SINGLE KERNEL MOISTURE VARIATION AND FUNGAL GROWTH OF BLENDED CORN

E. Bonifacio-Maghirang, M. R. Paulsen, L. D. Hill, K. L. Bender

ABSTRACT. *Corn at 29% moisture content (MC) was dried to 18% MC. Corn at 29% and at 10% MC was blended to obtain 18% MC. The dried and blended samples were monitored for single kernel MC using two single kernel moisture meters and a single kernel oven drying method. Deterioration due to fungal growth during storage was estimated based on visual observation. The mean moisture contents of dried and blended 18% moisture corn based on the single kernel oven method were not significantly different for all sampling days (days 1, 3, 7, and 14). The standard deviations of moisture content decreased over time for both dried and blended 18% MC corn samples. For the dried 18% MC corn, the standard deviation was consistently low throughout the 14-day observation period. For the blended 18% MC corn sample, the standard deviation for days 0 and 1 was significantly higher than for days 3, 7, 9, and 14. It appears that moisture equilibration was attained at day 3. Evidence of fungal growth was observed to occur one day sooner for the corn blended to 18% than for the corn dried to 18% MC.* **Keywords.** *Corn, Moisture, Measurement, Grain drying.*

Variation in single kernel moisture content (MC) exists in corn and varies from harvest on through subsequent handling and processing operations. Moisture contents of individual kernels can be measured using an oven method or by using commercially available single corn kernel moisture meters. Measurement of single kernel MC based on oven methods is a very time-consuming procedure that requires fast processing techniques for reliable single kernel MC determinations. Development of single kernel moisture meters and/or methods were performed and reported by Hill et al. (1986, 1988), Watson et al. (1979), Kandala et al. (1986, 1988), and Nelson et al. (1991). Several commercial single kernel moisture meters, such as the Shizuoka Seiki and the Seedburo, are currently available for corn.

Nelson and Lawrence (1991) studied the differences in harvest MC of individual kernels of yellow-dent field corn at three locations on a corn ear. They found highly significant variation in MC by location with MC highest at the butt and decreasing toward the tip with differences ranging from 2 to 6% MC depending on the mean MC. At lower MC, i.e., MC considered to be safe for storage, the butt-to-tip MC difference was reported to be about 2%. This implies that field drying reduces the variation in single kernel MC.

In the past, some farmers and grain elevator operators have blended high and low moisture corn to achieve a desired mean moisture level. White et al. (1972) investigated the nature of moisture equilibrium in mixtures of 20 to 25% (high) and 8% (low) moisture shelled corn. On the average, the blending and time-dependent equilibration procedure produced a final MC which was within 1.4, 1.7, and 2.6 percentage points of the theoretical average moisture, for equilibration temperatures of 38°C (100°F), 21°C (70°F), and 4°C (40°F), respectively. Watson et al. (1979) found that corn blended using different initial moisture levels equilibrated in two days. Brusewitz (1987), on the other hand, found that after blending low-moisture and high-moisture rewetted corn samples, the mixture had a variability larger than unblended corn during a 24-day storage period. Hart (1964), in a wheat research study, found that equilibration of wheat blended using different MC levels was dependent on temperature and kernel size, but was not affected by application of pressure. In a later study, Hart (1967) reported that mixing overdried corn with undried corn to produce a mean MC of 15.5% resulted in a mixture that was more susceptible to mold than unmixed samples at the same moisture level.

Blending may also affect mold growth and storability of corn. Fungal contamination is a commonly reported reason for grain quality deterioration. There are conditions that allow for favorable growth of fungi, such as favorably high moisture content of grains, high temperature and relative humidity and inferior grain quality from the onset of storage. Fungal growth is observed to appear first in the cracks and broken areas of the seed coat. Nguyen et al. (1984) reported that equilibrated mixtures of wet and dry

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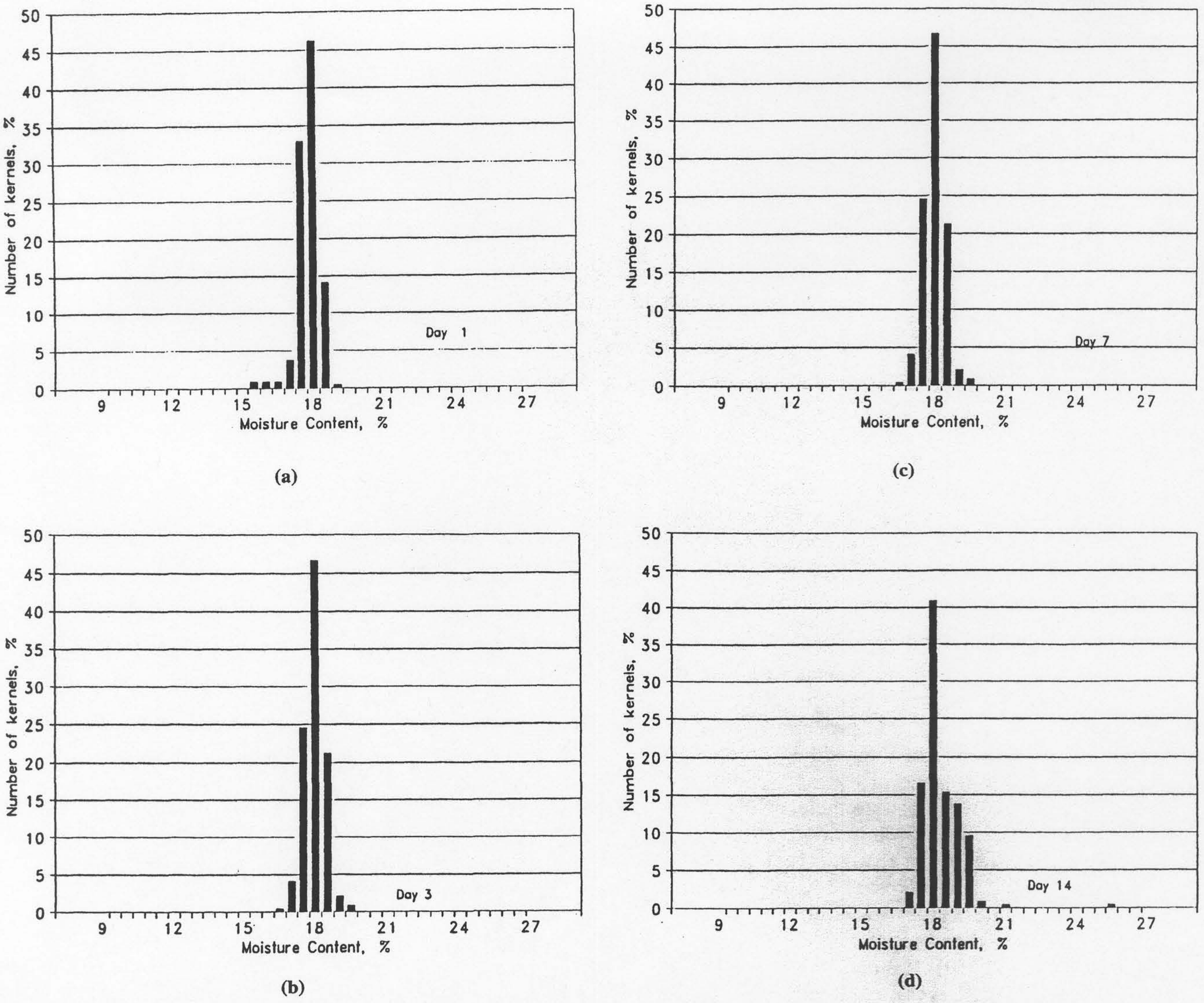


Figure 1–Frequency distributions of single kernel moisture contents for four replications of 60 kernels of corn dried to 18% MC based on the single kernel oven method for days 1, 3, 7, and 14.

corn had higher breakage susceptibility than corn dried to the average moisture content of the mixture, which implies that blended corn is more prone to fungal growth than dried corn. This study showed that blending increased the Stein breakage from 0.74 to 4.47 percentage points for a 15.5% blend and from 1.54 to 10.6 percentage points for a 20% moisture blend and that breakage due to handling was estimated to be from 0.1 to 1.7%. Also, the breakage of the blended corn increased when the dry portion of the blend had a lower moisture level.

As long as moisture differences exist, blending is a practice that will inevitably continue to occur. It is therefore essential that conditions which allow for safe storage of blended corn lots be defined. Moisture content is a critical consideration in storage. Several research studies, c.f., Seitz et al. (1982), Christensen and Sauer (1982), and Bailey (1982) presented discussions on the effect of moisture content on storage. Differing moisture levels within a corn lot will be greater for single kernel moisture measurements than for bulk moisture content measurements.

Objectives

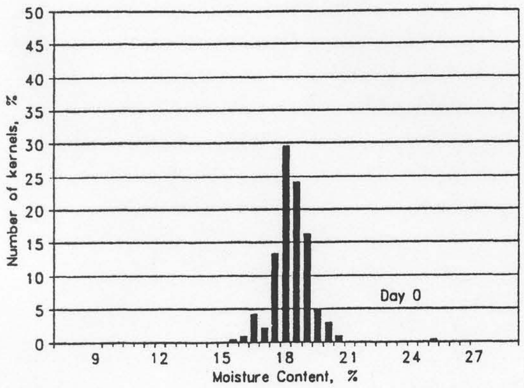
The objectives of this research were to:

1. Evaluate the performance of two commercially available single kernel corn moisture meters in comparison with a single kernel oven moisture determination method;
2. Determine the rate of moisture equilibration and the variation in single kernel moisture contents of corn dried to 18% and of corn blended to 18% moisture content during a 14-day period; and
3. Determine the differences in the rate of fungal growth for the dried and blended corn samples.

Materials and Methods

Corn Sample Preparation

The corn variety FR1141 × FR36 was harvested in October 1992 at 30% moisture content and then stored for six months at –18°C (0°F). Prior to drying and blending, samples were stored in a chamber at 4°C (40°F) for four days to allow samples to warm and equilibrate. The initial moisture content of the corn sample was 29% as measured



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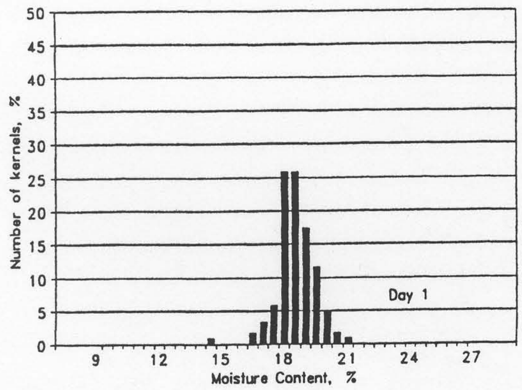

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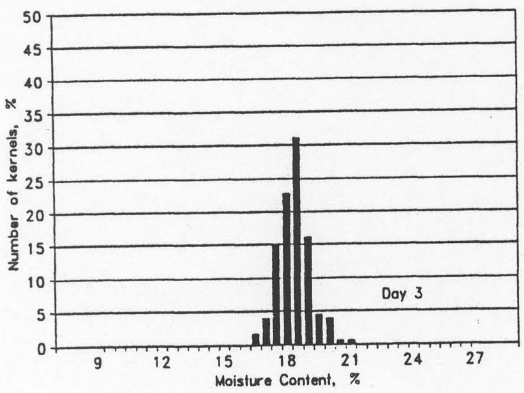

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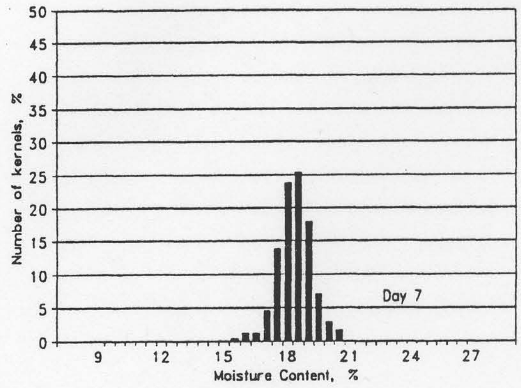

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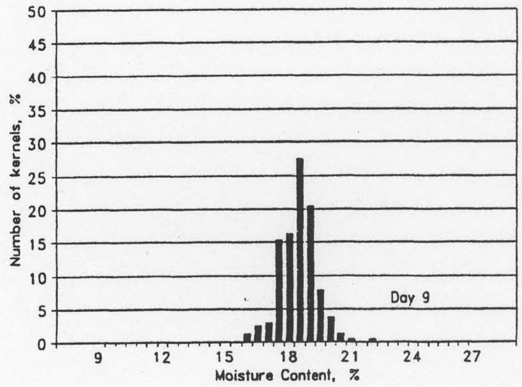

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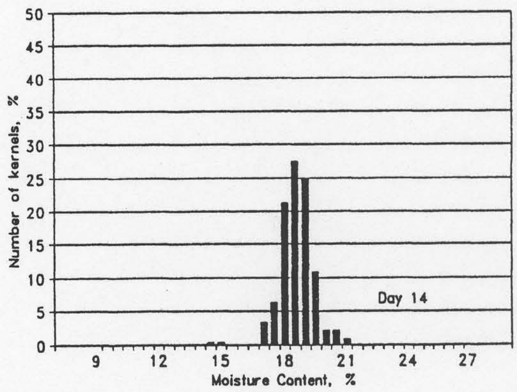

(f)

Figure 2–Frequency distributions of single kernel moisture contents for four replications of 60 kernels of corn dried to 18% MC based on the Seiki single kernel moisture tester for days 0, 1, 3, 7, 9, and 14.

using the oven moisture method on 100-g samples. A moisture content of 18% was obtained with the following procedure:

1. Corn samples at 29% wb MC were divided into three sub-samples. Sub-sample 1 (29% MC) was returned immediately to the 4°C (40°F) chamber. Sub-samples 2 and 3 were dried to 10% and 18% MC, respectively, using low-temperature forced air drying at 29 to 32°C (85 to 90°F) drying air temperature. After drying, sub-samples 2 and 3 were returned to the 4°C chamber and allowed to equilibrate for 24 h. All sub-samples were further divided with a Gamet precision divider into four lots, each lot representing one replicate.
2. Two working samples were prepared. Sample A was the sample dried directly to 18% from the initial 29% moisture level; and sample B was obtained by mixing the 10% MC sub-sample with the 29% MC sub-sample to obtain a theoretical 18% MC.

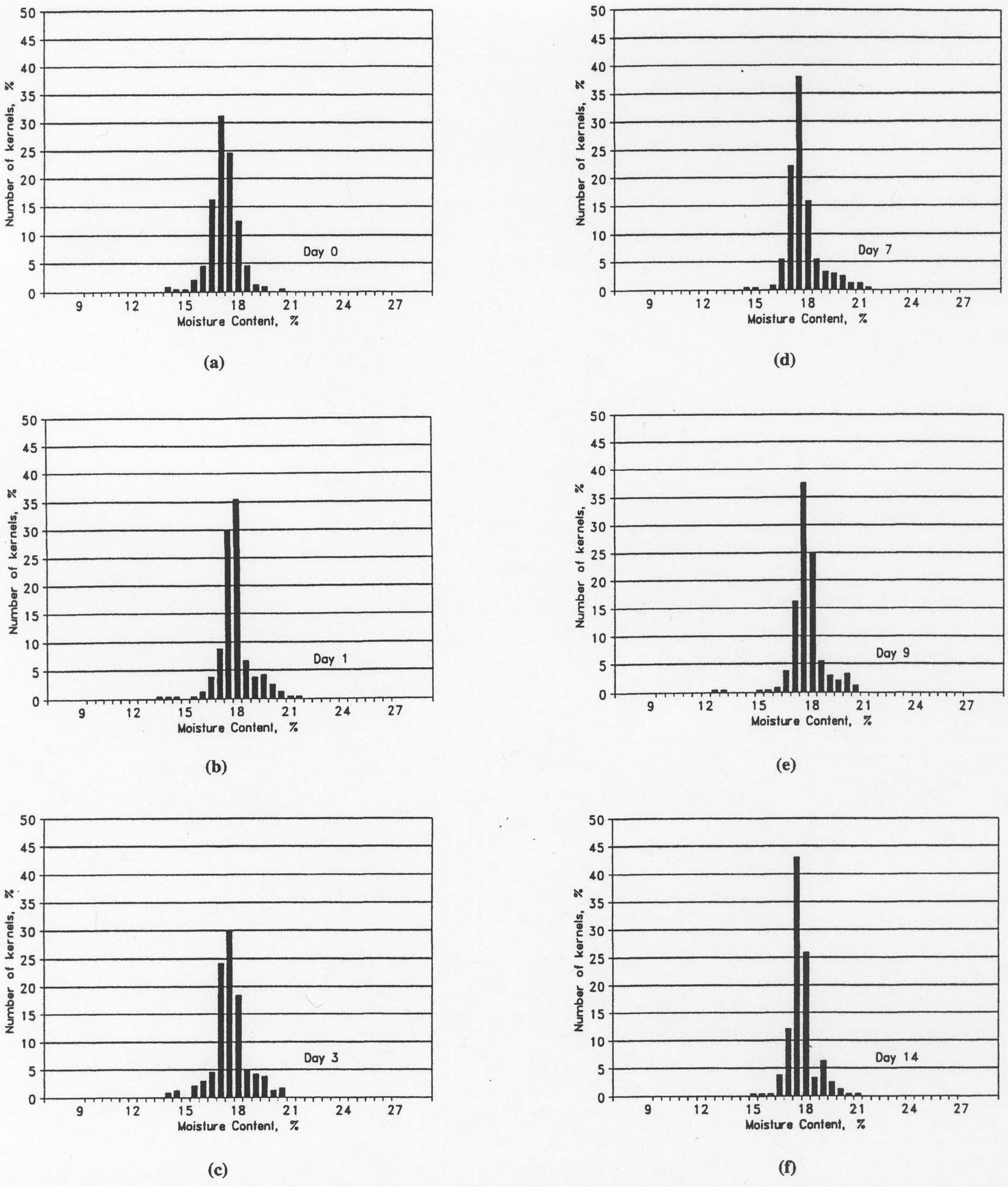

Figure 3–Frequency distributions of single kernel moisture contents for four replications of 60 kernels of corn dried to 18% MC based on the Seedburo single kernel moisture tester for days 0, 1, 3, 7, 9, and 14.

The theoretical 18% MC for Sample B was obtained using the equation:

$$M_f(x + y) = M_d(y) + M_w(x)$$

where

M_f = final theoretical moisture content (wb decimal)
x = weight of the wet sample (g)
y = weight of the dry sample (g)
M_d = oven moisture content of the dry sample (wb decimal)
M_w = oven moisture content of the wet sample (wb decimal)

Samples A and B were placed in plastic storage jars so that the jars were about two-thirds full and stored in a controlled temperature and relative humidity chamber at 24 to 26°C (75 to 79°F) and 73 to 75% relative humidity for 14 days. Samples were initially blended by turning the

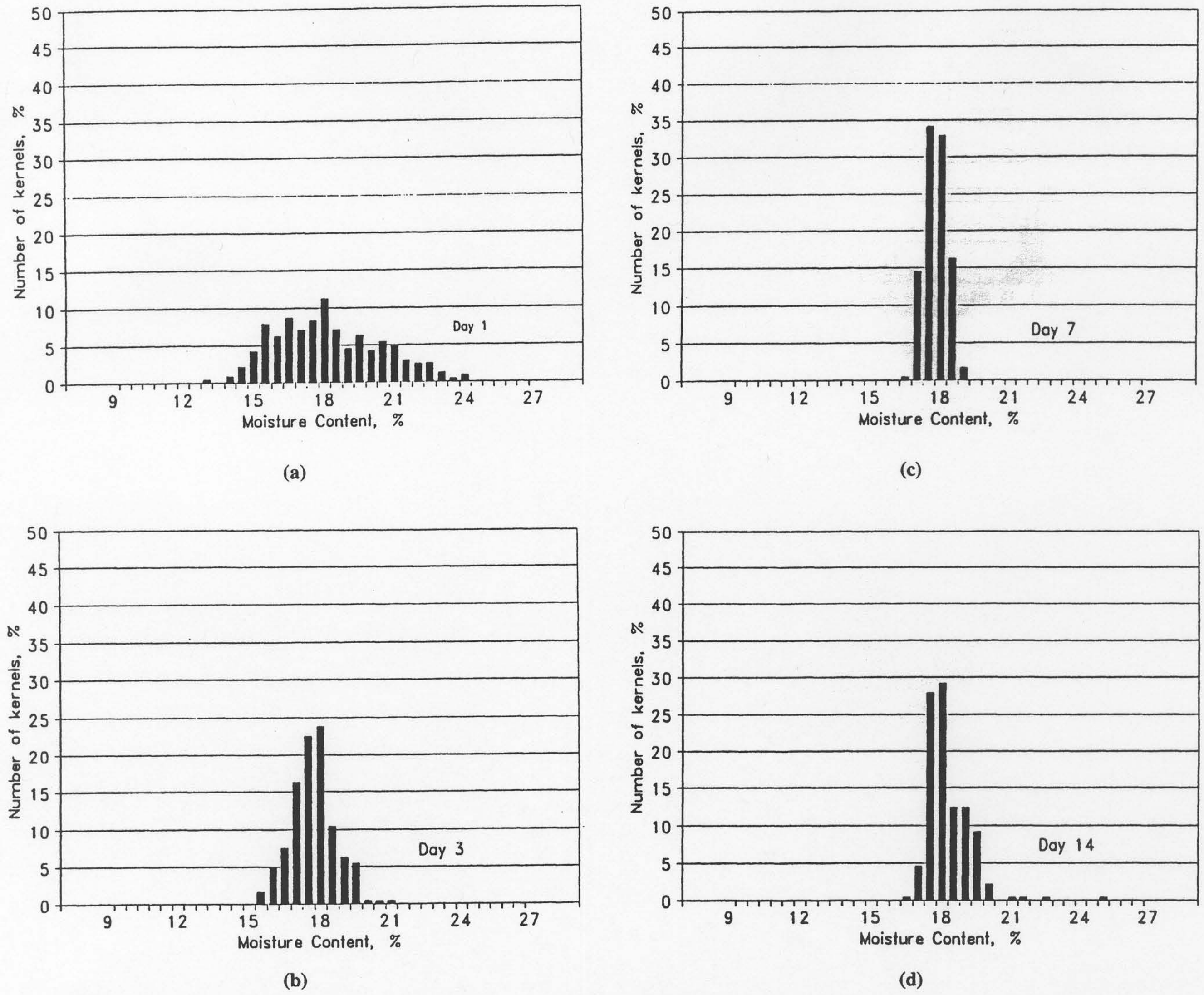

Figure 4–Frequency distributions of single kernel moisture contents for four replications of 60 kernels of corn at 10% and 29% blended to 18% MC based on the single kernel oven method for days 1, 3, 7, and 14.

storage jar upside down and over 10 times. To ensure continued sample blending, the storage jars were turned upside down and over 10 times on four occasions per day.

Moisture Determination

Single kernel moisture measurements using the single kernel oven method, Shizuoka Seiki single kernel moisture meter, and the Seedburo single kernel moisture meter were obtained using 60 randomly drawn kernels for each of four replicates. Moisture readings were taken at days 0, 1, 3, 7, 9, and 14 for all moisture determination methods, except for the single kernel oven method where days 0 and 9 were not taken.

Procedure used for the single kernel oven method was based on the moisture content determination used for bulk moisture samples (ASAE, 1994). Individual kernels in glass vials were weighed using a Mettler Model AE-240 balance (0.000 1 g sensitivity), then placed in a 103°C oven for 72 h. After 72 h, the vials were immediately stoppered and allowed to cool in a desiccator. The final kernel weight was determined using the Mettler balance. The balance was interfaced to a PC microcomputer to aid in weight recording and moisture calculation. Individual kernel moisture contents were calculated from the weight loss using a Quattro Pro spreadsheet with the acquired data.

Single kernel moistures were determined using a Shizuoka Seiki Model CTR-160A single kernel moisture meter and a Seedburo Model P-100 Version 3.2 single kernel moisture meter. The meters determine electrical resistance of individual kernels of grain as the kernels are crushed between two rotating rollers. These meters have the capability of giving a printed output, which included single kernel MC, average MC, standard deviation of single kernel MC and a histogram showing the frequency distribution of single kernel MC. Additionally, the Seiki moisture meter was interfaced to a PC microcomputer for data acquisition. The Seiki moisture meter was operated with the temperature compensation switch on and the roller electrode gap setting at 3 mm.

Fungal Growth Determination

The amount of fungal growth was obtained by visual observation of the corn kernels. A scale of 1 to 4 was used

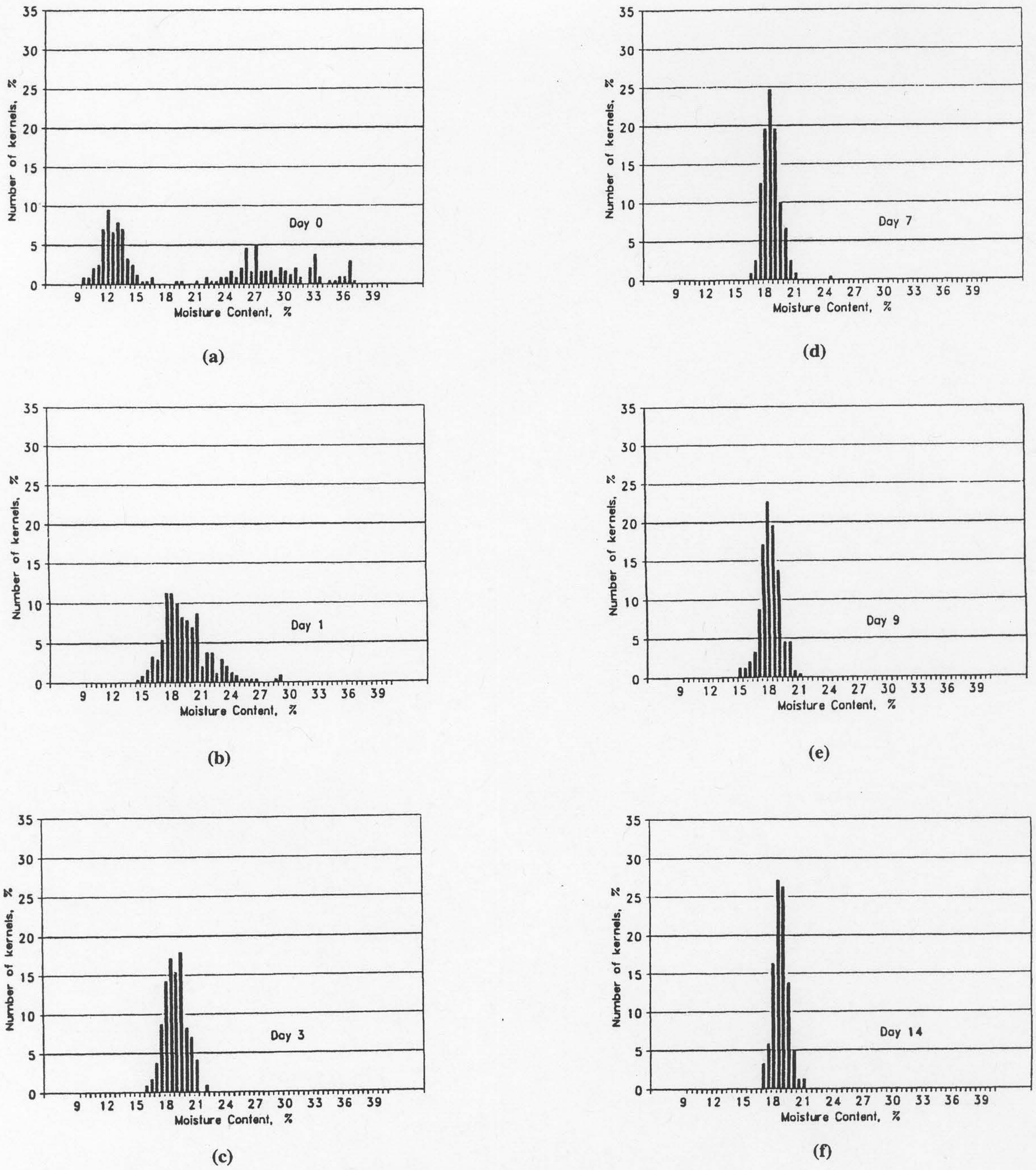

Figure 5–Frequency distributions of single kernel moisture contents for four replications of 60 kernels of corn at 10% and 29% MC blended to 18% MC based on the Seiki single kernel moisture tester for days 0, 1, 3, 7, 9, and 14.

to rate the extent of fungal growth, where: 1 referred to no fungal growth; 2 represented some fungal growth; 3 represented considerable fungal growth; and 4 represented extensive visible fungal growth. Observations were made once per day for days 0 to 14.

Statistical Analysis

Mean moisture contents and standard deviations for the three single kernel moisture determination methods were compared using an analysis of variance (SAS, 1990). All statistical tests were performed at the 0.05 probability level. The single kernel oven method was used as the control. Comparison of mean MC, standard deviation, and rated fungal contamination of Samples A and B were performed using an appropriate F-test (SAS, 1990).

Results and Discussion

Comparison of the Single Kernel Moisture Determination Methods

The moisture contents for days 1, 3, 7, and 14 were used to compare the performance of the Seiki and Seedburo moisture meters with the single kernel oven method (figs. 1, 2, and 3). Each histogram represents 60 kernels times four replications or 240 total kernels. Moisture contents are expressed in 0.5% point increments. For the 18% MC corn dried directly from 29%, the MC readings of the three single

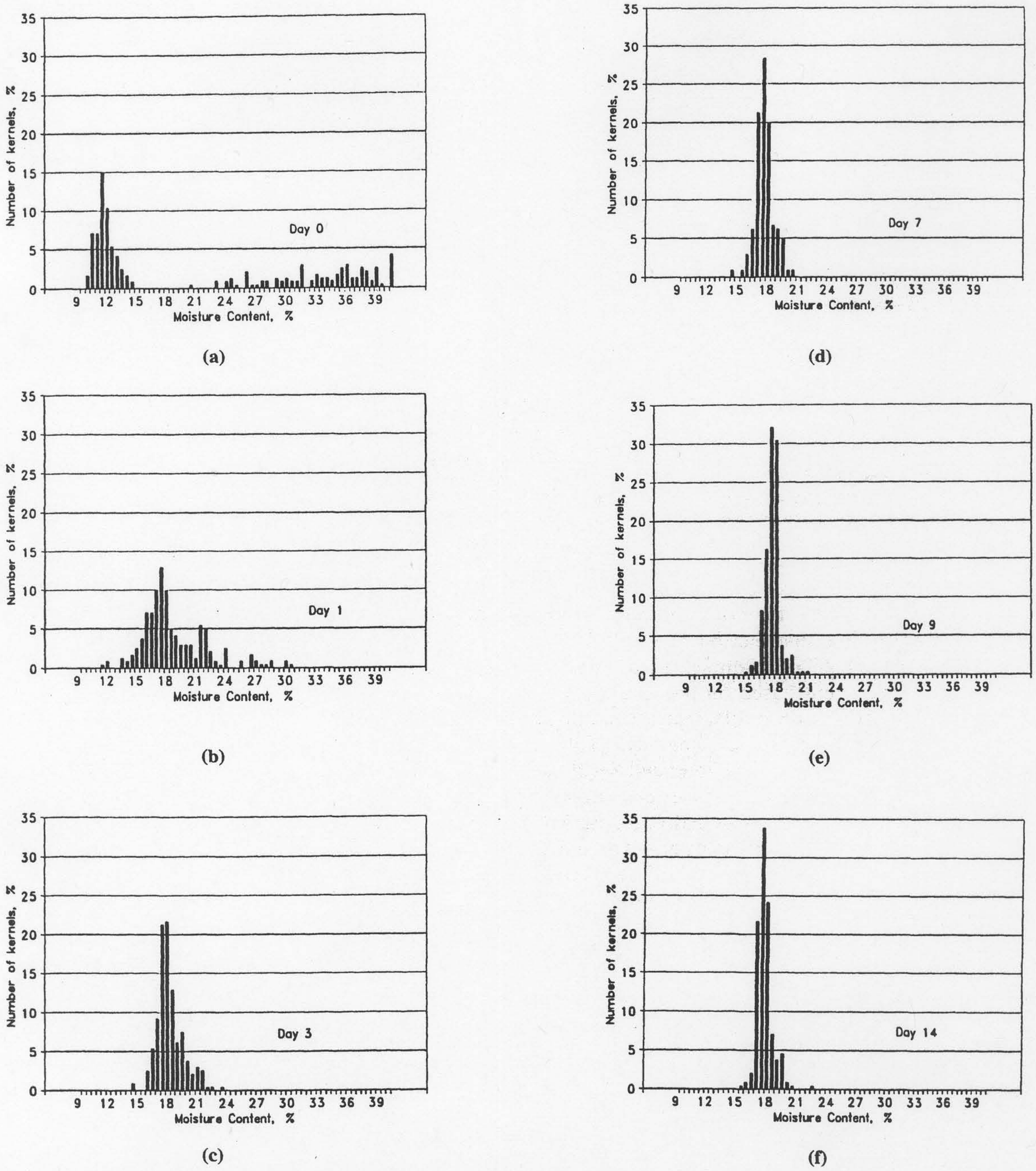

Figure 6–Frequency distributions of single kernel moisture contents for four replications of 60 kernels of corn at 10% and 29% MC blended to 18% MC based on the Seedburo single kernel moisture tester for days 0, 1, 3, 7, 9 and 14.

kernel MC determination methods were not significantly different at the 0.05 level. This shows the acceptability of the two moisture meters for measuring single kernel moisture content for corn dried directly to 18%.

For corn blended to 18% MC corn, the Seiki and Seedburo single kernel moisture meters gave significantly higher moisture readings than the single kernel oven method at day 1, but were not significantly different at days 3, 7, and 14 (figs. 4, 5, and 6). The higher MC reading during day 1 may be due to the tendency for the moisture meters to discard low MC kernels. This occurrence was clearly observed when the 10% moisture corn was tested for single kernel MC. The majority of the 10% MC kernels were simply crushed by the rollers but no reading was recorded. The Seiki moisture meter, however, rejected more kernels for low MC determination than the Seedburo moisture meter. Considering that the equilibration of the 10% and 29% MC samples was not completed by day 1, some kernels may also have been rejected by both moisture meters on day 1 because of low kernel MC.

Comparison of Variation in Moistures of Blended and Dried 18% Corn

The frequency distributions of single kernels dried to 18% and blended to 18% MC for the three moisture determination methods are shown in figures 1 to 6. Thus, while the corn samples had a mean of 18%, the individual kernels had a moisture range of 14 to 20% for the corn

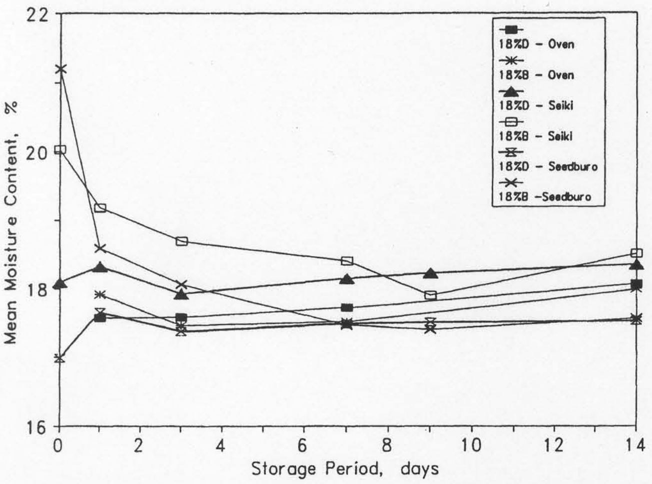

Figure 7–Mean moisture contents of corn dried to 18% (D) and corn blended to 18% MC (B) based on Seiki and Seedburo single kernel moisture testers and single kernel oven tests for different storage periods.

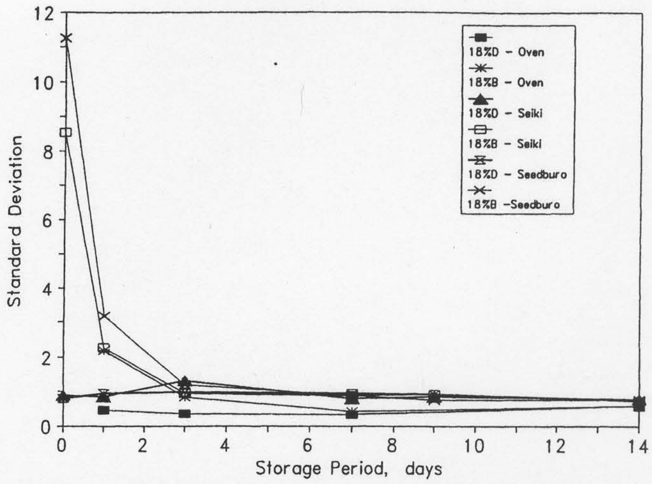

Figure 8–Standard deviations for moisture contents of corn dried to 18% (D) and corn blended to 18% MC (B) based on Seiki and Seedburo single kernel moisture testers and of single kernel oven tests for different storage periods.

dried to 18% and 9 to 40% for the corn blended to 18%. The differences between the distribution of single kernel moistures for the dried and blended samples are evident.

The mean moisture content based on the single kernel oven method was not significantly different for the dried and the blended corn for any of the sampling days (days 1, 3, 7, and 14), as shown in figure 7. The Seiki and Seedburo single kernel moisture meters, however, showed significantly higher mean MC for blended (B) 18% MC corn compared to dried (D) 18% MC corn at day 0 and 1. The same pattern of results was found for the single kernel oven method for days 3, 7, 9, and 14. As noted earlier, this difference may be attributed to operational characteristics of the meters in that kernels were not processed by the meters if the kernel MC was below a threshold level. From day 3 on and after some moisture equilibration, fewer kernels were rejected by the meters.

The standard deviations of the single kernel moisture contents are presented in figure 8. Standard deviations decreased over time for both dried (D) and blended (B) 18% MC corn samples. For the dried 18% MC corn, the standard deviation was not significantly different among moisture determination methods and was consistently low throughout the 14 day observation period. For the blended 18% MC corn sample, the standard deviation for day 0 for both moisture meters and day 1 for the three MC determination methods were significantly higher than for days 3, 7, 9, and 14. This showed that at day 3, the blended sample had equilibrated to a level that was not significantly different from that of the dried 18% corn. At this time, separation of corn dried to 18% from corn blended to 18% MC would be difficult. At days 0 and 1, such a differentiation could have been made.

Fungal Growth in Blended and Dried 18% Corn

Table 1 summarizes the results on fungal growth in the corn samples over a 14-day period at 24 to 26°C. The 10% MC corn did not show any sign of fungal growth during the 14 days. The 29% MC corn, showed some fungal growth starting from day 1; considerable fungal growth on day 2 and had extremely high fungal growth from days 3 to 14.

Table 1. Visual condition of corn dried to 18%, blended to 18%, dried to 10%, and wet 29% corn using a 1- 4 fungal growth scale; values shown are the means of four replications

Period of Storage (days)	Dried 18%	Blended 18%	Dried 10%	Wet 29%
0	1	1	1	1
1	1	1	1	2
2	1	1	1	3
3	1	1.75	1	4
4	1.75	2	1	4
5	2	2	1	4
6	2	2	1	4
7	2	2	1	4
8	2	2	1	4
9	2	2.5	1	4
10	2.5	2.75	1	4
11	3	3	1	4
12	3	3	1	4
13	3	3	1	4
14	3	3	1	4

Fungal growth scale rating is: 1 = negligible or no fungal growth; 2 = some fungal growth; 3 = considerable fungal growth; and 4 = extensive visible fungal growth.

The blended 18% MC corn had no fungal growth for days 0 to 2. The blended 18% MC corn showed some fungal growth on day 3, about one day earlier than the corn dried to 18% MC. Next, the blended 18% MC corn showed some fungal growth from days 3 to 8 and had considerable fungal growth on day 9, again about one day earlier than the corn dried to 18% moisture content.

The dried 18% MC corn sample had no fungal growth for days 0 to 3; it showed some fungal growth on day 4 and had considerable fungal growth from days 10 to 14. These results provide an indication of the safe storage period for 18% moisture corn at 24 to 26°C for both dried and blended procedures. Fungal growth on the blended corn was visible about one day sooner than for the dried corn.

Summary and Conclusions

This study was conducted to compare three single kernel moisture determination methods: single kernel oven, the Seiki single kernel moisture meter, and the Seedburo single kernel moisture meter for determining single kernel moisture contents of blended and dried 18% MC corn. The study also determined the rate of fungal growth in the dried and blended 18% corn samples. The following conclusions were drawn from this study:

The three, single kernel, moisture determination methods did not differ significantly for dried 18% MC corn and for blended 18% MC corn at days 3, 7, and 14. The Seiki and Seedburo single kernel moisture meters gave significantly higher moisture readings than the single kernel oven method for the blended 18% MC corn at day 1, when moisture equilibration had not yet been achieved.

The mean moisture contents of dried and blended 18% moisture corn based on the single kernel oven method were not significantly different for all sampling days (days 1, 3, 7, and 14). Mean moisture contents of blended 18% moisture corn using the two moisture meters were significantly higher than that of the dried 18% MC corn at days 0 and 1. Mean moisture contents of blended 18% MC corn measured using the two moisture meters were not significantly different at days 3, 7, 9, and 14 than the dried 18% moisture corn.

The standard deviations of moisture content decreased over time for both dried and blended 18% MC corn samples. For the dried 18% MC corn, the standard deviation was consistently low throughout the 14 day observation period. For the blended 18% MC corn sample, the standard deviation for days 0 and 1 was significantly higher than for days 3, 7, 9, and 14; moisture equilibration was attained by day 3.

Evidence of fungal growth was observed to be one day sooner for corn blended to 18% (day 3) than for the corn dried to 18% MC (day 4).

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