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MICRONAIRE, MATURITY AND FINENESS RESEARCH

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Abstract

Fiber property research to measure micronaire, maturity and fineness is ongoing at the Southern Regional Research Center. This paper presents an update of recent advances in several aspects of this research. First, a set of 305 cottons spanning the micronaire range from 2.2 to 5.7 was measured with an upgraded Shirley Developments Limited Micromat Fineness and Maturity Tester (FMT). The 305-cotton set was then used to calibrate a NIRSystems Model 6500 near infrared (NIR) instrument to predict micronaire, maturity and fineness. Separate specimens from the same cotton samples were analyzed by the FMT and the NIR. Prediction algorithms were generated and used to predict the fiber properties of a different set of 99 cottons. Again, separate specimens from the same cotton samples were analyzed by the FMT and the NIR for the validation set. Because of instrumentation failure, a different FMT was used to analyze the validation set than the calibration set. With excellent R^2 between FMT and NIR data, regression slopes very near 1 and intercepts near 0, the results indicate that NIR can be used to accurately predict the fiber properties of micronaire, maturity, and fineness. Secondly, FMT experimental relationships between fineness and maturity were investigated further and compared with modeling studies. Thirdly, recent publications are presented documenting significant advances in fundamental and experimental aspects of the research.

Introduction

Improvements in micronaire, fineness and maturity measurements by Southern Regional Research Center's upgraded FMT permit the calibration of those properties on a NIR system (Montalvo and Von Hoven, 2003; Von Hoven *et al*., 2001, 2002). Improved FMT precision was obtained with a mechanical tool to insert the sample into the sample chamber. Use of a leak detector module (LDM), sealing all plastic tubing, and a new FMT calibration protocol contributed to better results.

When studying the relationships between the fiber properties, variability of correlation coefficients (R^2) is noted. For example, a family of lines, a family being characterized by a perimeter range, develops when graphing fineness versus maturity to give widely varying R^2 (Montalvo, in press). Using the definitions of maturity (Lord and Heap, 1988) and fineness (Ramey, 1982), these properties can be modeled in terms of perimeter, thus stabilizing correlation coefficients. This model can be used to check data collected regardless of instrumentation. If high R^2 values occur and slope and intercept agree with a prescribed value, then the data are valid (Montalvo and Von Hoven, submitted for publication).

The focus of this paper is three-fold: to demonstrate the successful calibration and validation of a NIR instrument with micronaire, maturity and fineness, to present new diagnostic relationships between fineness and maturity, and to update readers on recent publications.

Materials and Methods

For this research, 404 worldwide cottons were used, 305 for NIR calibration and the remaining 99 for NIR validation. These cottons were cleaned with two passes on the Shirley Analyser and then tested on an upgraded FMT (Von Hoven *et al.*, 2001, 2002). A fixed mass of cotton is placed in the FMT sample chamber and the cotton is compressed (dual stage) while air is drawn through the fibers. The initial pressure drop at low compression is referred to as pressure low (*PL*, mm water). Then the airflow is reduced and compression increased; the second stage pressure drop is referred to as pressure high (*PH*, mm water).

The FMT had been calibrated with 12 cottons tested for fineness and maturity by image analysis (Boylston, 1991), and the British Standard Methods (British Standard BS 3085:1981, BS EN ISO 1973:1996). From this data, Lord's fineness and maturity models were back calculated to produce the FMT *PL* and *PH* measurements that were subsequently used to calibrate the FMT instrument (Lord and Heap, 1988).

For each NIR sample, six replications of 4-gram specimens were hand carded using Louete cards with 100 picks per inch. Each specimen was then rolled and inserted into the FMT with a mechanical tool (Montalvo and Von Hoven, 2003). Throughout testing, a strict quality control protocol was followed that included physical standards that mimic mid-micronaire cotton used throughout the testing. The six replications were then averaged to give mean *PL* and *PH* values. Mean micronaire, maturity, fineness and perimeter values were computed from algorithms that are functions of *PL* and *PH* (Montalvo and Grimball, 1994).

Different specimens of the Shirley-cleaned cottons were tested on a NIRSystems Model 6500 spectrophotometer (NIRSystems analysis software, 1990). For each cotton, four spectra per sample were generated and averaged from two 24-gram cotton specimens run with 2 spectral replications per specimen. Spectra were gathered by placing each specimen over a quartz window and off-center to a 12.7 cm diameter sample cell rotating at 2.2 rpm. A motorized plunger compressed the fibers against the quartz and controlled the rotation. Thirty-two scans were taken and averaged during one revolution of the sample cell. The calibrations were developed on 305 worldwide cottons using partial least squares (PLS) analysis with one-out-rotation to correlate the spectral data with the fiber properties. A separate set of 99 cottons was used to validate the NIR calibration algorithms. These NIR-predicted micronaire, maturity and fineness values were compared to those measured with the FMT. Correlations, R^2, were then made between the NIR predicted fiber properties and the actual fiber properties as measured by FMT.

Relationships

When studying the graphs of fineness versus maturity, a family of lines is noted, each at a fixed perimeter, regardless of the method in which the properties were gathered. Using the fundamental properties of wall thickness and perimeter, these relationships were modeled adhering to the basic definitions of maturity as maturity ratio and fineness as *mtex*. By following this exercise, one may determine if a set of cotton quality data (fineness, maturity and perimeter) fit a new diagnostic model (Montalvo and Von Hoven, submitted for publication). Additionally, if a specific sample does not fit the model, it may be hindering correlations between the measured and predicted properties.

Results and Discussion

NIR-FMT Correlations

Once the NIR was calibrated with the set of 305 cottons, the calibration equations for micronaire, maturity and fineness were tested by predicting those properties for a different set of 99 cottons. Correlations between the FMT measured micronaire, maturity and fineness values and the NIR predicted values (y-axis) were excellent, with R^2 values of 0.9899, 0.9674, and 0.9606, Figures 1, 2 and 3 respectively. This indicates that the NIR can be successfully calibrated to quickly and accurately generate micronaire, maturity and fineness values for cleaned cottons.

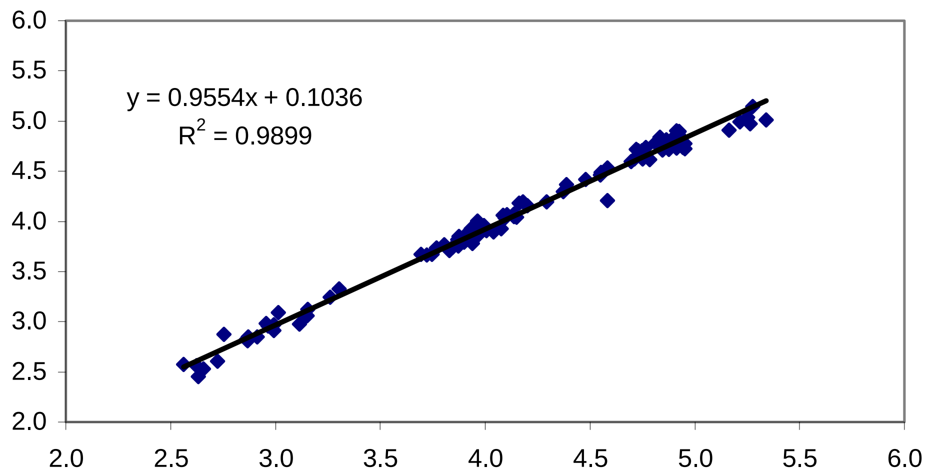

Figure 1. NIR Predicted vs FMT Measured Micronaire

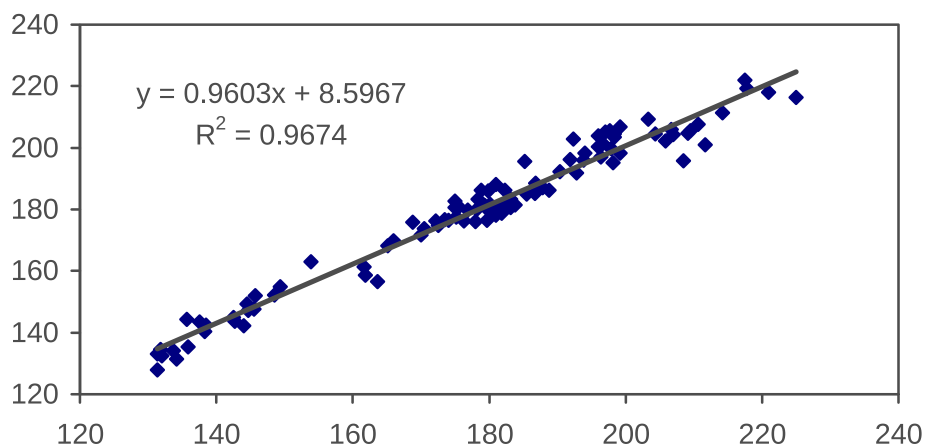

Figure 2. NIR Predicted vs FMT Measured Maturity Ratio

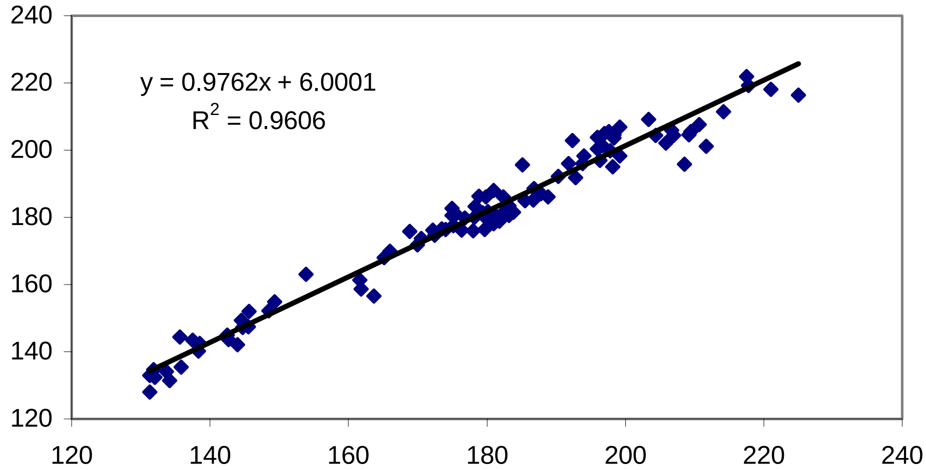

Figure 3. NIR Predicted vs FMT Measured Fineness (*mtex*)

Diagnostic Relationships

When studying the relationships between the micronaire, maturity and fineness fiber properties, incorrect interpretation of results is probable. For example, consider the observed variability in the correlation coefficient between fineness and maturity. It may be due to an error in the data, no relationship between fineness and maturity, or an underlying family of lines, each at a fixed perimeter. By using the definitions of maturity as maturity ratio and fineness in *mtex* units, the data can be modeled in terms of perimeter (Montalvo and Von Hoven, submitted for publication). With this new model, the true correlation between cotton maturity and fineness can be studied regardless of the perimeter value – constant for the whole sample set or variable. The expected results are a high R^2, and slopes and intercepts that are in line with prescribed values. As a consequence, the relationships can be studied independently of how the data were measured.

Figure 4 demonstrates a conventional graph of fineness versus maturity for a subset of 30 of the 404 cottons, with a poor correlation coefficient. The linear regression model in the conventional plot is $H = kM$. Examination of the perimeter values shows a range of perimeters, rather than fixed. This results in an underlying family of lines and poor R^2. When the same 30 cottons are graphed using the new model ($H/P = 0.0698MP$), the correlation coefficient becomes excellent as shown in Figure 5. H/P versus MP is plotted rather than H versus MP^2 since the latter gives large numbers. This model can also be used to explore a dataset, discover if there truly is a poor correlation between these two fiber parameters and screen for outliers.

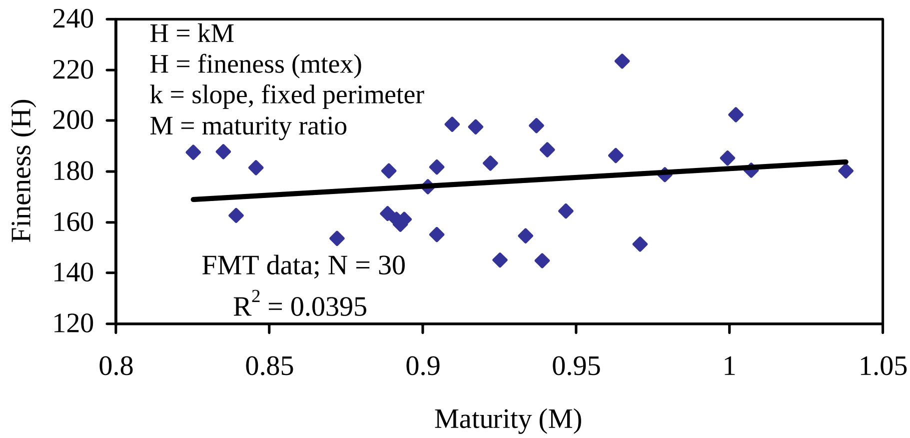

Figure 4. Conventional graph of fineness vs. maturity

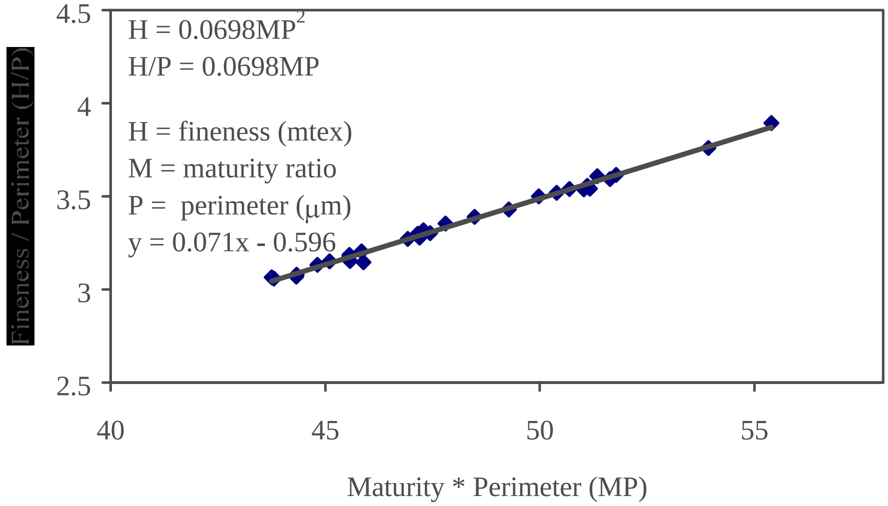

Figure 5. New model collapsing family of lines into one line ($R^2 > 0.98$).

Recent Publications

Further reading of the published work can be found in different sources. One source is Chapter 25 of the monograph *Near-Infrared Spectroscopy in Agriculture*, reviewing the use of NIR in cotton quality measurements (Montalvo and Von Hoven, 2004). There are over 100 references in this. Also, three papers are currently being published in the Journal of Cotton Science related to exploring the relationships between micronaire, maturity and fineness. The first in the series, 'Fundamentals', has been accepted for publication (Montalvo, in press). The second in the series, 'Experimental', has been submitted (Montalvo and Von Hoven), and the third, 'Added Error', is being written. These are the first articles on using modeling to understand variability in R^2 between the properties, testing derived models with a large dataset, and the effects of added errors on model performance.

Conclusions

When the NIR was calibrated with over 300 cottons for the measure of micronaire, fineness and maturity, this analysis method predicted the fiber properties of a set of unknown cottons very well. Thus, NIR is capable of measuring the three properties quickly, easily and accurately. When plotting paired fiber properties, poor correlations emerged that are difficult to interpret without additional information. The need for diagnostic relationships to study the data further was demonstrated in this paper.

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