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Testing of Handheld Grain Moisture Meters on Shelled and Whole Pod Peanuts

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Abstract. *For peanut yield monitoring it has been demonstrated that determination of peanut moisture content may be useful in reducing yield prediction error. There are no commercially available technologies that provide accurate means of measuring moisture content of whole pod peanuts. In this study, two hand held grain moisture meters were evaluated for use in determination of shelled and whole pod peanut moisture content. The meter readings were compared to oven-dried moisture contents using ASAE S410.2. Whole pod moisture contents were measured on 38 samples of virginia and 10 samples of runner type peanuts using a Dickey John M3G handheld moisture meter. A regression model was developed to adjust the meter readings as a function of the oven dried moisture contents. The results from the whole pod moisture tests demonstrated an average absolute prediction error of 1.9 %MC, or 10.3% average absolute error. Shelled moisture contents were measured on 31 samples of virginia type peanuts using a Dickey John mini GAC plus grain moisture tester and a regression model was developed as described above. The results from the shelled moisture tests demonstrated an average absolute prediction error of 1.3 %MC, or 7.5% average absolute error. The kernel moisture samples were subsamples of larger samples for which oven dried moisture whole pod content was also determined. This allowed comparison of whole pod to kernel moisture content for the 31 samples. The results of the whole pod tests are suggestive that dielectric methods already used for determining grain moisture content may be viable for on-the-go non-destructive moisture determination on peanut combines, but that the accuracy will be less than that experienced when using the same devices for measuring grain moisture.*

Keywords. *Peanut, precision agriculture, kernel moisture, pod moisture, handheld grain moisture meter*

Introduction

For yield monitoring technology to be most successful for peanuts an accurate means of measuring moisture content of in-shell peanuts must be developed. Currently there are no accurate “real-time” methods to acquire whole pod moisture in peanuts. One conventional method for determining whole pod moisture is the oven drying method (ASABE Standards, 2010). This method requires that a sample of peanuts be taken and weighed in the field or shortly after being taken from the field. The sample is then dried for a length of time variably dependent on initial moisture content and sample size. Drying times too short do not vaporize all of the moisture and drying times too long result in volatilization of oils. Once the sample has been removed from the oven it is weighed and the field wet weight compared to that of the dried weight. This process is time consuming and cannot be applied to yield monitors that need near real-time moisture for on-the go correction of the recorded yield data. The same challenges have been mentioned and addressed in research in peanut drying applications (Lewis et al., 2013). It is possible to post-process calibrate the yield monitor data after the traditional moisture method is complete but this is impractical and creates more opportunities for human error.

There are however on the go moisture meters for grain crops such as corn, soybeans, and wheat. These moisture meters are currently incorporated into modern grain combines and play an integral part of the yield monitoring systems of these machines. Not correcting for moisture content can result in substantial inaccuracies in predicting dry weight yields when the harvester is used in different fields where moisture contents vary. Peanut moisture contents from field to field are often more variable than those for grain, due to the two stage harvest where peanuts are first windrowed in order to partially dry in the sun prior to being combined. Length of time between digging and combining, as well as weather conditions experienced in that time period play a large role in controlling in-windrow peanut drying rates. Evidence was presented in Porter et al. (2013) suggesting that inclusion of moisture content as a regressor in peanut mass flow prediction with an AgLeader cotton yield monitor (AgLeader Technology, Ames, Iowa) could substantially improve the yield prediction error. In Oklahoma data, moisture content inclusion improved load weight prediction error from 3.1% to 2.1% and in South Carolina data, moisture content inclusion improved load weigh prediction error from 6.0% to 3.3%.

Besides built in moisture meters in yield monitoring systems there are also commercially available handheld meters for use in grains such as those supplied by Dickey-John (Auburn, Ill.), and Agratronix (Streetsboro, Ohio). Other crops such as forages and hay also have handheld moisture meters available such as the Delmhorst F2000 Hay Moisture Meter (Delmhorst Instrument Company, Towaco, N.J.).

Some research has been conducted using different technologies to attempt to detect the whole pod moisture content of peanuts. Studies (Kandala et al., 2008; 2010; Trabelsi and Nelson, 2010) have tested the ability of sensors to detect in shell peanut moisture content in laboratory settings. Parallel plate and near inferred spectroscopy technologies have been evaluated for use in peanuts by Kandala et al. (2008, 2010) and have shown promise in the laboratory setting. Kandala et al. (2008) stated that their parallel plate moisture sensor was able to obtain a 1% prediction error when compared to the oven dried moisture content in 93% of his samples. The moisture contents of this study were between 6 and 23% which is encompasses the range expected in harvested peanuts and stored peanuts. Kandala et al. (2010) stated that their “Non Destructive Near Infrared Reflectance Spectroscopy” machine with proper calibration was able to closely identify moisture contents for in shell peanuts. Problems indicated by this study are that peanuts do not have a smooth surface and careful calibrations must be made to account for the light reflectance on the rough surface.

Trabelsi and Nelson (2010) developed algorithms and calibrations for using microwave sensors in determining moisture contents of in shell peanuts. A standard error of 0.9% was observed when using the calibrations developed with peanuts. In more recent study conducted within USDA ARS, researchers were able to successfully use a microwave moisture sensor to determine kernel moisture content and automate a drying system (Lewis et al., 2013). Results from this study showed no significant differences in sensed moisture content and oven-dried moisture content.

Research at the Clemson University Edisto Research and Education Center in 2012 and 2014 was conducted to determine the feasibility of using commercially available handheld grain moisture meters for in-shell and kernel moisture measurement of peanuts. The objectives of this study were to quantify the accuracy of these sensors for peanut and to identify a relationship between kernel moisture content and whole pod moisture content.

Methods and Materials

Whole Pod Moisture

Harvested peanuts used for this portion of the study were collected from the Clemson University Edisto Research and Education Center in Blackville, South Carolina. The peanuts were virginia and runner type from three different fields of the research center with a total of 48 samples collected and tested. All peanuts used for this study were harvested with a four row Bush Hog 9004 (Bigham Brothers, Inc., Lubbock, Texas) pull-type peanut combine. Drying and post-harvest evaluation was conducted at McAdams Hall of Clemson University. The drying temperature for the study was 130 degrees centigrade.

The harvested peanuts were dumped into a wagon where five samples were taken, one from each corner of the dumped load and one from the center. These samples were bagged with field weights recorded using an electronic scale. A Dickey John (Auburn, Ill.) model M3G handheld moisture meter handheld moisture meter, which is labeled for use in grains was then used to obtain estimated whole pod moisture content. This is a dielectric meter that measures the dielectric constant of the moisture in the grain (Lee D. G. 2006).

The moisture meter was used on the soybean setting as this was the only setting of the four crop types that would give moisture readings for whole pod peanuts consistently. The other three settings would sometimes respond with an error message. Three separate readings of the same sample were conducted to ensure that the moisture meter was giving a stable reading for the sample. Care was taken to remove foreign matter i.e. sticks, stems, rocks before predicting the moisture content with the moisture meter. An average of the three moisture meter readings per sample was used as the moisture meter's prediction of the moisture content for the sample. Each sample was dried according to the ASABE peanut moisture measurement standard (ASABE Standards, 2010) for determination of moisture content as percent, wet basis. Because handheld meter readings were conducted in the soybean setting, meter readings were corrected by regressing them against oven-dried moisture contents using linear regression models developed in Microsoft Excel.

Kernel Moisture

Peanuts used in this portion of the study were virginia type and samples for moisture analysis were collected with a two row research plot combine (Kirk et al., 2012). Each sample was divided into two subsamples, one of which was oven dried to determine whole pod moisture content and one of which was shelled for measurement in a handheld moisture meter and subsequent oven drying to determine kernel moisture content. Peanuts were shelled in the field at the time of harvest using a custom-fabricated, crank-operated peanut sheller and kernels were separated from hulls using a custom-fabricated seed cleaner (fig. 1). Cleaned kernels were then measured in a Dickey John (Auburn, Ill.) mini GAC plus grain moisture tester on the soybean setting, a peanut setting was not available on this model. Immediately after taking the moisture reading with the handheld meter, field weights were measured and bagged for subsequent drying. Each whole pod and kernel sample was dried according to the ASABE peanut moisture measurement standard (ASABE Standards, 2010) for determination of moisture content as percent, wet basis. Because handheld meter readings were conducted in the soybean setting, meter readings were corrected by regressing them against oven-dried moisture contents using linear regression models developed in Microsoft Excel.

Figure 1. Students operating peanut sheller and seed cleaner in the field for use in measurement of kernel moisture content.

Results and Discussion

Whole Pod Moisture

Figure 2(a) shows a plot of the oven dried whole pod moisture contents as a function of the model M3G moisture meter's predictions. The mini GAC plus grain moisture tester would not generate readings for whole pod samples, so direct comparisons of the two units for whole pod moisture could not be made. As there was no peanut setting for the moisture meter a linear regression (eq. 1) was developed to correct the meter readings to the actual moisture content of the oven dry method.

$$MC_1 = 0.902 \cdot MC_0 + 1.03 \quad (1)$$

where
MC_1 = corrected meter moisture content (%, w.b.)
MC_0 = uncorrected meter moisture content (%, w.b.)

Oven dried moisture contents as a function of corrected meter measurements are shown in figure 2(b). Prior to application of the regression model, average error of meter predictions was 2.13%, w.b., or 12.7% absolute error. After application of the regression, average error of meter predictions was 1.99%, w.b., or 11.4% absolute error. Approximately half of the corrected moisture meter predictions were within 1.5%, w.b. of the measured moisture contents. The Dickey-John operations and field handling instructions for the meter state that the meter has a 1% resolution when predicting the grains moisture content (Dickey-John). Three quarters of the corrected meter measurements were within 3%, w.b. of the oven-dried moisture content; and for two of the 48 samples the corrected meter measurement was more than 5%, w.b. different from the oven-dried moisture content.

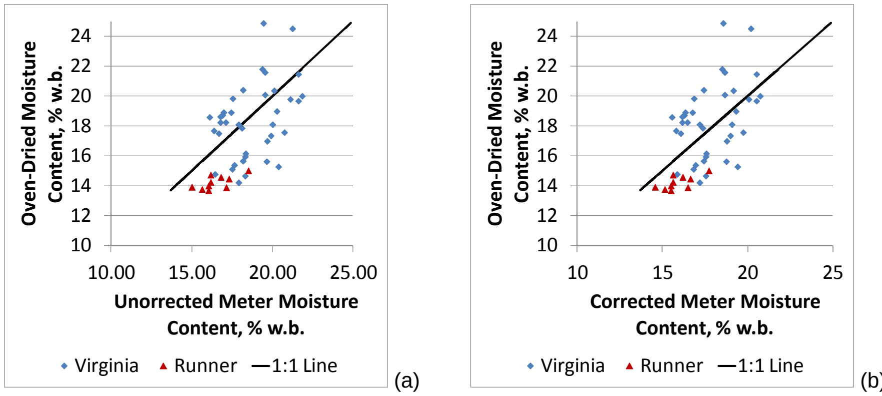


Figure 2. Whole pod moisture content: (a) Oven dried vs. meter measurement and (b) oven dried vs. corrected meter measurement. In both charts, the solid line indicates a 1:1 relationship.

Moisture prediction error for the corrected meter measurements as a function of oven-dried moisture content is shown in figure 3. The points above the x-axis are over-predictions; it is likely that over-predictions generally result from peanuts with a relatively high hull moisture content compared to the kernel moisture content. This high hull moisture content is possibly attributed to dew or rainfall since digging. It is also possible that the soil type in which the peanuts are planted could affect the moisture content on the hulls, especially if soil remains attached to the pods. The under-predictions, or those values below the x-axis are likely peanuts that are high in kernel moisture compared to the hull moisture content. This high hull moisture content can be attributed to a shortened drying time in the field before combining or to the maturity of the peanuts. Distinct hull and kernel moisture contents were not measured as a part of this project to confirm these hypotheses. The over-predictions were generally associated with the lower oven-dried whole pod moisture contents, whereas the under-predictions were generally associated with the higher moisture contents.

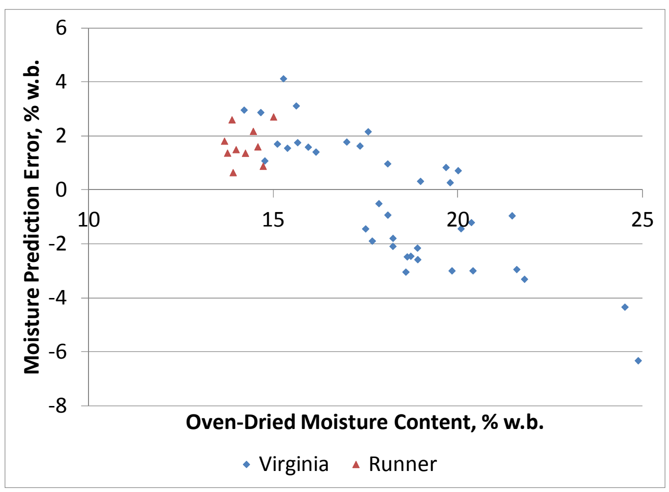


Figure 3. Whole pod moisture prediction error for corrected meter measurements vs. oven-dried moisture content.

A distinct regression model (eq. 2) was developed to correct the meter readings of the virginia type peanuts, independent of the runner type peanuts, which reduced the measurement error to 1.88%, w.b. or 10.5% average absolute error.

$$MC_1 = 0.591 \cdot MC_0 + 7.30 \qquad (2)$$

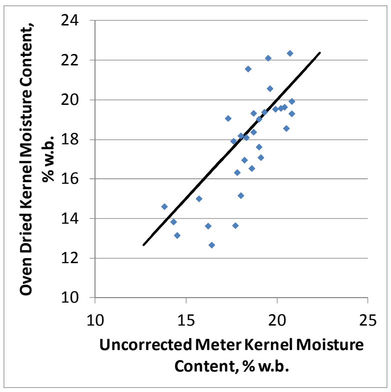
Due to the small number of samples (N = 10) and small range of oven-dried moisture contents (13.4 – 15.0%, w.b.) for the runner type samples, an independent regression model for this type was not developed.

Kernel Moisture

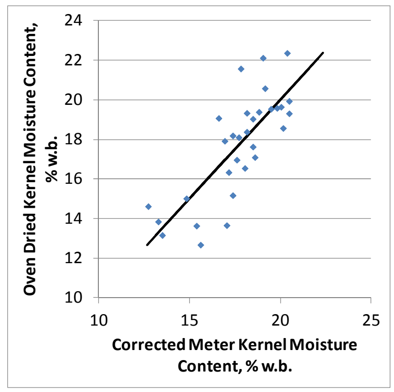
Kernel moisture measurements using the mini GAC plus grain moisture tester were more accurate than those of the whole pod measurements using the model M3G moisture meter. Kernel moisture samples were not measured with the model M3G moisture meter so comparisons between the units for kernel moisture cannot be made; the objectives of this study were to characterize accuracy of the moisture meters for peanut and not to compare the accuracy of the units to one another. As discussed in the previous section, the moisture meter's kernel moisture readings were regressed against the oven-dried kernel moisture contents to build eq. 3 for correction of the meter readings.

$$MC_1 = 1.109 \cdot MC_0 - 2.58 \tag{3}$$

Figure 4(a) shows the oven dried kernel moisture contents as a function of the uncorrected meter readings. Application of eq. 3 to the uncorrected meter readings reveals the relationship shown in figure 4(b). Prior to correction of the meter readings and as compared to the oven-dried kernel samples, the average error was 1.4%, w.b. or 8.3% average absolute error across the 31 samples. After correcting the meter readings, the error was 1.3%, w.b. or 7.5% average absolute error. Of the 31 samples, 19 of the corrected meter readings were within 1.5%, w.b. of the oven-dried kernel moisture content, 28 samples were within 3%, w.b., and the maximum absolute error of any sample was 3.7%, w.b.



(a)



(b)

Figure 4. Kernel moisture content: (a) Oven dried vs. meter measurement and (b) oven dried vs. corrected meter measurement. In both charts, the solid line indicates a 1:1 relationship.

Analysis of corrected meter moisture prediction error as a function of oven-dried kernel moisture content (fig. 5) shows a similar trend to what was revealed in figure 3 for the whole pod samples, with over-prediction generally occurring for the lower moisture content samples and under-prediction generally occurring for the higher moisture content samples. The hypothetical argument provided for the whole pod data is not relevant here, surface moisture contents relative to internal moisture contents may be playing a role here as well.

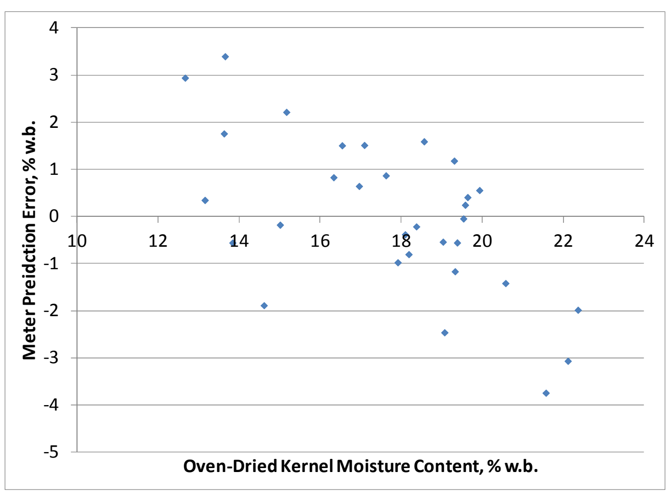


Figure 5. Kernel moisture prediction error for corrected meter measurements vs. oven-dried moisture content.

Kernel Moisture vs. Whole Pod Moisture

As a part of this study, oven dried moisture contents of whole pod subsamples were compared to those of kernel subsamples taken from the same primary sample in an effort to evaluate the ability of predicting kernel moisture as a function of whole pod moisture or vice versa. In the context of this study, such a relationship might be useful, for example, if whole pod moisture content be more accurately predicted by measuring kernel moisture content with a handheld sensor and then converting to whole pod moisture content. Figure 6 shows the relationship found in this study between whole pod moisture content and kernel moisture content.

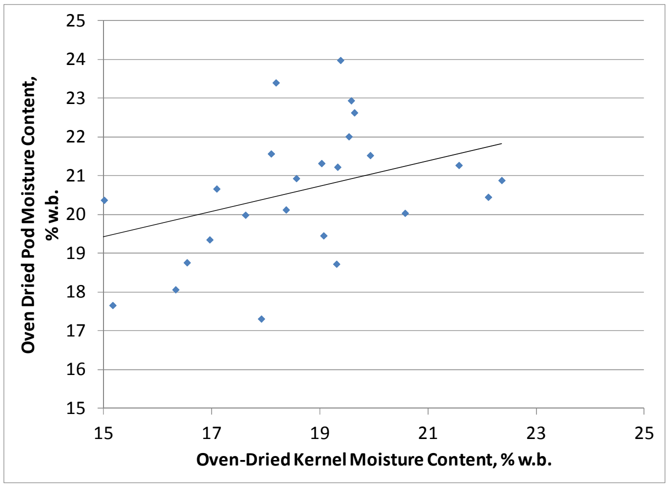


Figure 6. Relationship between oven dried whole pod moisture content and oven dried kernel moisture content.

Based on the data in this study, prediction of whole pod moisture content as a function of kernel moisture content is given in eq. 4 and prediction of kernel moisture content as a function of whole pod moisture content is given in eq. 5. Average error of predicting whole pod moisture content from kernel moisture content was 1.1%, w.b. or 5.6% average absolute error; 23 of the 31 estimates were within 1.5%, w.b. Average error of predicting kernel moisture content from whole pod moisture content was 1.8%, w.b. or 10.5% average absolute error; 16 of the 31 samples were within 1.5%, w.b.

$$MC_p = 0.326 \cdot MC_k + 14.55 \quad (4)$$

$$MC_k = 0.826 \cdot MC_p + 0.93 \quad (5)$$

where
MC_p = whole pod moisture content (%, w.b.)
MC_k = kernel moisture content (%, w.b.)

Conclusion

Measurements and sensor responses of physical properties of harvested peanuts are highly variable; there are factors other than the crop itself that can skew results. Factors such as dirt, dust, stems, and other foreign material that are common in the harvesting process may drastically affect predicted moisture contents. A combine that is not properly set up can be passing more stems and foreign material through the combine and into the basket than a combine that is properly set up. This could adversely affect a moisture meter's predictions if an on-the-go sensor is installed on the machine. Careful and consistent machine setup will likely prove to be essential for a moisture meter to operate effectively on a peanut combine.

The authors believe that the technology employed in the handheld units could not work for on-the-go peanut moisture estimation to be used in mass flow correction. While not as accurate as the methods described in Kandala et al. (2008; 2010), Lewis et al. (2013), and Trabelsi and Nelson (2010), some knowledge of moisture content would likely be better than no knowledge of moisture content in mass flow correction; almost all of the samples fell under 5%, w.b. error for in-shell peanuts. It may also be possible to use technology similar to that described by Kandala et al. (2008; 2010), Lewis et al. (2013), and Trabelsi and Nelson (2010) for on-the-go peanut combine moisture sensing, although within this cost and robustness must be considered relative to the application.

More information must be obtained to clearly determine the validity of applying the Dickey-John handheld moisture meter technology for use with whole pod peanuts. While it seems that the handheld meter can give the user a rough idea of the moisture of his crop it is not a very reliable method to accurately measure whole pod moisture in peanuts. The largest percentage of the samples run through the Dickey-John moisture meter fell under 1.5% moisture content error from the actual moisture content as measured with the oven dry method.

It would be beneficial to test other manufacturer's handheld moisture meters to determine if the results from this study are duplicated in other meters. Collaboration with developers of moisture meters could prove beneficial in development of an in-shell peanut moisture meter, making the raw sensor data available for algorithm development. It may also be useful to perform future work similar to that conducted in the whole pod moisture content portion of this study, but coupled with independent analyses of hull and kernel moisture contents to assess the magnitude of the effects of surface (hull) moisture.

Moisture is a very important component of peanut harvest and it would be beneficial for an on-the-go—whether it be a stand-alone system or a component of a peanut yield monitor—or handheld whole pod moisture meter to be made commercially available to peanut producers. Not only is moisture beneficial to know when used with yield monitoring technology it is also beneficial to know when a producer conveys his crop to the buy point. Further research should be conducted towards development of a suitable handheld and on-the-go moisture sensor for in-shell peanuts.

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References

ASABE Standards. 2010. S410.2: Moisture Measurement—Peanuts. St. Joseph, Mich.: ASABE,

Dickey-John Corporation. M-3G Portable Moisture Tester. “Operation and File Handling Instructions”

Kandala, C., C. L. Butts, and M.C. Lamb. 2008. Moisture Content Determination for In-Shell Peanuts With a Low-Cost Impedance Analyzer and Capacitor Sensor. Trans. ASABE. 51(4):1377-1381.

Kandala, C., J. Sundaram, G. K. Naganathan, and J. Subbiah. 2010. Non Destructive Determination of Peanut Moisture Content Using Near Infrared Reflectance Spectroscopy. ASABE Paper No. 1008520. St Joseph, Mich.: ASABE.

Kirk, K. R., W. M. Porter, W. S. Monfort, Y. J. Han, W. G. Jr. Henderson, and J. Thomas. 2012. Development of a Yield Monitor for Peanut Research Plots. ASABE Paper No. 12-1337625. St Joseph, Mich.: ASABE.

Lewis, M. A., S. Trabelsi, S. O. Nelson. 2013. Evaluation of in-shell kernel moisture content monitoring with a microwave moisture meter during peanut drying. ASABE Paper No. 131618991. St. Joseph, Mich.: ASABE.

Lee D. G. 2006. What do Grain Moisture Meters Measure and How are They Calibrated?. NIST.

Porter, W. M., J. Ward, K. R. Kirk, R. K. Taylor, J. B. Fravel, and C. B. Godsey. 2013. Application of an AgLeader® cotton yield monitor for measuring peanut yield: a multi-state investigation. ASABE Paper No. 131596295. St. Joseph, Mich.: ASABE.

Trabelsi, S., S. O. Nelson. 2010. Microwave moisture sensor for rapid and nondestructive grading of peanuts, In Proc. IEEE Southeast Conf. 57-59. Concord, NC.