DETECTION OF PLASTIC AND OILY CONTAMINATION IN SEED COTTON AT THE GIN USING INFRA-RED

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Abstract

Plastic and oily foreign material in bales of cotton lint poses problems to spinning and textile mills in the form of decreased productivity and products with inferior quality. Detecting and removing this plastic and oily foreign material at the gin is a long term goal of the cotton industry. In this study, an infra-red (IR) spectrometer was used to determine the transmission of infra-red radiation in the 2.5 to 25 micron wavelength range through seed cotton and fourteen commonly occurring plastic and oily contaminants. Significant differences were noted. Results were simulated using an IR light source and commercially-available filters that allow infra-red light to pass in the ranges of 3.03, 3.44, 4.35, and 6.68 microns. Simulated results were promising and further verification testing is underway. A method of applying this knowledge in a cotton gin was conceptualized.

Introduction

The presence of plastic and oily contamination in ginned lint is a problem for the textile industry resulting in numerous complaints to the National Cotton Council, Cordova, Tennessee, and Cotton Incorporated, Cary, North Carolina (http://westernfarmpress.com/cotton/plastic-contamination-threatens-us-cotton-industry). These problems include decreased productivity and impurities in finished products which result in a lowering of product quality (http://www.itmf.org/publications/free/datei8.pdf).

A research goal has been set to develop a sensor that will differentiate plastic and oily contaminants from seed cotton in a flowing stream of seed cotton within the gin plant and then to develop a method of separating these contaminants from the seed cotton. The objective of this study was to determine if infra-red radiation can be used to differentiate selected plastics and oils from seed cotton in a laboratory setting.

Materials and Methods

A Thermo-Nicolet iS10 spectral analyzer (a research grade Fourier transform infra-red spectrometer [FTIR], Thermo Fisher Scientific, Inc., Waltham, Massachusetts) at New Mexico State University was used to analyze cotton and common plastic and oily contaminants in attenuated total reflectance (ATR) mode (Figure 1). Transmission of infra-red energy was measured for wavelengths ranging from 2.5 to 25 microns. Eighteen products were analyzed including the following (see also Figure 2);

- Upland and pima seed cotton
- Trash from upland and pima seed cotton
- Hydraulic oil and spindle grease
- Shopping bags, both colored and white
- Bale bags, both yellow and white

- Module tarp, both new and weathered
- John Deere module wrap, from inner, middle and outer layers
- Black plastic, orange bale twine, and green bale strap

Three replications of each material were scanned with the spectral analyzer and the results for each material averaged.

Figure 1. The Thermo-Nicolet is10 spectral analyzer.

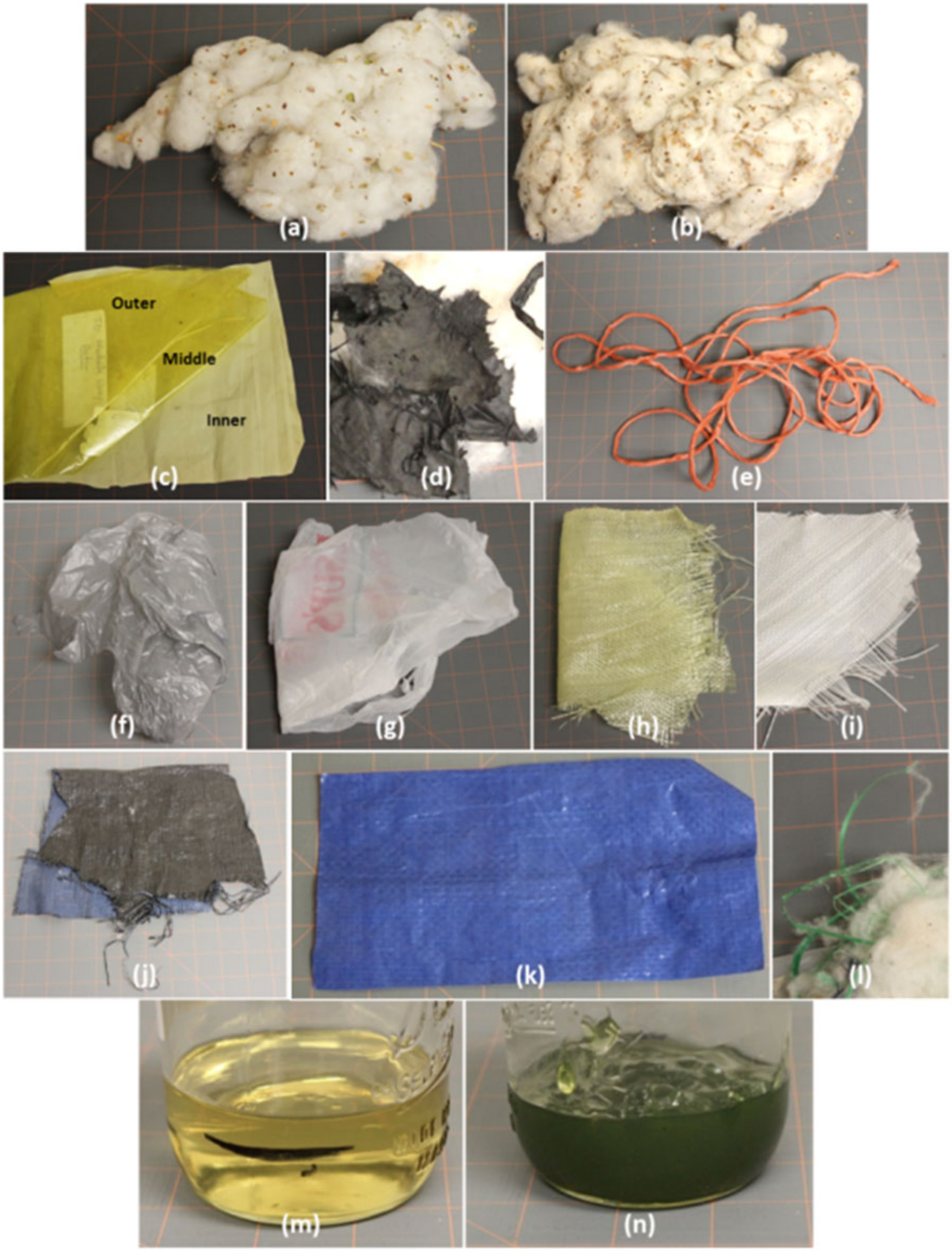

Figure 2. Cotton and contamination samples: a) Upland seed cotton; b) Pima seed cotton; c) plastic round-module wrap outer, middle, and inner layers; d) black plastic mulch; e) orange bale twine; f) colored and g) white plastic shopping bags; h) colored and i) white bale bags; j) old and k) new blue module tarps; l) plastic cotton bale strapping; m) hydraulic oil; and n) spindle grease.

In order to determine the number and wavelengths of filters needed to adequately detect the plastic and oily contamination in a mass of seed cotton, principal component (PCA), multi-curve regression and cluster statistical analyses of the spectral data were conducted. To theoretically test that the selected wavelengths could be utilized with commercially available components, simulations were run for selected band-pass filters that center on the selected wavelengths: 6.680±0.066, 4.350±0.043, 3.440±0.034 and 3.030±0.030 microns. The 10.00 micron wavelength was eliminated from the analysis, because the IR instrumentation components become much more complex and expensive at the higher wavelengths. The simulations used the transmittance curve for each filter and values from the IR reflectance curve for each sample that fall within the range of each filter. From this information, the IR intensity through each filter was estimated for each sample. These data were again analyzed by PCA and Cluster analysis.

Results and Discussion

Average values of infra-red transmittance through upland cotton over the wavelength range are shown in Figure 3. Transmittance is highest for the 4 to 8 micron wavelength range, with a significant drop occurring around 10 microns then an increase in transmittance through the 11 through 14 micron range, until dropping off and becoming 0 transmittance around 15.5 microns.

Average values of infra-red transmittance through upland and pima cotton are shown in Figure 3. Transmittance values are very similar in the 2.5 to 10 micron wavelength range, with a little variation occurring in the 11 to 15 micron range. In the higher wavelength range, transmittance through pima cotton is slightly greater than transmittance through upland cotton. These spectra match the closest of any two products analyzed.

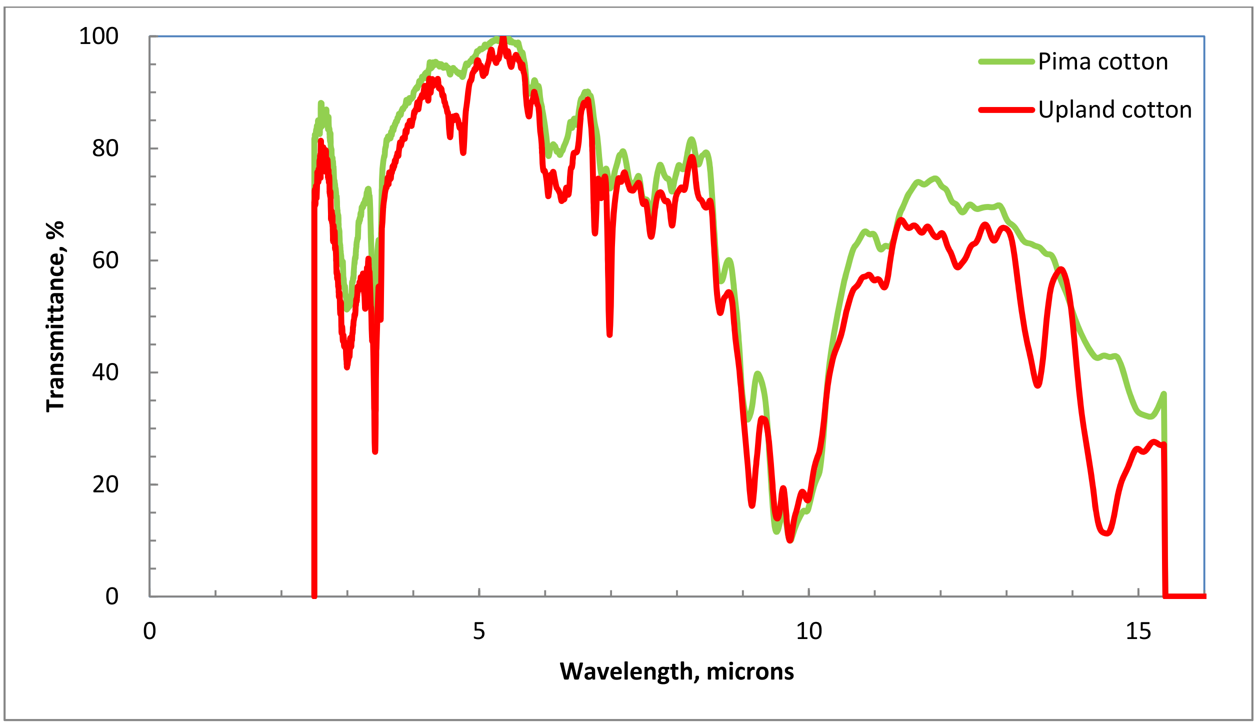

Figure 3. Comparison of transmittance of infra-red energy through upland and pima seed cotton.

Average values of infra-red transmittance through plastic materials were markedly different from those through seed cotton. Results for three common contaminants (orange bale twine, black plastic, and the outer layer of module wrap used by John Deere in 2013) are shown in Figures 4, 5 and 6. These figures generally show that infra-red transmission is greater for plastics than for upland seed cotton over several ranges of the spectrum. Of these three contaminants, the spectral distribution of orange bale twine most closely resembles that of seed cotton. Orange bale twine has spectral differences around the 3, 4.5, 6, and 7.5 to 9 micron range. Black plastic and module wrap used for John Deere modules have much greater spectral differences from seed cotton than occurs for orange bale twine.

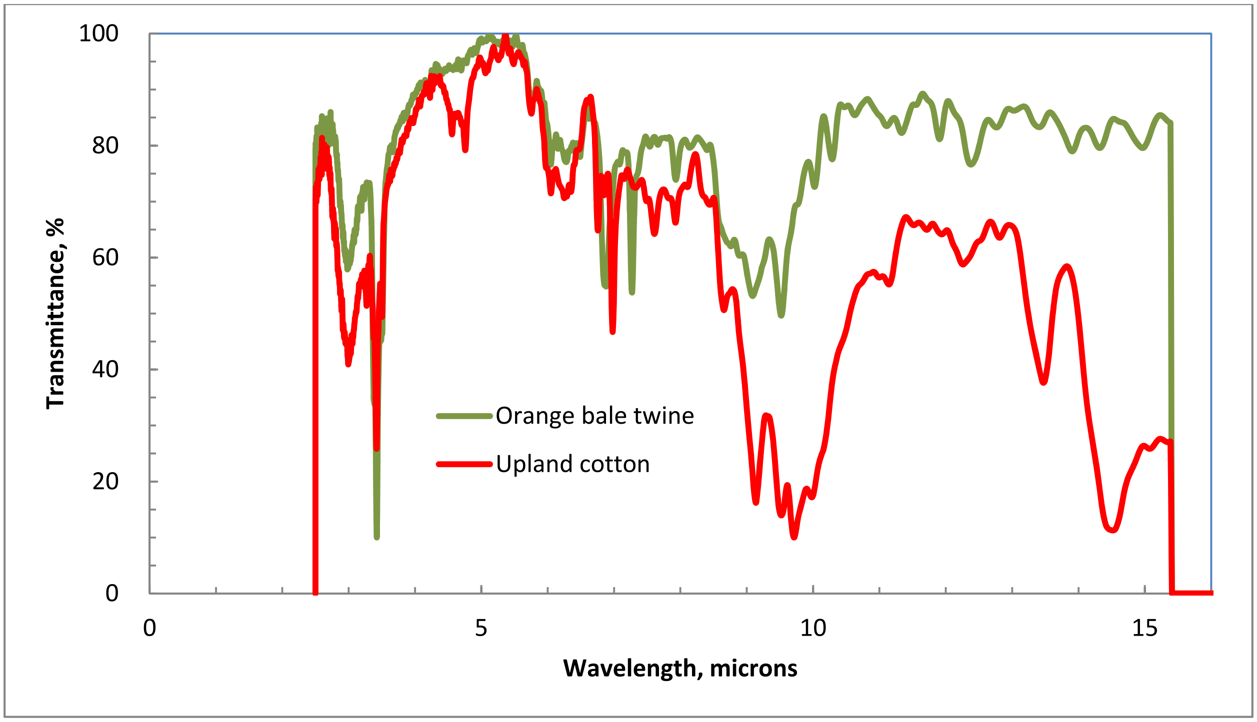

Figure 4. Comparison of transmittance of infra-red energy through upland cotton and orange bale twine.

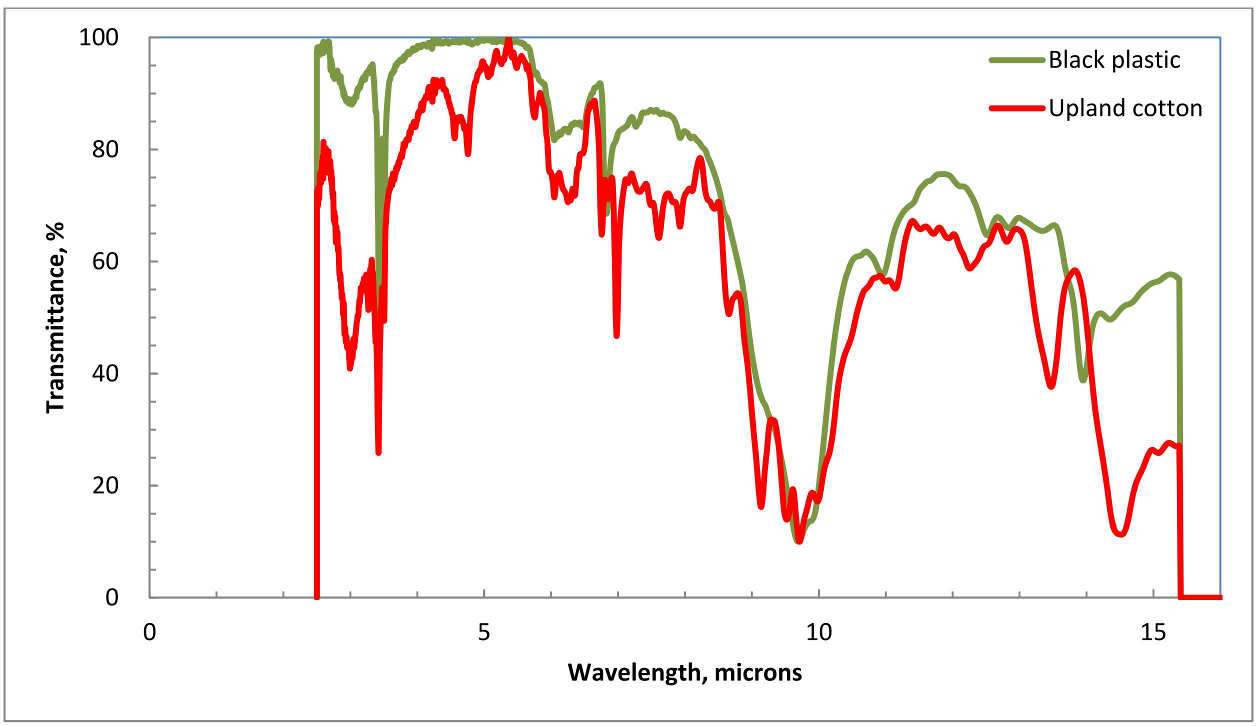

Figure 5. Comparison of transmittance of infra-red energy through upland cotton and black plastic.

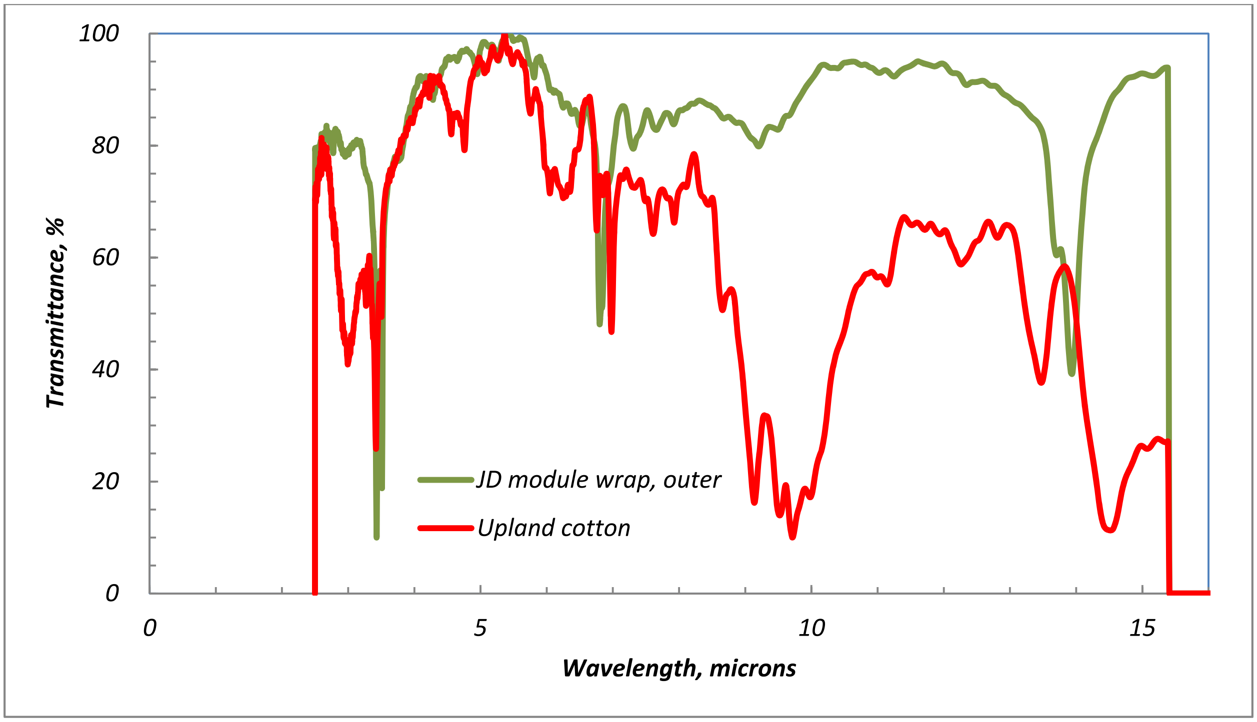

Figure 6. Comparison of transmittance of infra-red energy through upland cotton and the outer layer of the module wrap used by John Deere in 2013.

In order to use infra-red radiation as a method of detecting plastic and oily contamination in a cotton gin, the concept of using an infra-red light source in combination with wavelength filters and infra-red photodetectors was developed (Figure 7). Photodetectors may be placed in a position that senses transmitted radiation (as shown on the left in Figure 7) or reflected radiation (as shown on the right in Figure 7). Differences in values of either transmitted or reflected infra-red radiation would indicate that some type of plastic and oily contamination was present and should be removed.

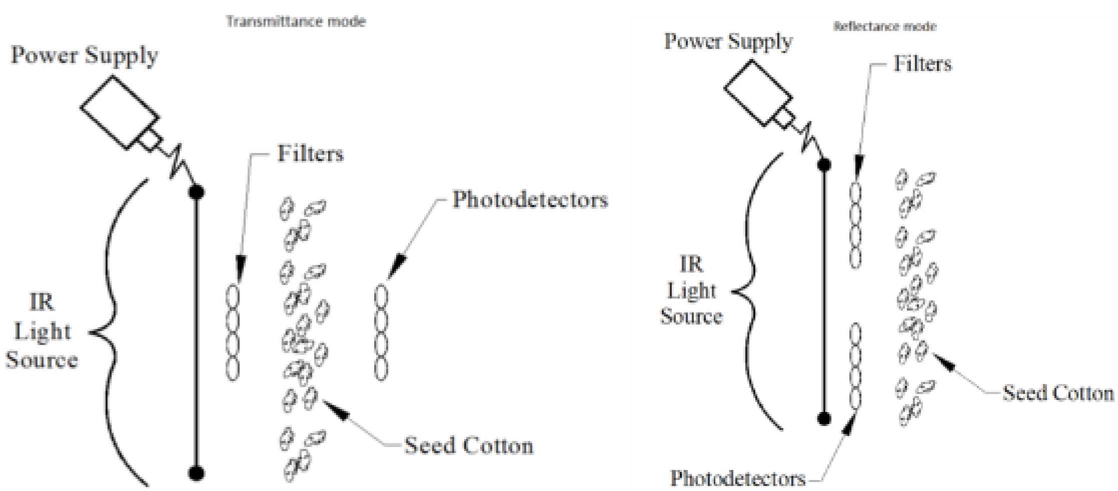

Figure 7. Concept drawing concerning the use of infra-red radiation for detecting contamination in a flowing stream of seed cotton in a cotton gin. Transmittance mode is shown on the left and reflectance mode is shown on the right.

Based on the principal component, multi-curve regression and cluster statistical analyses, five wavelengths in the infra-red spectra were selected to differentiate between the contaminants and cotton samples: 3.03, 3.44, 4.35, 6.68, and 10.00 microns. In investigating the cost of such a system, it was noted that the cost and complexity of the system components to include the 10.00 micron wavelength would be considerably higher than without. Further statistical analysis showed that the detection system would still work adequately without 10.00 micron wavelength. Therefore, the decision was made to use a detection system with 3.03, 3.44, 4.35, and 6.68 micron wavelengths. Figure 8 shows the selected wavelengths values imposed on the spectral graphs for upland cotton and the outer layer of module wrap.

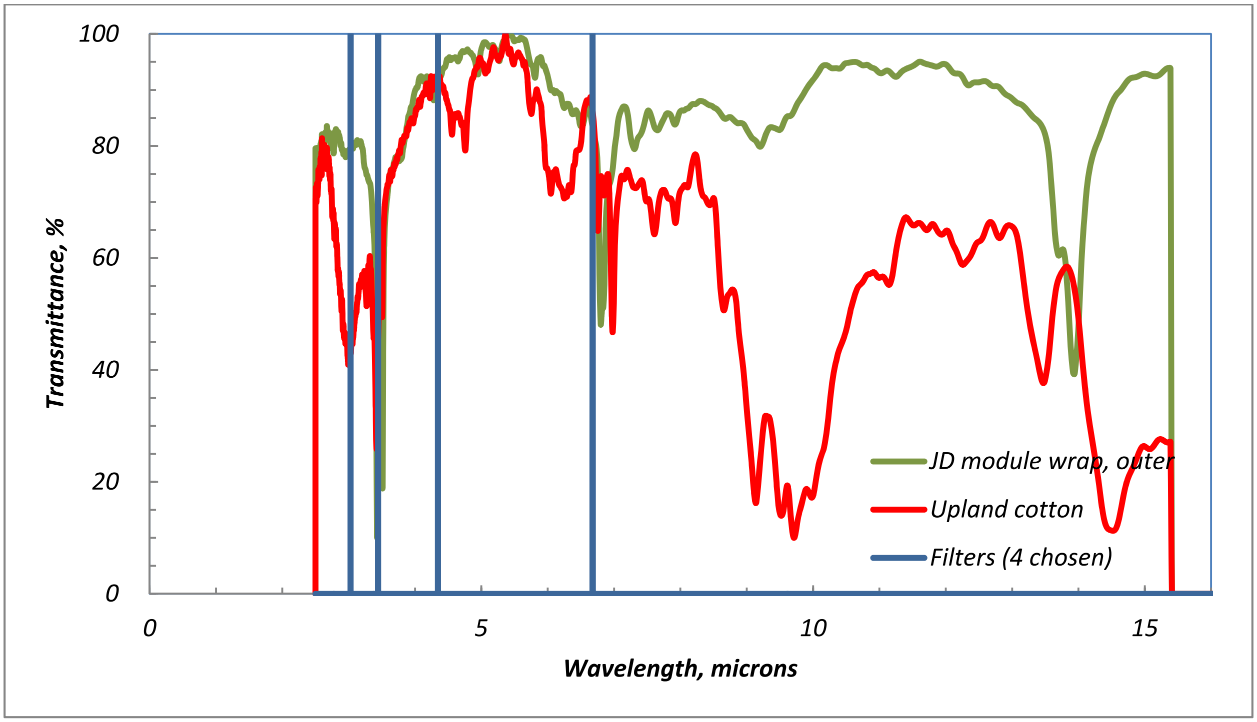

Figure 8. Comparison of transmittance of infra-red energy through upland cotton and the outer layer of the module wrap used by John Deere in 2013 as in figure 6 with filter values added at 3.03, 3.44, 4.35 and 6.68 microns.

Simulation modelling of the proposed system showed promising results. Principal component analysis and cluster analysis results from the simulated data showed that the selected plastics and oils were distinctly different from cotton trash and seed cotton as shown in Figure 9. This indicated that the simulated instrument using the available filters could differentiate contaminants from the cotton samples.

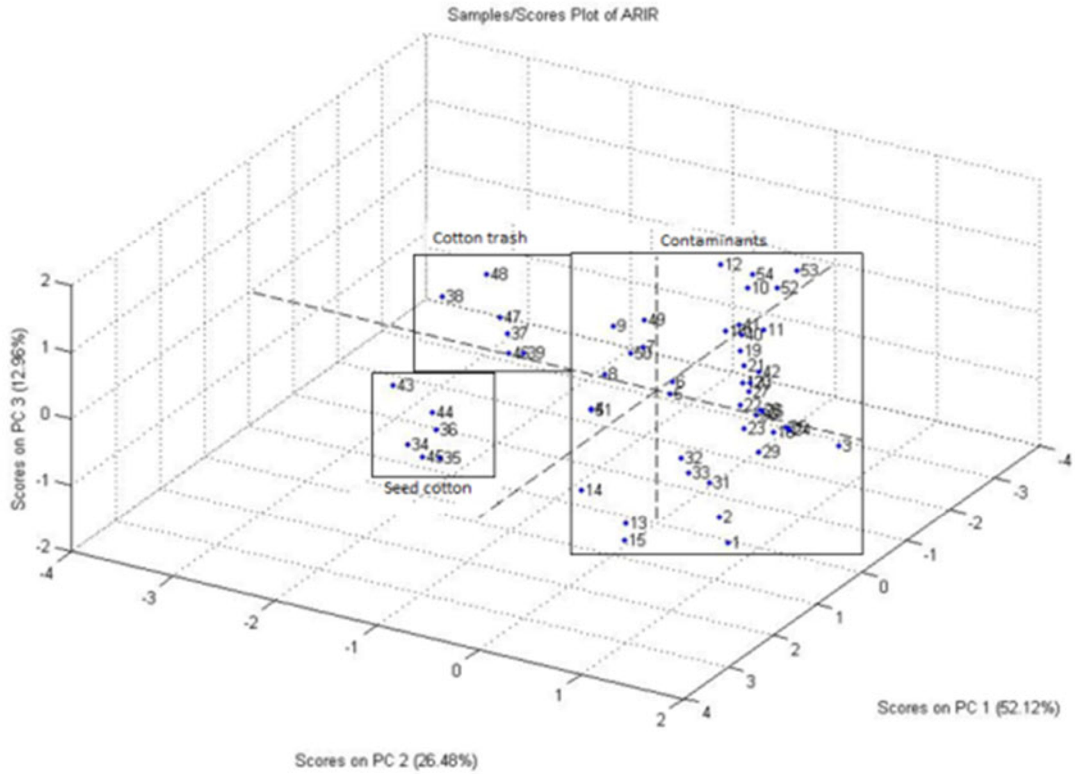

Figure 9. A principal component drawing of simulated results using the simulated four filters (3.03, 3.44, 4.35 and 6.68 micron). The distinct separation among seed cotton, cotton trash, and common plastic and oily contaminants is shown.

Future work will include building a prototype detection system using components shown in Figure 7 and testing this system in the laboratory with individual items, then with mixtures of items. The reflected photodetector position from Figure 7 will be tested first. These benchtop tests will be used to, evaluate the reproducibility of measurements, and quantify the instrument limitations, such as sensitivity, resolution, and field-of-view. If results continue to be promising, a prototype system will be tested in a cotton ginning research lab with flowing cotton and the field of vision and allowable thickness of the cotton stream will be determined.

Summary

Plastic and oily foreign material in bales of cotton lint poses problems to spinning and textile mills in the form of decreased productivity and products with inferior quality. Detecting and removing this plastic and oily foreign material at the gin is a long term goal of the cotton industry. In this study, an infra-red (IR) spectrometer was used to determine the transmission of infra-red radiation in the 2.5 to 25 micron range through seed cotton and fourteen commonly occurring plastic and oily contaminants. When comparing the infra-red spectra results, marked differences were noted. A method of applying this knowledge in a cotton gin was developed that uses an IR light source, filters allowing infra-red light to pass in the ranges of 3.03, 3.44, 4.35, and 6.68 microns, and then photodetectors placed to measure either transmitted or reflected values of IR radiation. Mathematically simulated results of the IR system were promising and a prototype is being constructed for further testing. This device could fit will with a system to detect and reduce contamination at the gin.

Disclaimer

Acknowledgements

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