[Reprinted from Food Technology, 1951, Vol. V, No. 6]

A Comparison of Three Methods for Determination of Moisture in Sweet Corn

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(Manuscript received March 2, 1951)

Comparative moisture tests have been made on five varieties of sweet corn over the range of 62-79%. The vacuum oven method used as a standard was compared with results obtained using the Brown-Duvel and the Steinlite instruments. Results indicate that the Steinlite instrument is well adapted for simple rapid determination of the moisture content of sweet corn for canning.

For each determination by the vacuum oven method, 3 are required for the Steinlite and 9 for the Brown-Duvel to obtain results of equivalence.

Moisture content of sweet corn has been established as a reliable index for maturity in the canning stage by Culpepper and Magoon *(3)*, Huelsen and Michaels *(4)*, Jenkins and Sayre *(5)*, Kramer, Guyer, and Ide *(6)*, Kramer and Smith *(7)* and Pratt *(8)*. Maturity appears to be a summation of chemical and physical factors which depend on the period, during the growth of the plant, in which they are determined. Determinations of indexes of maturity have taken a wide variety of forms. Among the earlier methods which gained prominence were the thumb nail test, puncture tests and measurements of density. The measurement of the starch-sugar ratio in corn has been used as an index of maturity but has not come into wide use because the methods of analysis require too much time and technical skill. Other methods have been proposed including (1) measurement of alcohol insoluble solids, (2) measurement of the refractive index of expressed corn juice, (3) vacuum drying, (4) oven drying without vacuum, (5) removal of moisture by oil or solvent distillation (Brown Duvel method) and (6) measurement of the volume of juice squeezed from a sample of corn under standardized conditions (succulometer).

A new method has recently been introduced by the Fred Stein Laboratories for measuring the moisture in corn samples electrically. The moisture from a weighed sample is dissolved in a known volume of hygroscopic solvent. The solvent containing the moisture from the corn sample is used as the dielectric constituent in a coaxial cylindrical condenser. Changes in the dielectric characteristics of the solvent-corn extract mixture correspond with changes in the moisture content in the corn sample. The resulting alteration in the radio frequency impedance of the condenser is measured by an electronic oscillator as a change in frequency in the circuit. This change in frequency may be read from a meter and, after calibration, interpreted in terms of the moisture content of the sample. Since this operation may be completed in a very short period of time, it is important to determine the accuracy which may be expected in the use of this instrument in a quality control laboratory. The Brown-Duvel moisture tester and the vacuum oven were chosen for a comparison with the Steinlite moisture tester. The Brown-Duvel method was chosen because it has been widely used in the canning industry and the vacuum oven because of its general dependability as a laboratory instrument.

EXPERIMENTAL PROCEDURE

In making the comparison, five varieties of corn were used. These were Golden Cross Bantam, Golden Glory, Tendermost, Victory Golden, and Iochief. Golden Cross and Tendermost were selected because they are varieties commonly grown in the midwestern states for canning while the others, Golden Glory, Victory Golden, and Iochief are promising new hybrids which have recently been introduced. Daily samples of these varieties were obtained from experimental plots grown on the Horticulture Farm at Ames. Samples were harvested in the morning and brought immediately to the laboratory for husking and cutting The silks were removed using a laboratory size screen silker.

Although water is used at several points in the canning procedure, none was used in the preparation of these samples to avoid apparent changes in moisture content which might be expected if wash water remained on the kernels. The cut kernels were packed in No. 2 C-enamel cans, sealed under mechanical vacuum, and rapidly frozen in an immersion freezer at —45.6° C.

[a] Journal Paper No. J-1914 of the Iowa Agricultural Experiment Station, Ames, Iowa, Project No. 1052.

(—50° F.). The frozen samples were stored at —17.8° C. (0° F.) until tests were completed.

The frozen samples were retained until the completion of the canning operation when they were analyzed for moisture content by the three methods being compared. Samples for the vacuum oven of approximately 10 g. were weighed out on a torsion balance to ± 0.01 g. Vacuum oven determinations were made on samples which were pre-dryed in an air oven at 80° C. (176° F.) for a five hour predrying period to prevent excessive boiling under vacuum. The partially dried samples were then dried for five hours in the vacuum oven at 95° C. (203° F.) under a vacuum of 30 inches of mercury. At the completion of the drying period, samples were removed to a desiccator to cool, then weighed, and the moisture content of the sample calculated in percent.[b]

Brown-Duvel determinations were made using 20 gram samples. Weighing was done on a torsion balance to ± 0.1 g. The distilling flasks were pre-conditioned each day by running a blank determination with corn before operations were begun. The oil-corn mixture was heated to 190° C. (374° F.) when the source of heat was removed. The distillate was then collected in 25 ml. graduated cylinders calibrated to read to 0.01 ml. The results were expressed as percent moisture by multiplying the number of milliliters of distillate by a factor of five.

Samples prepared for the Steinlite instrument were of approximately 10 g., weighed to 0.01 g. accuracy on a torsion balance. Accuracy of 0.01 in the weighing of the sample was prescribed for this method by the manufacturer of the instrument; whereas, accuracy of 0.1 g. in weighing samples for the Brown-Duvel was sufficient in the commercial procedure being followed.

Tared squares of cellophane were used in conveying the weighed samples to the blendor. Cellophane was used since it is sufficiently impervious to moisture and is easily macerated in the blending operation. The use of pliofilm was attempted, but the elastic properties prevented its maceration and it wrapped around the blendor knives in such a manner as to decrease the efficiency of blending.

In accordance with the objective of this investigation, the operating instructions of the Steinlite moisture tester were adhered to with the exception of sample preparation. Moisture was released from the kernels upon thawing of the frozen samples; therefore the entire frozen sample was blended in order to obtain a homogeneous sample. Whole kernels, cut from the cob, constituted the recommended sample. The prepared sample and tared square of cellophane were transferred to a one-half pint mason jar to which 100 ml. of the solvent, Aquafin No. 1, was added. The mason jar and the knives of an Osterizer were assembled and the sample blended for two minutes. The moisture was filtered through Eaton and Dikeman No. 615 filter paper, an open texture type with creped surface which permits rapid filtration. The filtrate was used immediately for conductivity measurement by the instrument, being added to the test cell after the instrument was properly set, removed and added the second time to establish complete wetting of electrodes. A reading was obtained by manipulation of the selector switch and then the temperature of the filtrate was measured. The chart for conversion of meter readings to percent moisture was calibrated for a 29.4° C. (85° F.) temperature of the filtrate. After conversion, the results were corrected for temperature. In addition to a temperature correction, it was necessary to make a solvent correction. The solvent correction was a value obtained from a daily blank determination using a sample of the solvent, since moisture content may vary from day to day. The moisture content reported is the average of three determinations.

[b] The instructions for use of the Steinlite instrument contain tables of moisture values for corn which were determined by comparison with samples dried at 85 or 101° C. (185 or 214° F.) for 16 hours in an air oven. Duplicate determinations were made using 2-g. samples.

RESULTS

The mean moisture determinations with the three methods on 51 samples ranging from 62% to 79% moisture and taken from five varieties of sweet corn are given in Table 1. Each sample mean is the average of three determinations. The average percentage moisture of all samples was 70.4 with the vacuum oven, 70.0 with the Brown-Duvel tester and 70.5 with the Steinlite tester.

TABLE 1

Means of Triplicate Determinations of Moisture Content of Sweet Corn Using Five Varieties and Three Methods of Estimation.

Variety	Instrument		
	Vacuum oven	Brown-Duvel	Steinlite
Golden Cross	72.8	73.2	72.5
	72.5	67.8	71.4
	74.0	76.4	73.5
	70.5	69.8	70.8
	70.9	69.5	70.7
	67.9	68.1	68.4
	68.9	67.6	69.0
	67.9	66.2	67.5
	66.4	63.7	67.8
	66.7	65.8	68.3
	62.8	66.8	65.2
Golden Glory	71.0	71.2	72.4
	70.4	68.7	69.8
	69.2	68.3	69.6
	69.2	68.6	69.7
	67.6	67.5	68.7
	66.1	69.4	67.3
	65.8	66.2	66.2
	65.9	64.2	67.5
	65.1	65.0	66.8
	63.3	60.5	65.4
Tendermost	78.1	75.0	75.1
	78.5	77.5	77.6
	75.1	78.3	74.8
	74.6	75.2	74.2
	74.8	75.2	73.8
	72.5	71.0	71.0
	72.0	73.7	70.8
	72.5	71.9	71.9
	69.4	69.3	70.6
	69.9	69.6	68.9
	68.4	67.2	68.6
	67.4	67.0	68.7
Victory Golden	76.9	75.1	75.5
	77.3	77.6	75.7
	73.2	74.3	73.1
	71.7	68.6	71.5
	71.8	71.6	71.2
	68.7	69.6	69.2
	68.3	69.8	69.3
	66.2	65.4	67.9
Iochief	78.2	77.5	75.9
	77.3	75.4	75.1
	72.8	70.3	71.6
	72.7	70.8	72.4
	71.2	72.3	71.0
	68.4	68.4	69.2
	68.7	67.0	69.3
	67.2	67.2	67.1
	66.4	65.5	67.8
	66.4	66.4	67.4
Instrument Mean	70.4	70.0	70.5

For purposes of comparisons among the three methods, the vacuum oven is used as the standard. Analyses of variance of the differences in moisture determinations between the vacuum oven and the Brown-Duvel tester and between the vacuum oven and the Steinlite tester are given in Table 2. A test for the equivalence of two scales in measuring differences among treatments given by Cochran *(2)* is the ratio of the pooled mean square for varieties and mean and the

TABLE 2

Analyses of Variance of Determinations Between Means of Methods and Among Varieties

Source of Variation	Degrees of freedom	Vacuum oven-Brown-Duvel, Mean square	Vacuum oven-Steinlite, Mean square
Mean	1	10.645	0.201
Varieties	4	0.724	3.930
Error	46	2.975	1.215

mean square for error. This test indicates that the Brown-Duvel tester and the vacuum oven are equivalent in measuring the differences in moisture content among the varieties. The mean difference between the two methods is not quite significant at the 5% level as measured by the ratio of the mean square for mean and the mean square for error. Additional evidence based on the linear regression of the 51 mean determinations by the Brown-Duvel tester on those by the vacuum oven supports the conclusion that the two are equivalent in measuring the moisture percentage in sweet corn that has been frozen. This regression is $Y_1 = 3.3 + 0.95\ X$. If the two are equivalent the y-intercept should equal zero, the regression coefficient should equal one, and neither of the observed values in the above equation differs significantly from the expected.

The analysis of variance of the differences between the determinations made with the vacuum oven and the Steinlite indicates that the two methods are not equivalent and that they do not differ by a constant, although the means of all determinations by the two methods are almost identical. That the determinations are not the same on the individual samples for the two methods is also shown by the regression $Y_2 = 18.37 + 0.74\ X$. The value 18.37 differs significantly at the 1% level from zero, the regression coefficient differs significantly from one, and there is sufficient evidence to conclude that the regression is linear. The differences between the vacuum oven and Steinlite and between the vacuum oven and the Brown-Duvel are plotted against the determinations by the vacuum oven shown in Figures 1 and 2.

The scatter diagram shown in Figure 1 is a comparison of the results obtained with the vacuum oven with deviations of the Steinlite results from those of the vacuum oven. It should be apparent from this figure that use of the vacuum oven as a standard of comparison

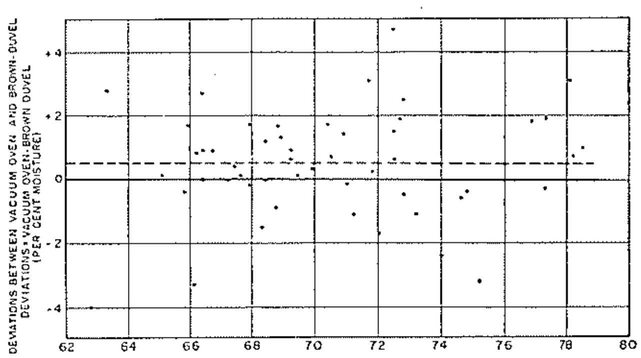

FIG. 1. Regression of (vacuum oven—Steinlite) on vacuum oven readings showing how the difference between the two methods varies over the range 62-78% moisture.

yields results which are not identical with those derived through use of the Steinlite instrument. Within the range of 68-73% moisture as determined by the vacuum oven, deviations are generally within 1%. When the range is extended to include 62-79% the deviations increase to approximately 3%.

A comparison of Figure 1 with Figure 2, indicates that the deviations of the Brown-Duvel determinations

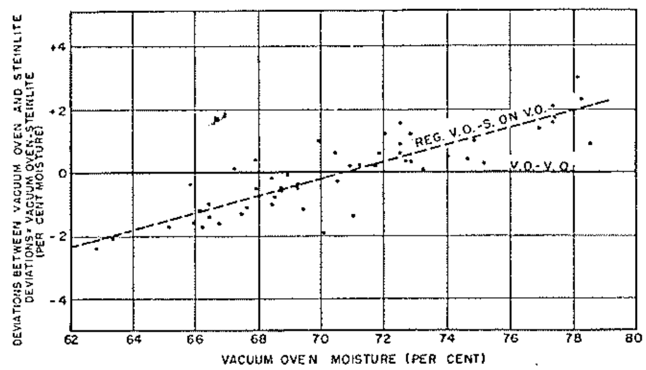

FIG. 2. Regression of (vacuum oven— Brown-Duvel) on vacuum oven showing wide variations between the two methods over the range from 62-78% moisture.

from those of the vacuum oven are consistently large over the entire moitsture range tested. This is illustrated again in the regression lines shown in Figures 3 and 4.

Actual corrections for either the Steinlite or the Brown-Duvel could be made from the regression lines (Figures 3 and 4) or perhaps more conveniently from a chart containing the same information.

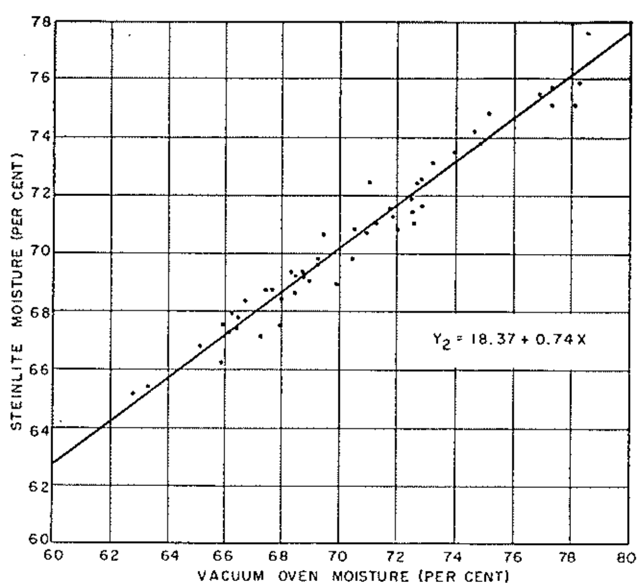

FIG. 3. Regression of Steinlite on vacuum oven moisture determinations.

The standard deviations were 0.39, 0.69 and 1.17% for the vacuum oven, Steinlite, and Brown-Duvel instruments (Table 3), indicating that the least average deviation from the mean would be expected through use of the vacuum oven. The standard deviation of the Steinlite instrument was approximately twice that of

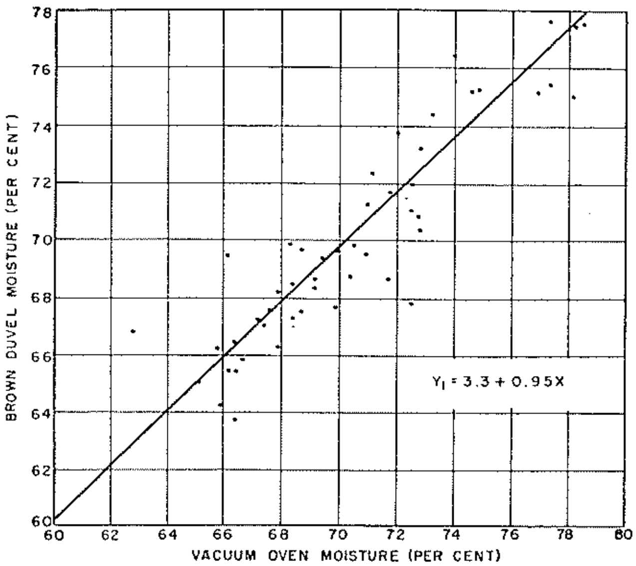

FIG. 4. Regression of Brown-Duvel on vacuum oven determinations.

the vacuum oven while the Brown-Duvel standard deviation was approximately three times that of the vacuum oven. The standard deviation 1.17% was the same as that obtained by Carter, Olson, and Henry *(1)*.

In terms of relative efficiency, assuming the vacuum oven to be 100%, the Steinlite was 32.3% as efficient and the Brown-Duvel only 11.0% as efficient as the vacuum oven. Efficiency may also be expressed in terms of its effect on sampling requirements. Three samples for the Steinlite and nine for the Brown-Duvel would be required to yield moisture values of approximately equivalent accuracy.

TABLE 3

Sampling and Operation Time Requirement For the Vacuum Oven, Steinlite and Brown-Duvel Methods

Comparative Expression	Instrument		
	Vacuum oven	Steinlite	Brown-Duvel
Mean Square Deviation (Variance)	0.15	0.47	1.36
Standard Deviation	0.39%	0.69%	1.17%
Relative Efficiency	100.0%	32.3%	11.0%
Number of determinations for equivalence	1	3	9
Time required to obtain equivalent accuracy by each method	5 hours	15 min.	5.25 hours
Time required for one determination	5 hours	5 min.	35 min.
Probable equivalent time under plant conditions	5 hours per 20 samples	5 hours per 60 samples	30 hrs. per 180 samples

Another factor of importance in evaluating efficiency is the time required to obtain results. If determinations were made one at a time, five hours would be required using the vacuum oven, 35 minutes with the Brown-Duvel, and only five minutes for each determination in the Steinlite instrument.

If the required times for determination of moisture are adjusted to include sufficient samples to provide a similar degree of accuracy in each case, the vacuum oven and the Brown-Duvel methods would require approximately five hours each while the Steinlite method would require only 15 minutes.

In a quality control operation it is usually desirable to operate instruments near their rated capacity. The ordinary vacuum oven will hold about 20 samples and a bank of six Brown-Duvel flasks will accommodate six samples simultaneously. The Steinlite instrument has a capacity of only one sample at one time. Taking these factors into account in addition to the sampling requirements for equivalent accuracy (Table 3), 20 samples could be run at one time in the vacuum oven in five hours. Sixty samples would be required if the Steinlite instrument were used, but the sixty samples could also be run in five hours. Using the Brown-Duvel, six-unit instrument, 180 samples and approximately 30 hours would be required.

Results from the Steinlite could be obtained at five minute intervals while those from the Brown-Duvel instrument would be available at approximately 35 minute intervals. The vacuum oven would provide results only after five or more hours.

SUMMARY

Comparisons of moisture content have been made on 51 samples of 5 varieties of sweet corn over the range of 62-79%.

The vacuum oven method was used as a standard and was compared with the Steinlite and the Brown-Duvel methods.

Three samples for the Steinlite and nine for the Brown-Duvel would be required to yield moisture values approximately equivalent to one vacuum oven sample.

Determinations of moisture content of frozen sweet corn samples made with the vacuum oven were found to vary less from their mean than those of the Steinlite and the Brown-Duvel.

Under laboratory conditions moisture estimates may be obtained in approximately 5 minutes using the Steinlite tester, 35 minutes using the Brown-Duvel instrument, and only after 5 or more hours with the vacuum oven.

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