PERFORMANCE OF A COMMERCIALLY AVAILABLE MICROWAVE-BASED BALE MOISTURE CONTENT METER

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Abstract

Measuring the moisture content of cotton bales has been a topic of intense interest in the last few years. A non-contact microwave-based bale moisture meter, Vomax 851-B (Vomax Instrumentation through Samuel Jackson, Lubbock, TX) has been commercially available but independent verification of these measurements has not been available. Holly Ridge Gin Company (Holly Ridge, MS) provided access to the commercial meter installed in their facility. For the first phase of study bales were prepared by the Cotton Ginning Research Unit for measurement on the commercial instrument as well as by the oven reference method. The effect of bale orientation and bale packaging was also studied with these samples. In the second phase samples were collected from 50 bales, over 5 days, during the 2007 ginning season. The collected bale samples were tested by the oven reference method for moisture content and those readings were compared to the microwave-based meter readings for moisture content. Bales were tested with a moisture content ranging from 4.2% to 7.2 %, wet basis. The Vomax measurements tracked variation in bale moisture content; however the factory calibration tended to predict higher moisture content than determined by the oven method.

Introduction

Proper control of the moisture content (mc) of lint in bales leaving the gin has always been important. Cotton bales are marketed on a weight-basis so if the lint is dryer than necessary value is lost to the owner of the lint. However, if the mc of the lint is too high the quality of the lint will deteriorate during storage and the lint will arrive at the mill with unacceptably low color. In 2006, the Farm Service Agency defined cotton bales with excessive moisture as those with mc greater than 7.5%, wet basis, at the gin. Therefore it is important for gins to assure themselves that the bale mc is no higher than 7.5%. A non-contact microwave-based meter has been commercially available but independent verification of these measurements has not been available.

Method and Materials

This project was divided into two phases. The first phase involved the production of 12 bales at the Cotton Ginning Research Unit (CGRU) (Stoneville, MS). These 12 bales were produced using two varieties and utilizing different drying schemes in order to produce bales with a range of moisture content. All bales were ginned using a standard sequence of cylinder cleaner, stick machine, cylinder cleaner, extractor-feeder/gin stand, and one saw-type lint cleaner. Six bales were produced each day, with each day dedicated to one variety. The first day produced six bales from Phytogen 480 (PhytoGen Seed Company, Corcoran, CA) and six bales of Stoneville 4892 (Stoneville Pedigree Seed Company, Stoneville, MS) were produced on the second day. The first three bales on the first day were produced with all dryers turned off. The second three bales on the first day were produced with the first dryer set to 100°F and the second burner turned off. On the second day the first three bales were produced with the first burner set to 100°F and the second burner turned off. The second three bales were produced with the first burner set to 250°F and the second burner turned off.

Six lint samples were collected at the lint slide for each bale to allow for moisture content determination by the oven reference method (Shepherd, 1972). Three lint samples were collected at the lint slide for characterization of the fiber properties via HVI (Uster Technologies, Knoxville, TN) and AFIS (Uster Technologies, Charlotte, NC) testing. Three samples of seed cotton were collected for seed cotton moisture content determination before each bale was ginned. Three lint samples were collected at the gin stand, for each bale, to determine moisture content at the gin stand.

The bales were loaded onto a truck, shortly after ginning each day, and transported to a nearby commercial gin where the commercially available non-contact microwave-based moisture meter was installed. The commercial meter used in this study was the Vomax 851-B (Figure 1) unit from Vomax Instrumentation of Australia (Samuel Jackson, Lubbock, TX). The Vomax 851-B scans each bale several thousand times as the bale passes between the antennas of the unit which scan an area approximately 8 inches by 11 inches across the full width of the bale. Each scan of the Vomax takes less than 20 milliseconds (Kelly, 2007). The bales were passed through the meter three times without bale bagging and the moisture content measurement recorded. The bales were then bagged in standard white woven polypropylene bagging (Propex Fabrics Inc., Chattanooga, TN) and sent through the meter three additional times. The moisture content for each pass was recorded. For each of the six runs the bales were oriented in the same direction for each run. Two additional runs were made, one with bagging and one without bagging, in which the bales orientation was reversed to determine if bale orientation affected the moisture content measurement.

Figure 1. Vomax 851-B installed in a commercial gin.

The second phase of the project involved collecting lint samples from 50 bales during the 2007 ginning season. Ten bales per day were sampled on five different days during the ginning season at Holly Ridge Gin Company (Holly Ridge, MS). One lint sample was collected per bale for moisture content determination. The lint sample was collected, immediately before the bale was scanned by the Vomax, at the location of one of the classing samples for each bale and sealed in an airtight canister for transportation to the CGRU for testing. The Vomax reading was recorded as was the bale weight.

Results and Discussion

Phase 1

The seed cotton was sampled prior to ginning to determine the initial seed cotton moisture content (mc). The average mc of the seed cotton as well as HVI and AFIS properties of the ginned lint are shown in Table 1. The two varieties had similar initial mc of the seed cotton but differed in micronaire and maturity.

One of the claims of the Vomax unit is that it is unaffected by bale bagging. The bales were passed through the Vomax sensors three times without bagging and then bagged for three additional passes. The average readings for each bale were identical, with and without bagging (Table 2). The Vomax proved to be consistent; the highest standard deviation for any set of readings was 0.06%. The consistency is likely due to the scanning of each bale several thousand times and reporting the average of those readings. The bales were marked to ensure they were sent through the meter in the same orientation and direction for each of the six passes. However, in handling and orienting the bales the conveyor system on which the meter was mounted was used. This arrangement allowed for several passes of the bales in different orientations to be observed. Although that data is not reported here, there were no differences in readings observed, regardless of the orientation of the bales.

Table 1. Average properties of cotton used in Phase 1.

	Phy 480	**Stv 4892**
Seed Cotton MC (%wb)	9.6	9.3
HVI		
Length (in)	1.11	1.09
Strength (g/tex)	30.3	29.7
Mic	4.3	5.0
Uniformity	82.5	82.6
Rd	71.5	75.8
+b	7.3	9.2
AFIS		
UQL(w)	1.19	1.16
SFC(w)	7.03	6.96
Neps	222	170
SCN	20	12
Maturity Ratio	0.88	0.92

Table 2. Comparison of Vomax readings with and without bale bagging.

Bale	Vomax Reading w/No Bagging		Vomax Reading w/Bagging	
	Average	Std Dev	Average	Std Dev
1	7.9	0.06	7.9	0
2	7.3	0	7.3	0
3	7.3	0.06	7.3	0
4	7.0	0.06	7.0	0
5	6.8	0	6.8	0
6	6.4	0	6.4	0
7	6.9	0	6.9	0
8	6.8	0	6.8	0
9	6.4	0.06	6.4	0.06
10	5.4	0	5.4	0
11	5.3	0	5.3	0
12	5.2	0	5.2	0

Six lint moisture samples were collected at the lint slide before baling each bale, and their mc results averaged for the bale. A comparison of the average reference and the Vomax mc readings is shown in Table 3. The Vomax readings are shown to be more consistent than the oven mc measurements. The lower standard deviation of the Vomax measurements is, again, likely due to the one reading per scan being the average of several thousand scans. The six individual measurements from the oven method represent six individual points within the bale and represent the range in mc that exists throughout the bale. An area of higher or lower mc would be "averaged out" by the Vomax. Figure 2 shows the relatively high correlation, $R^2 = 0.93$ with a corrected standard error of 0.24, of the Vomax readings with the reference method for the first phase of these trials. The Vomax readings were higher then the oven method results in all cases with an average difference of 0.5%.

Table 3. Average moisture contents as measured by two methods for Phase 1.

Bale	Variety	Weight (lbs)	Vomax MC (%wb) Average	Vomax MC (%wb) Std Dev	Oven MC (%wb) Average	Oven MC (%wb) Std Dev	Vomax-Oven Difference
1	PHY 480	539	7.9	0.04	7.2	0.17	0.7
2	PHY 480	500	7.3	0	6.9	0.31	0.4
3	PHY 480	501	7.3	0.04	7.0	0.29	0.3
4	PHY 480	496	7.0	0.04	6.9	0.20	0.1
5	PHY 480	494	6.8	0	6.4	0.11	0.4
6	PHY 480	420	6.4	0	6.5	0.16	-0.1
7	STV 4892	538	6.9	0	6.6	0.11	0.3
8	STV 4892	522	6.8	0	6.3	0.23	0.5
9	STV 4892	507	6.4	0.06	6.0	0.30	0.4
10	STV 4892	485	5.4	0	4.7	0.09	0.7
11	STV 4892	488	5.3	0	4.3	0.08	1.0
12	STV 4892	491	5.2	0	4.2	0.10	1.0
	Mean	498	6.6		6.1		0.5

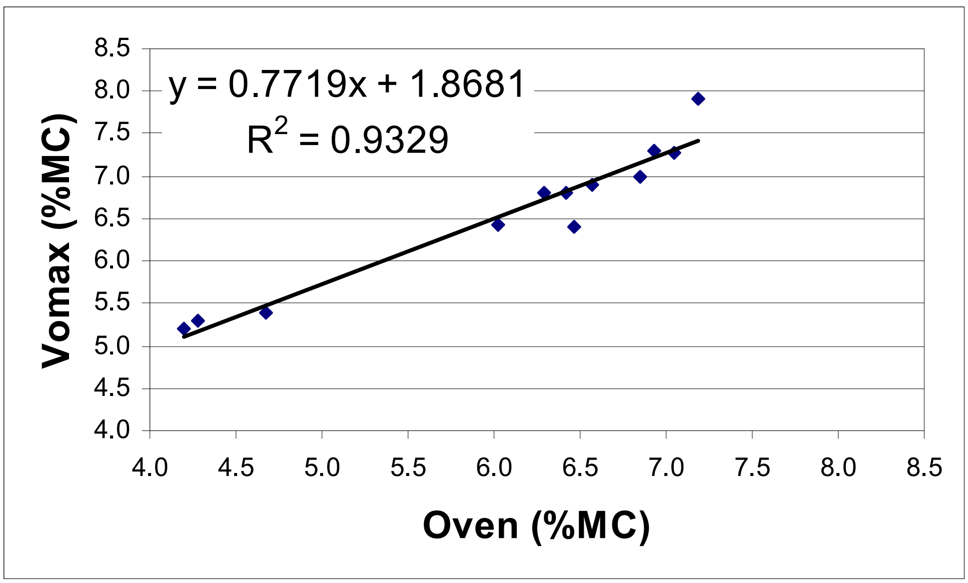

Figure 2. Comparison of Vomax and oven method moisture content readings for Phase 1.

On a few occasions the Vomax sensor was activated by accidental contact with the contact switch which starts the scan. The accidental scans resulted in an error being displayed on the meter, but there was no additional indication of a problem and any bales passed through the meter before clearing the error were not read. This error was not a problem for this work, but may pose a problem for a commercial user. When this error occurred the error was cleared from the instrument and the bale was passed through the meter again to collect a measurement.

Phase 2

Samples were collected at a commercial gin on five separate days throughout October 2007. Ten bales were sampled on each day. The Vomax reading and bale weight were recorded and a sample of lint was collected for oven mc testing. Table 4 shows the average results for each day of sample collection during the second phase of this project. The range of mc measured in the second phase is substantially narrower then the range produced in the first phase. This is not surprising as these samples were collected during the course of commercial ginning. A single sample was collected from each bale during the second phase compared to the six lint samples collected per bale during the initial phase.

Figure 3 shows the correlation of the Vomax readings with the reference method results for all 50 samples in this phase of the project. The correlation, $R^2 = 0.62$ with a corrected standard error of 0.27, is much lower for these 50 commercial bales than for the 12 bales produced by the CGRU. It is possible that the wider range of oven method results is due to having only one sample per bale. The Vomax readings are higher then the oven results for all 50 bales, with an average difference of 1.1%. The effect of the bale weight on the Vomax readings was studied, but no relationship was found to exist. The larger differences between the Vomax and the oven method results in phase 2 may be due to the collection of only one lint sample for oven mc measurement. The scanning of the Vomax would allow for mc variation across the bale to be averaged out.

Table 4. Average results from commercial gin in Phase 2.

Day	Bale Weight (lb)			Vomax MC (%wb)			Oven MC (%wb)		
	High	Low	Avg	High	Low	Avg	High	Low	Avg
1	498	467	477	6.4	6.1	6.2	5.3	4.6	5.0
2	514	472	496	7.0	6.9	7.0	6.1	5.5	5.8
3	503	477	490	6.8	6.5	6.7	5.9	5.5	5.7
4	507	477	489	7.1	6.5	7.0	6.1	5.4	5.9
5	503	445	474	6.7	5.7	6.1	5.7	5.0	5.3

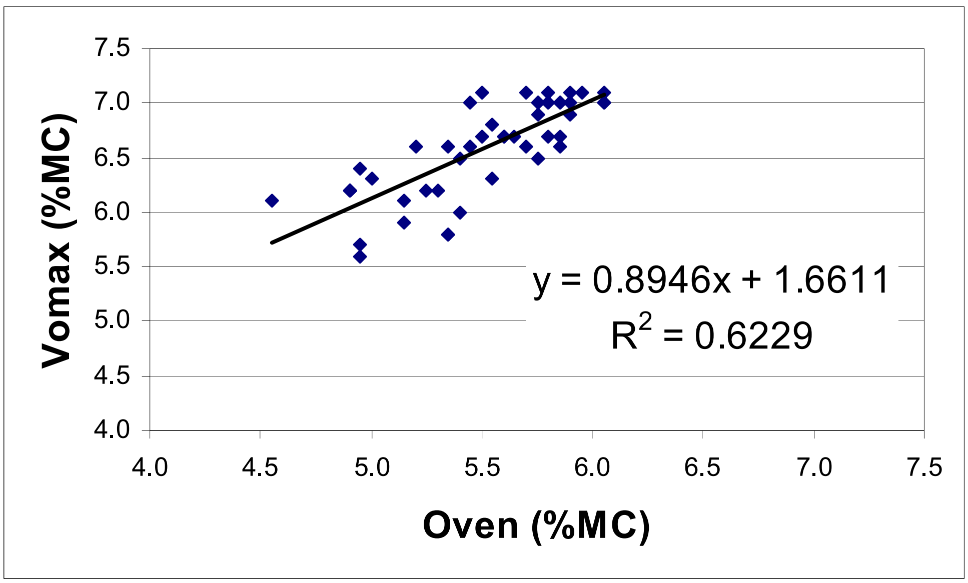

Figure 3. Comparison of Vomax and oven method moisture content readings for Phase 2.

Conclusion

The Vomax 851-B moisture meter was compared to the reference oven method for measuring moisture content of cotton bales in both an idealized setting and a commercial setting. The Vomax mc readings were consistently higher then the mc as measured by the reference oven method. For the first phase of the project, in which the bales had a mc range of 4.2% to 7.2% and the bales were thoroughly sampled for oven mc, the correlation between the Vomax and the oven method was quite high ($R^2 = 0.93$). However when only one mc sample per bale was collected, as in Phase 2, the correlation dropped ($R^2 = 0.62$). The Vomax appears to work well to assist the gin in producing bales of consistent mc, as shown by the small range of mc on individual days of Phase 2. Bale bagging did not have any discernible effect on the performance of the Vomax meter and orientation of the bale did not have any effect on the performance of the Vomax. Commercial gins are not likely to perform a calibration sequence on the instrument, and no calibration sequence is called for by the manufacturer (Kelly 2007). However the meter readings were routinely higher then oven mc by an average of 0.5% for Phase 1 and 1.1% for Phase 2.

Disclaimer

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