhorm and Verma (1982), and Verma and Noomhorm (1983) employed microwave ovens to dry different materials for the purpose of rapid moisture determination. Farmer and Brusewitz (1980) employed a home microwave oven for determining moisture of wet alfalfa. They used a water reservoir, along with the sample, to protect the magnetron, but found that the large quantities of water used in the oven absorbed most of the microwave energy, and so the sample dried slowly. Moreover, the moisture content greatly depended on the amount of water used. They also tried using an asbestos pad for absorbing excessive energy, but within 20 min the pad became very hot and tended to scorch the bottom of the samples. Having used the microwave oven in different ways, the moisture of alfalfa was, at best, 1.6% less than that given by the standard air-oven method (ASAE 1986).

Noomhorm and Verma (1982) used a microwave oven for determining the moisture of whole and ground samples of rough rice. They also used an asbestos board to protect the magnetron. Different power levels and time combinations were tried. The microwave moisture results after 20 min at 80% power were about 4% lower than those found by a standard air-oven method. Also, the bottoms of the grain samples were burned by the asbestos pad which became hot after about 20 min. They found that, in general, the moisture shown by microwave drying was always lower than the standard moisture value for the whole grain sample, and the samples were burned if either the power level or the time was increased.

Verma and Noomhorm (1983) dried sorghum forage, wheat, soybeans, and rough rice in a microwave oven for rapid moisture determination. Burning of wheat and soybeans was observed before complete moisture removal for all power levels tried. Moisture results were lower by 0.92 and 1%, respectively, for wheat and soybeans. Davis and Lai (1984) employed a home microwave oven for rapid moisture determination of flour. They found that a larger sample size required a longer drying time than did a small amount of sample. Longer drying times for larger samples resulted in their charring because of excessive heat buildup within the sample layer. Charring occurred in all flours at the 415 W and 4 g combination. Microwave moisture values were reported to be consistently lower than the air-oven values.

With the repeated reports of sample burning or under-prediction of moisture content, the potential use of a microwave oven for moisture determination is not very encouraging. However, the speed and efficiency of microwave drying encourages its use.

The results of a convection air-oven drying test for rapid moisture determination in whole kernels of corn and soybeans by Sharma and Hanna (1988) suggested that a microwave oven could be used for partially drying the sample and would not only prevent burning but might also accurately predict moisture. The objective of this study was to develop a microwave oven method for rapidly determining the moisture content of whole soybeans without burning.

MATERIALS AND METHODS

A Litton 500 Series microwave oven was used and operated at its full power. The useful power absorbed was determined to be 619 W with a standard deviation of 33 W over four replications using the technique described by Charlie et al (1982). An electronic balance (Allied Fisher Scientific, model 7215A) with a resolution of 0.01 g was used to weigh the samples.

Samples of Hobbit soybeans were obtained from the University of Nebraska-Agricultural Research and Development Center at Mead, NE. Moisture was determined to be 9.3% (wb) by air-oven drying for 72 hr at 103°C (ASAE 1986). Different moisture content samples were prepared by adding the required amount of water to a 9.3% moisture sample. Each sample was placed in a plastic bag and kept at 4°C for a month to equilibrate. Final sample moisture contents were 9.3, 11.0, 13.8, 14.8, 17.0, 21.4, 23.4, 30.7, and 33.2%, wb.

Small paper baskets (6 × 6 × 2 cm) capable of holding a 25-g sample were made. Based on the results of some initial drying tests on soybeans in the microwave oven, each of the samples was exposed for times of 0.5, 1.0, 1.5, 2.0, 2.5, and 3.0 min. For each moisture content sample, four replications were made for each of the selected microwave time periods.

Samples were taken out of the refrigerator and brought to room temperature before they were exposed to microwave heating. A sample of approximately 25 g was weighed in a paper basket, and the basket was placed at the center of the oven. Only one basket was placed in the oven at a time. After microwave heating of the sample for the specified time, the basket and sample were taken out, weighed, and discarded. This procedure was repeated for the respective times for each moisture content sample. The weight loss after each drying time was expressed as an apparent moisture content, M_a, and was defined as

$$M_a = (W_i - W_t / W_i) \times 100 \quad (1)$$

where W_i was the initial mass of the sample and W_t was the mass of sample after t minutes of microwave drying.

[1]Department of Agricultural Engineering and Food Science and Technology, University of Nebraska, Lincoln, NE 68583-0726.

TABLE I
Apparent Moisture Contents (%, wb) After Different Microwave Exposure Times for Different Moisture Levels

Actual Moisture Content, %, wb	Microwave Exposure Time (min)					
	0.5	1.0	1.5	2.0	2.5	3.0
9.31 (0.06)[a]	0.83 (0.0)	3.48 (0.2)	7.08 (0.35)	8.82 (0.06)	...[b]	...
11.04 (0.0)	1.32 (0.09)	5.17 (0.25)	8.69 (0.08)	10.62 (0.13)	...	...
13.75 (0.08)	2.28 (0.20)	7.52 (0.15)	11.34 (0.20)	13.04 (0.16)	...	...
14.80 (0.41)	2.60 (0.27)	8.14 (0.35)	12.42 (0.06)	14.21 (0.13)	15.67 (0.39)	...
17.04 (0.08)	3.40 (0.10)	10.44 (0.44)	14.00 (0.20)	16.39 (0.02)	17.87 (0.14)	...
21.41 (0.09)	4.77 (0.28)	12.57 (0.41)	17.02 (0.24)	19.35 (0.15)	20.87 (0.18)	...
23.42 (0.07)	6,03 (0.11)	14.01 (0.39)	18.47 (0.18)	21.27 (0.28)	22.39 (0.06)	24.15 (0.30)
30.65 (0.13)	7.63 (0.54)	16.42 (0.41)	22.78 (0.14)	26.27 (0.40)	29.14 (0.26)	30.55 (0.09)
33.21 (0.12)	8.82 (0.35)	16.60 (0.59)	23.71 (0.45)	28.25 (0.17)	31.07 (0.19)	32.66 (0.25)

[a]Numbers in parentheses are the standard deviations in %, wb, and each number is an average of four observations.
[b]Dashes indicate that the soybeans were burned during that exposure time.

Simple regression analyses were conducted to determine the relationships between the apparent and the "actual" moisture content of the sample. The actual moisture of the sample was determined by drying approximately 25 g of the samples at 103°C for 72 hr (ASAE 1986). Using the relationships developed, the moisture of the sample was predicted through the use of the apparent moisture contents obtained for the different exposure times, and finally the moisture values obtained by partial microwave drying were compared with the "actual" moisture values. Later, the validity of the prediction model was checked by drying other soybean varieties using the same regression coefficients.

RESULTS AND DISCUSSION

The apparent moisture contents obtained after different microwave exposure times for each of the moisture levels used are presented in Table I. When the actual moisture values were compared with their corresponding apparent moistures (M_a), for each of the times used, it was found that the actual moistures were exponentially related to the apparent moistures, with a high coefficient of determination ($R^2 > 0.96$) as

$$M = a \exp(bM_a) \quad (2)$$

TABLE II
Regression Coefficients for Equation 2

Microwave Exposure Time, min	a	b	R^2
0.5	9.3637	0.1538	0.9681
1.0	6.7886	0.0921	0.9895
1.5	5.7979	0.0746	0.9944
2.0	5.7247	0.0646	0.9827

where M was the actual moisture content (%, wb) as determined by a standard method (ASAE 1986), and a and b were regression coefficients. This relationship was good for all of the microwave exposures times. The regression coefficients for equation 2 are shown in Table II, and the moisture results, as determined by equation 2, are shown in Table III.

A comparison of the predicted moisture results with the actual moisture values in Table III shows that exposure times of 1 and 1.5 min gave good predictions of moisture over the entire range of moisture, whereas the other times showed good results for only a few moisture levels. Table III shows the residuals and the percent error in the prediction of moisture using the regression coefficients for times of 0.5, 1.0, 1.5, and 2.0 min. This table clearly shows that the times of 1 and 1.5 min are sufficient to predict the moisture content with reasonable accuracy. Table IV shows the actual and the predicted moisture content using equation 2 with regression coefficients corresponding to the exposure times of 1 and 1.5 min for soybean samples of different varieties (Century 84 and Hoyt). The ability to predict moisture content of other varieties, even though only limited naturally dried samples were available, serves to at least partially validate the models. For the varieties Century 84 and Hoyt, the model using regression coefficients for 1 min gave better results than did the coefficients for 1.5 min. A time for 1.5 min overestimated the moisture, but drying for 1 min predicted the moisture within acceptable limits. This again suggests that for comparatively dry samples (moistures below 12%, wb) a time of 1 min is sufficient, whereas for samples with moisture contents above 12% exposure to microwaves for 1.5 min will be required. The close agreement of the microwave predicted moisture results with the actual moisture values suggested that there was no need to completely dry a sample, which would eliminate the problem of scorching the sample. Predicting the moisture contents of the samples through partial drying provided a rapid technique for moisture determination without burning.

TABLE III
Actual and Predicted Moisture Contents, Residuals, and Percent Error in Prediction of Moisture Content After Different Microwave Exposure Times Using Equation 2

Actual Moisture %, wb	Exposure Times (min)											
	0.5			1.0			1.5			2.0		
	Predicted Moisture	Residual Moisture	Percent Error	Predicted Moisture	Residual Moisture	Percent Error	Predicted Moisture	Residual Moisture	Percent Error	Predicted Moisture	Residual Moisture	Percent Error
9.31	10.64	−1.33	14.3	9.35	−0.04	0.4	9.83	−0.52	5.6	10.12	−0.81	8.7
11.04	11.47	−0.43	3.9	10.93	0.11	1.0	11.09	−0.05	0.5	11.37	−0.33	3.0
13.75	13.30	0.45	3.3	13.57	0.18	1.3	13.51	0.24	1.7	13.29	0.46	3.3
14.80	13.97	0.83	5.6	14.37	0.43	2.9	14.64	0.16	1.1	14.34	0.46	3.1
17.04	15.80	1.24	7.3	17.76	−0.72	4.2	16.48	0.56	3.3	16.50	0.54	3.2
21.41	19.50	1.91	8.9	21.61	−0.20	0.9	20.64	0.77	3.6	19.98	1.43	6.7
23.42	23.67	−0.25	1.1	24.67	−1.25	5.3	23.00	0.42	1.8	22.62	0.80	3.4
30.65	30.28	0.37	1.3	30.80	−0.15	0.5	31.72	−0.07	3.5	31.24	−0.59	1.9
33.21	36.36	−3.15	9.5	31.32	1.89	5.7	34.00	−0.79	2.4	35.51	−2.3	6.9

[a]Residual moisture = actual − predicted, %.

TABLE IV
Predicted Moisture of Other Varieties (%, wb)
After 1 and 1.5 min of Exposure in Microwave Oven

Variety	Actual Moisture	Predicted Moisture	
		1 min	1.5 min
Hoyt	8.94	8.95	9.66
Century 84	9.29	9.41	9.73

The technique used in convection oven drying for rapid moisture determination (Sharma and Hanna 1988) worked well when applied to a microwave oven with an additional advantage of further accelerating the moisture determination. However, using the microwave oven, the actual moisture was an exponential function of the apparent moisture content, whereas a linear relationship was observed between actual and apparent moisture content using the convection oven.

CONCLUSIONS

Using the technique of partial drying, a microwave oven can be used for determining the moisture of whole soybeans without burning. Moisture can be accurately predicted in 1 min, compared with the standard 72-hr air-oven method currently being used for soybean moisture determination. The prediction model can be successfully used for rapidly determining the moisture of whole soybeans provided the same microwave conditions are used. A time of 1 min is required to determine the moisture of whole soybeans using this technique.

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[Received October 26, 1989. Accepted June 15, 1989.]