2 PRELIMINARY STUDIES OF COTTON NON-LINT CONTENT IDENTIFICATION BY NEAR-INFRARED SPECTROSCOPY

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Abstract

The high demand for cotton production worldwide has presented a need for its standardized classification. There currently exists trained classers and instrumentation to distinguish key cotton quality parameters, such as some trash types and content. However, it is of interest to develop a universal instrumental method with higher trash identification specificity. A program was implemented to determine the capabilities of Near-Infrared (NIR) spectroscopy to identify various forms of cotton trash, including hull, leaf, seed coat, and stem. A NIR bench-top instrument was used to analyze small cotton trash samples. Subtle spectral differences between the cotton trash samples were used to classify the non-lint material components. The current method is beneficial due to the ease of use, short analysis time, and non-destruction of sample.

Introduction

Cotton is the primary natural textile fiber produced globally (Wakelyn *et al.*, 2007). Thus, the determination of the qualities of cotton and cotton trash using a standardized, universal method is important. Since cotton trash directly affects the ginning procedures and overall quality grade of cotton, it is of interest to create instrumental methods that specifically classify trash to improve the quality assessment and provide information for the further processing of cotton. Presently, the most common methods of cotton trash categorization involve using gravimetric or geometric methods. Although both techniques yield a relative measurement of cotton trash, neither give detailed information about the specific type of cotton foreign matter included in a sample.

Application of the HVI method to determine key characteristics of cotton has successfully been used to measure length, length uniformity, strength, micronaire, color, and trash content in a cotton sample. However, particularly with regard to cotton trash, the HVI method reports only an indirect amount of trash content. A visual (camera) method is used to discern the total trash content of a sample. A few limitations of this method are that it must be used in climate controlled environments, cost, and the lack of specificity in the identification of individual trash components such as the hull, leaf, seed coat, and stem.

In a recent preliminary study, FT-MIR, using an Attenuated Total Reflectance (ATR) method, reported on the efficacy of this instrumental technique to classify trash (Himmelsbach *et al.*, 2006). A spectral library was designed using FT-MIR which showed the ability to match unknown cotton trash spectra with reference spectra in the library. This method was able to specifically categorize cotton trash on small-size samples.

With the many advantages of NIR, including being rapid, precise, non-destructive, easy to use and accurate, it is an attractive technique for the analysis of textiles, specifically cotton (Taylor, 1980; Montalvo and von Hoven, 2004; Rodgers and Ghosh, 2008; Rodgers and Beck, 2009). It is the goal of this study to report on the creation of a spectral library for cotton trash component identification using Fourier transform Near-Infrared (FT-NIR) spectroscopy. The ability of the FT-NIR method to separate and classify/identify botanical cotton trash (hull, leaf, seed coat, and stem) from each other and from clean cotton fiber (lint) will be demonstrated and validated. NIR spectra of several types of cotton trash and cotton will be employed and their spectra will be compared and differentiated.

Materials and Methods

One class of "clean" cotton was used as the cotton reference and powder and pepper trash samples of 5 trash varieties from three states (Mississippi, New Mexico, and South Carolina) were used in the FT-NIR spectral library and the prediction set. The powder and pepper samples were acquired from USDA ARS CQRS and were used as is. Three replicates were made of each cotton trash variety sample. The calibration set was different from the prediction set in that the corresponding powder and pepper samples in the calibration set were represented as the opposite powder and pepper samples the prediction set. The spectral library was composed of the sample varieties belonging to the hull, leaf, seed coat and stem groups. Both a Bruker FT-NIR MPA instrument and a Bruker FT-MIR Vertex 70 instrument were used to analyze the cotton and cotton trash. In this study, the spectral library was created with the FT-NIR instrument only.

Results and Discussion

A key problem in the ginning and processing of cotton is the pervasive presence of cotton trash present with the lint. During the ginning and processing of cotton, pepper- and powder-sized cotton trash can adhere to the cotton lint. Since these sizes are small, removal and identification of the various forms of cotton trash can be difficult. As mentioned previously, a program was developed in the current study to identify cotton and individual cotton trash components using FT-NIR.

Initial evaluations compared the FT-MIR spectra for cotton trash to spectral results reported previously. The FT-MIR spectra, using the Bruker Vertex 70, were compared to the FT-MIR spectra observed in the preliminary studies using FT-MIR (Himmelsbach *et al.*, 2006). Figure 1 presents the Bruker FT-MIR representative spectra on clean cotton fiber (lint) and four types of cotton trash at resolution 8cm^{-1}. Compared to the FT-MIR study by Himmelsbach and co-workers (Himmelsbach *et al.*, 2006), there was good agreement between distinctive spectral bands of each study.

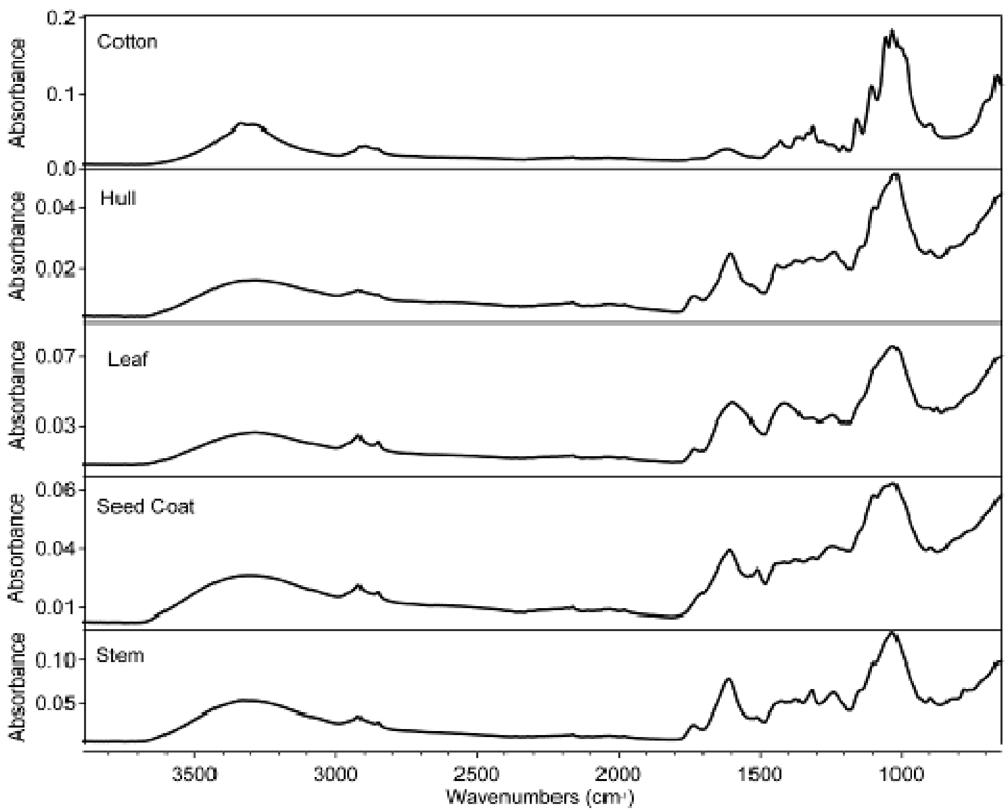

Figure 1. Average FT-MIR absorbance spectra of cotton and cotton trash components at a resolution of 8cm^{-1} with 128 scans.

In the development of the FT-NIR reference library, it was necessary to include spectra from numerous sources so as to make the qualitative method robust. Thus, both powder- and pepper-sized trash components representing 3 states and 9 cotton varieties were incorporated into the calibration set, and threshold values were calculated for each respective group. To optimize setting up the reference library, many pre-processing methods were available to use (Bruker Optics, 2004). Figure 2 shows average representative FT-NIR spectra for the current study for “clean” cotton and botanical trash over a spectral region of 1100-2400nm. As can be observed from the spectra, considerable overlapping of the spectra was observed. Many other pre-processing methods and spectral regions were examined. In Figure 3, it was shown that using the factorization pre-processing technique, applying the first derivative, and using a narrow frequency range, the cotton and most of the individual trash types except for hull and seed coat could be uniquely identified. To overcome the overlapping of the hull and seed coat spectra, a sublibrary to the main library was created.

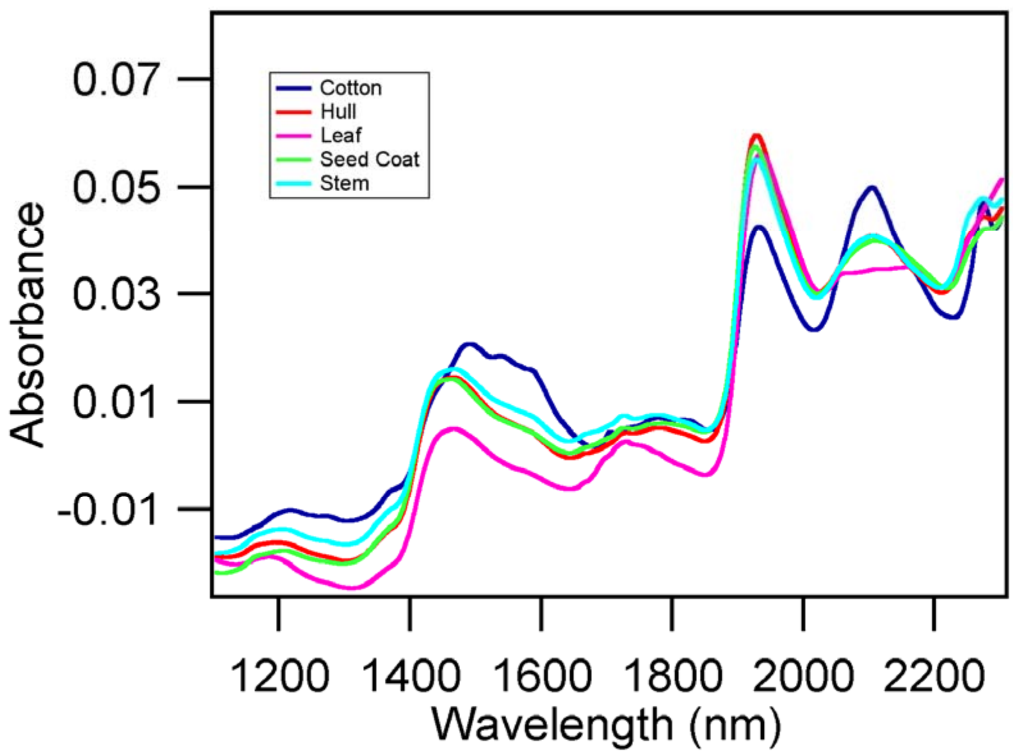

Figure 2. Average FT-NIR absorbance spectra for “clean” cotton and cotton trash samples over entire spectral range 1100-2400nm where cotton can be identified but cotton trash components are overlapping. Vector normalization and standard method pre-processing was applied during this run.

Table 1 shows the overall prediction set identity test results for each cotton trash group. The high accuracy prediction for 103 out of 105 cotton trash samples (98.1%), coupled with the ease of updating the library, makes this method attractive and proved the NIR method’s capabilities. The overall results were very favorable, with some minor misidentification results in the seed coat group where the unknown seed coat spectra were labeled as the hull variety. This result was not surprising since the hull and seed coat groups were found to be so spectrally similar that a sublibrary had to be created to distinguish between the two groups. The addition of more seed coat and hull samples may enable improved discrimination between the seed coat and hull samples.

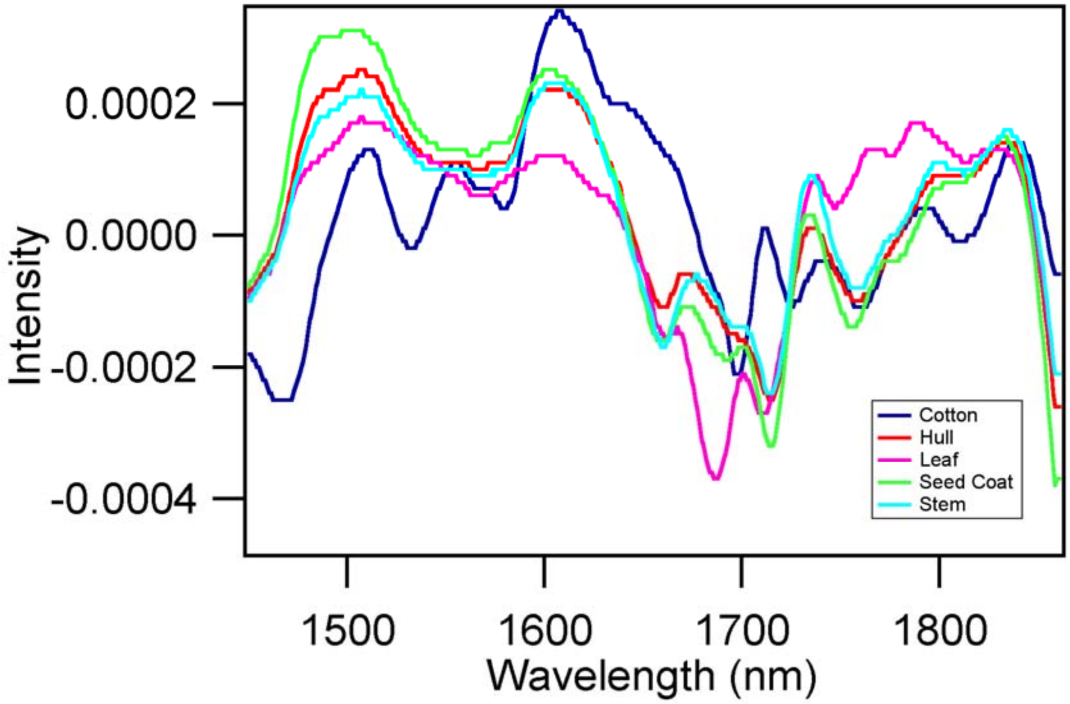

Figure 3. Average FT-NIR spectra for cotton and cotton trash over a narrow spectral range where cotton and cotton trash components are uniquely identified except for hull and seed coat. A factorization and first derivative pre-processing method was applied.

Table 1. NIR Identification by Cotton Trash Type in the Prediction Set

	%Correct	Number of samples	Number Correct
Hull	100%	27	27
Leaf	100%	27	27
Seed Coat	91.7%	24	22
Stem	100%	27	27
Total	98.1%	105	103

Summary

In this study, a FT-NIR technique that yielded specific information regarding the individual identities of cotton trash that is often present with cotton lint was established. Compared to the previous FT-MIR reports, FT-NIR offered distinct advantages, including sample size and flexibility. The enhanced selectivity afforded by this current study, in contrast to the visible spectral region method used in the HVI method, was successfully shown. This technique involves spectral identification of cotton trash in the NIR region, and it can be used to complement the HVI method. There were subtle differences spectrally between the individual cotton trash types. The calculation of the first derivative and factorization pre-processing techniques were shown to minimize the similarities between the cotton trash types and yield the best separation between reference spectra in the calibration set. In addition, it was necessary to create a sublibrary to the existing reference library to aid in the determination of hull and seed coat trash because these groups were so spectrally similar. The favorable overall findings of this study, 98.1%, demonstrated the "proof of concept" for this method. The feasibility for expansion of the library to include more reference samples of different varieties can make use of this library even more robust.

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.

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