ENVIRONMENTAL IMPACTS ON THE MICRONAIRE RESULTS FROM NEAR INFRARED (NIR) INSTRUMENTS

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Abstract

Micronaire is a key quality and processing parameter for cotton fiber. Previous evaluations indicated potential impacts on the Near Infrared (NIR) measurements of micronaire, performed outside of the laboratory, due to measurement environmental conditions (temperature and relative humidity/RH). The extent of the impacts of temperature and RH on fiber moisture and NIR micronaire results were examined on a laboratory, research-grade NIR and portable NIR units. The micronaire results of the portable NIR units were more impacted by fiber conditioned at varying temperatures and RHs compared to the laboratory research NIR unit, providing a rationale for the potential deviations in NIR micronaire results in outside the laboratory micronaire measurements with portable NIR units.

Introduction

Micronaire is a key quality and processing parameter for cotton fiber. (USDA, 2005) Micronaire is an indirect measurement and indicator of the fiber's maturity (degree of secondary wall development) and fineness (linear density) (Wakelyn et. al., 2007). In the U.S., cotton fiber's overall quality is assessed (classed) by the USDA-Agricultural Marketing Service (AMS) using a high volume instrument (HVI). One quality parameter from the HVI is fiber micronaire, which is measured in a tightly controlled and conditioned laboratory by the resistance to airflow of a specified mass of sample under compression. Although the HVI is very accurate and fast, it is a laboratory-only instrument, can be expensive, and requires tightly controlled environmental conditions in the laboratory and trained operators. A technology that has been shown to be a complementary technique for the HVI micronaire measurement is Near Infrared (NIR) spectroscopy. Laboratory NIR techniques have been extensively applied in the fiber, textiles, and textile auxiliary industries (Montalvo and Von Hoven, 2004; Ramey, 1982; Tincher and Luk, 1985; Rodgers and Ghosh, 2008; Fortier et. al., 2012). NIR techniques have been developed that rapidly and accurately monitor fiber micronaire in the laboratory, using bench-top, research grade instruments and hand-held, portable NIR instruments (Montalvo and Von Hoven, 2004; Rodgers et. al., 2010a; Rodgers et. al., 2010b; Liu et. al., 2015). In addition, NIR techniques for monitoring fiber micronaire outside the laboratory (e.g., greenhouse, field) have been developed with portable NIR instruments (Rodgers et. al., 2010c; Zumba et. al., 2016). One concern with the out of laboratory NIR measurements is the impact of environmental conditions and conditioning (temperature/T and relative humidity/RH) on fiber moisture and NIR measured micronaire. A program was implemented to determine the extent of impact of T and RH on fiber moisture and NIR micronaire results.

Material and Methods

A set of 10 wide-range, diverse fiber samples were used for this evaluation (2.4-5.5 micronaire), and the HVI micronaire values at standard conditions (21˚C, 65% RH) were used as the reference micronaire values. The fiber samples were measured conditioned at 13 T-RH combinations (from 15˚C/45% RH to 27˚C/85% RH, as shown in Table I). At each T-RH condition, the fiber sample was measured for fiber moisture content with the Strandberg M400 moisture instrument (Strandberg Engineering Laboratories, Greensboro, NC) and for fiber micronaire with two NIR instruments –one wide spectral range bench-top and one narrow spectral range portable instrument (Figure 1). The instrumental and sampling specifics for the two NIR instruments were as follows:

- Bruker MPA (research grade, bench-top unit; FT-NIR measurement, 1100-2500 nm, rotating cell sampling system; Bruker Optics Inc, Billerica, MA)
- Viavi MicroNIR 1700 (portable unit, Linear Variable Filter/LVF measurement, 908-1676 nm, direct contact sampling system; Viavi Solutions Inc, San Jose, CA)

Two moisture measurements and five NIR measurements were made per sample. Vendor recommended operational procedures and protocols were used. NIR micronaire results were obtained at each T-RH condition using pre-established NIR calibrations for the Bruker and Viavi instruments. The changes in fiber moisture and the changes in

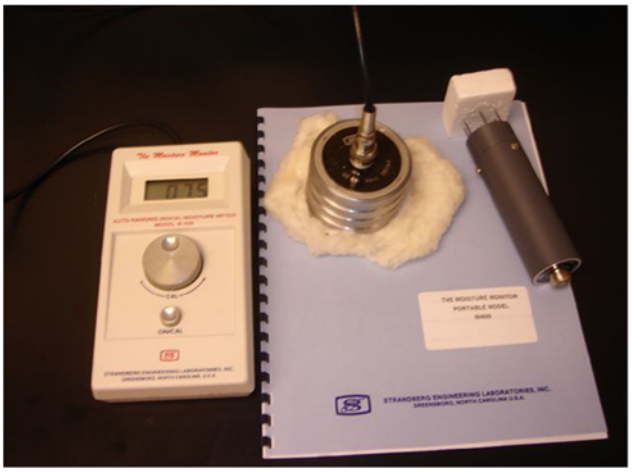
NIR micronaire results as a function of changing T-RH were examined and compared. The higher deviation with changing T-RH, T alone, and RH alone, the greater the impact by that variable on the fiber moisture and NIR micronaire results.

Table I. T and RH conditions/treatments (base is 21˚C and 65% RH)

TREATMENT	T(˚C)	RH (%)
1	15	45
2	15	65
3	18	55
4	18	65
5	21	45
6	21	55
7	**21**	**65**
8	21	75
9	21	85
10	24	65
11	24	75
12	27	65
13	27	85

BRUKER MPA FT-NIR

VIAVI MicroNIR 1700



STRANDBERG M400

Figure 1. NIR and moisture instruments used in the evaluation.

Results and Discussion

A program was implemented to determine the extent of the impact of T and RH on fiber moisture and NIR micronaire results. For both NIR micronaire and Strandberg moisture measurements, the fiber measurements were relatively fast (<30 seconds per sample for the portable instruments), easy to perform, and required no sample preparation.

As observed in Figure 2, variations in T and RH yielded large differences in fiber moisture content (MC), with lower MC at low T and RH (down to an average of approximately 3% MC for all varieties) and higher MC at high T and RH (up to an average of approximately 13% MC for all varieties). For each variety, the fiber MC results were different for the different varieties at a specific T and RH combination, but each variety responded similarly to the change in T and RH condition (as T and RH increase, the fiber MC for all varieties increased). The variations in T and RH resulted in distinct impacts on the NIR micronaire results. The combined T and RH variation impacts on the bench-top MPA unit were much less compared to the portable MicroNIR 1700 instrument, and a greater number of NIR micronaire outliers were observed for the portable NIR instrument. The T and RH impact on the portable NIR instrument was more pronounced at higher T and RH combinations. In general, the higher the T and RH combination (and resulting fiber moisture), the lower the NIR micronaire result.

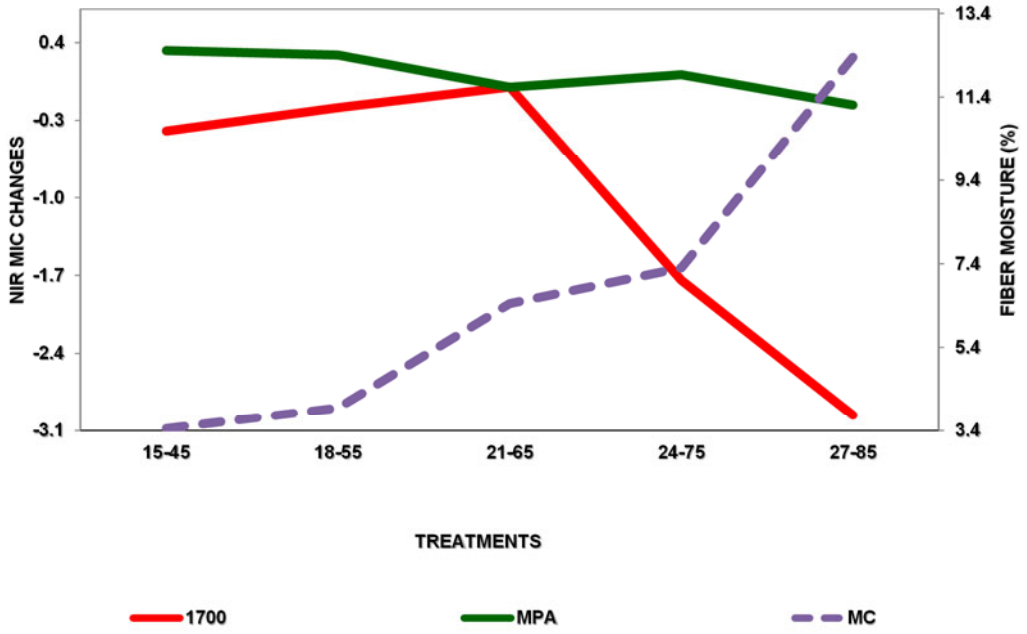


Figure 2. Combined T and RH impacts on NIR micronaire (MPA, MicroNIR 1700) and fiber moisture (M400) results

The combined T and RH environmental condition impacts were very distinct on fiber MC and the NIR micronaire results, but the question remained—which variable was the primary impact on the results? The NIR micronaire results and fiber MC were analyzed for RH only and T only impacts. For the RH only impacts, the fiber MC and NIR micronaire results were compared for RHs of 45/55/65/75/85% at the constant temperature of 21˚C. For the T only impacts, the fiber MC and NIR micronaire results were compared for Ts of 15/18/21/24/27˚C at the constant RH of 65%.

For the conditions with varying RH at constant T, large differences in fiber moisture content (MC) were observed, with lower MC at low T and RH and higher MC at high T and RH (Figure 3). In addition, major impacts were

observed on the NIR micronaire results, especially for the portable MicroNIR 1700 instrument. The fiber MC and MIR micronaire results with varying RH and constant T were very similar to those observed for all T and RH combinations (Figure 2).

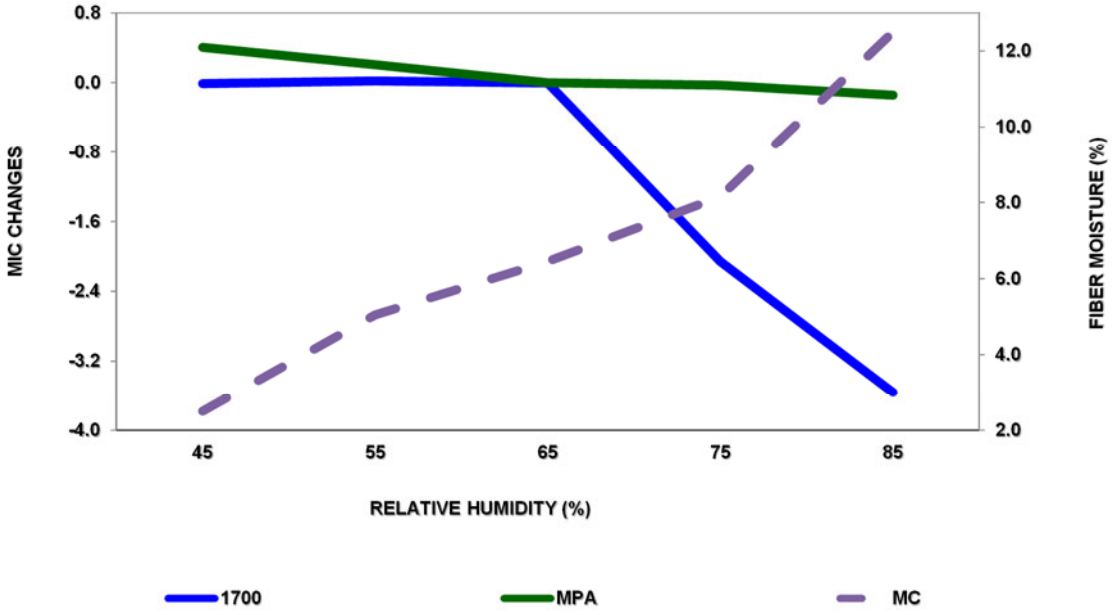


Figure 3. RH only impacts on NIR micronaire (MPA, MicroNIR 1700) and fiber moisture (M400) results

For the conditions with varying T at constant RH, the differences in fiber moisture content (MC) were much less than the fiber MC differences observed previously (Figure 4). In addition, the impacts observed at varying T at constant RH on the NIR micronaire results were much less than the impacts observed with varying RH at constant T, especially for the portable MicroNIR 1700 instrument. Micronaire outliers were observed for the portable NIR instrument, but the number of outliers was greatly reduced and occurred primarily at very low T and at very high T conditions. The fiber MC and NIR micronaire results with varying RH and constant T were very dissimilar to those observed for all T and RH combinations (Figure 2). Therefore, the major impact on the fiber MC and the NIR micronaire results was RH, and the impact was significant. The impact of T on the fiber MC and the NIR micronaire results was minor.

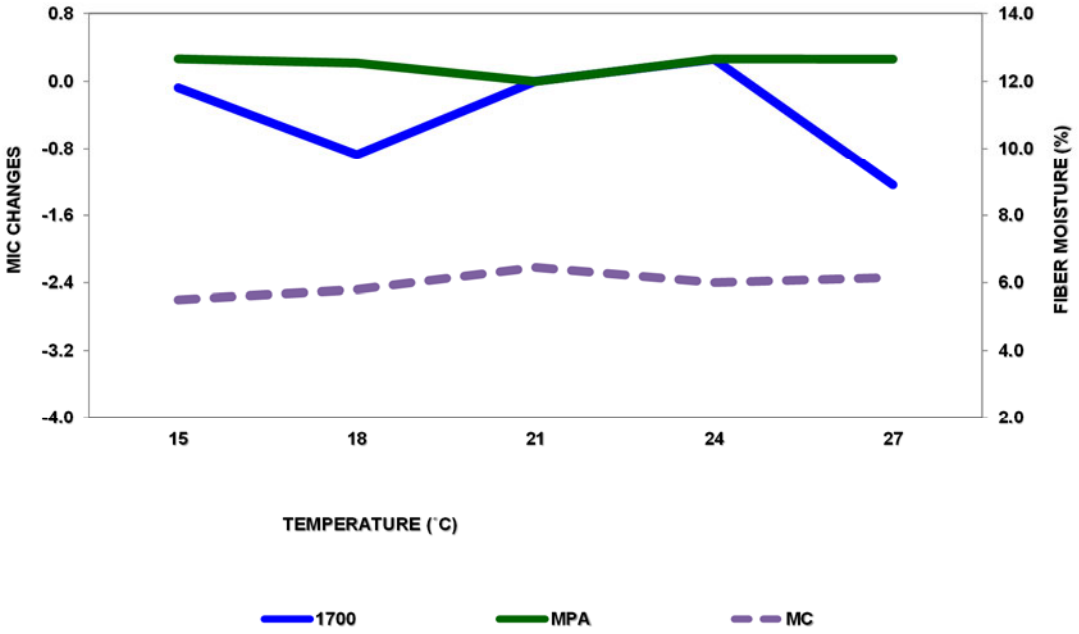


Figure 4. T only impacts on NIR micronaire (MPA, MicroNIR 1700) and fiber moisture (M400) results

Summary

A program was implemented to determine the extent of impact of varying environmental conditions (by varying temperature T and relative humidity RH) on fiber moisture and NIR micronaire results. As expected, it was shown that varying T and RH impacted significantly the fiber moisture content. Varying the environmental conditions with varying T and RH yielded minor to major impacts on the NIR micronaire results. The portable NIR instrument was more impacted by varying T and RH than the bench-top NIR instrument, especially at high T and RH conditions. RH had a much larger and significant impact on fiber moisture and the NIR micronaire results compared to T, demonstrating that RH was the primary environmental condition variable in this evaluation. The results indicate that T and RH at fiber conditioning, and the resulting fiber moisture differences, should be accounted for (and their impact minimized) for all NIR measurements performed at non-standard conditions and for all NIR measurements performed by portable instruments outside of the laboratory (field, greenhouse, processing, etc.).

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Disclaimer

The use of a company or product name is solely for the purpose of providing specific information and does not imply approval or recommendation by the United States Department of Agriculture to the exclusion of others.

References

Fortier, C., Rodgers, J. Foulk, J., and Whitelock, D. 2012. Near infrared classification of cotton lint, botanical and field trash. Journal of Cotton Science, 16:72-79.

Liu, Y., Campbell, B., Delhom, C., and Martin, V. Variation and relationship of quality and near infrared spectral characteristics of cotton fibers collected from multi-location field performance trials. *Textile Research Journal* 2015; 85(14): 1474-1485.

Montalvo, J. and Von Hoven, T. 2004. Analysis of cotton. pp. 671-728. *In* C. Roberts, J. Workman, and J. Reeves (eds.) Near-Infrared Spectroscopy in Agriculture. American Society of Agronomy, Agronomy Monograph No. 44, Madison, WI.

Ramey, H. 1982. Estimating quality components of natural fibers by Near-Infrared reflectance. Textile Research Journal, 52(1): 20-25.

Rodgers, J, and Ghosh, S. 2008. NIR analysis in textiles, Chapter 25. pp. 485-520. In: Burns, D., and Ciurczak, E. (eds.) Handbook of Near-Infrared Analysis, 3rd Ed. CRC Press, Boca Raton, FL, USA.

Rodgers, J., Montalvo, Davidonis, G., and Von Hoven, T. 2010a. Near Infrared measurement of cotton fiber micronaire, maturity, and fineness—A comparative investigation. Textile Research Journal, 80(9): 780-793.

Rodgers, J., Kang, S.Y., Fortier, C., Montalvo, J., Cui, X., and Martin, V. 2010b. Near Infrared measurement of cotton fiber micronaire by portable Near Infrared instrumentation. Textile Research Journal, 80(15): 1503-1515.

Rodgers, J., Kang, S.Y., Fortier, C., Cui, X., Davidonis, G., Clawson, E., Boquet, D., and Pettigrew, W. 2010c. Preliminary field measurement of cotton fiber micronaire by portable NIR. Spectroscopy, 25(9): 38-44.

Tincher, W., and Luk, A. 1985. NIRS analysis of cotton/polyester yarns. Textile Chemist and Colorist, 17(10): 25-29.

USDA AMS Cotton Program Brochure. April 2005. Cotton classification, understanding the data.

Wakelyn, P., Bertoniere, N., French, A., Thibodeaux, D., Triplett B., Rousselle, M., Goynes, W., Edwards, J., Hunter, L., McAlister, D., and Gamble, G. 2007. Physical properties of cotton, Chapter 7. pp. 107-114. *In* M. Lewin (ed.) Cotton Fiber Chemistry and Technology. CRC Press, Boca Raton, FL, USA.

Zumba, J., and Rodgers, J. 2016. Micronaire measurements on seed cotton and cotton fiber, in and outside of the laboratory, using micron NIR instruments. Proceedings of the 2016 National Cotton Conference Beltwide Cotton Conference. pp. 327-330.