Comprehensive Investigation of NIR Technique in Cotton Fiber Quality Assessment

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Abstract

Near infrared (NIR) spectroscopy, with an extension to UV and visible region, has been applied for the quantitative measurements of key cotton characteristics. However, the results have been inconsistent, mostly due to the use of different spectral regions. This work examined and compared the NIR model performances built from various regions for the prediction of cotton color / physical indexes and also visible trash content. On the basis of findings, improvement in reference determination and consideration of other spectroscopic approach were suggested.

1. Introduction

- Need for rapid, non-destructive, and routine methods for assessing cotton qualities has been a great concern.
- Physical measurements, such as HVI and Shirley Analyzer, have been developed as viable tools to characterize a number of cotton qualities. However, the procedures are destructive and time consuming.
- It is of interest to obtain independent and complementary information on cottons from other techniques.
- NIR spectroscopy is desired due to speed, easy of use, low-cost, and potential on-line/off-line implementations. However, most of earlier NIR work were limited to 1100-2500 nm region.

2. Objective

- To examine NIR for the prediction of key cotton color and physical properties and also trash content.

3. Experimental

- **Cotton fibers & reference readings.** Samples were taken from different bales, then color / physical indexes and visible trash content were determined by established HVI and Shirley Analyzer. They were well conditioned at relative humidity of 65% and temperature of 72 ± 2 ºF.
- **UV/Visible/NIR reflectance spectra.** JASCO V-670 spectrometer with the capability of scanning the 220-2500 nm region was used. Ca 0.5 g of samples were loaded into NIR cup (0.38 in. in depth and 2 in. in diameter).

4. Results and Discussion

4.1 Univariate correlations for color and physical indexes

	Rd	+b	ML	SFI	STR
Lightness (Rd)					
Yellowness (+b)	-0.59				
Mean Length (ML)	0.24	-0.40			
Short Fiber Index (SFI)	-0.27	0.35	-0.86		
Strength (STR)	0.45	-0.39	0.51	-0.48	
Micronaire (MIC)	0.20	-0.10	-0.15	-0.15	0.01

4.2 Reference values in calibration and validation sets

Cotton	Calibration set (n =82)			Validation set (n = 41)		
characteristics	Range	Mean	SD	Range	Mean	SD
Rd	72.97 - 84.80	78.08	2.68	72.97 - 84.80	78.23	2.65
+b	10.92 - 17.20	14.96	1.57	10.92 - 17.20	14.93	1.55
ML (inch)	0.692 - 0.964	0.853	0.069	0.700 - 0.964	0.857	0.066
SFI (%)	9.10 - 14.10	11.77	1.75	9.10 - 14.10	11.62	1.72
STR (gm/tex)	22.84 - 36.15	28.55	3.08	24.11 - 36.39	29.12	3.16
MIC (units)	2.51 - 5.38	4.01	0.84	2.51 - 5.38	4.02	0.83
Visible Trash (%)	0 - 65.20	28.5	19.8	0 - 60.20	27.9	19.0

(calibration (110) & validation (55) for visible trash only)

4.3 UV/visible/NIR reflectance spectral response

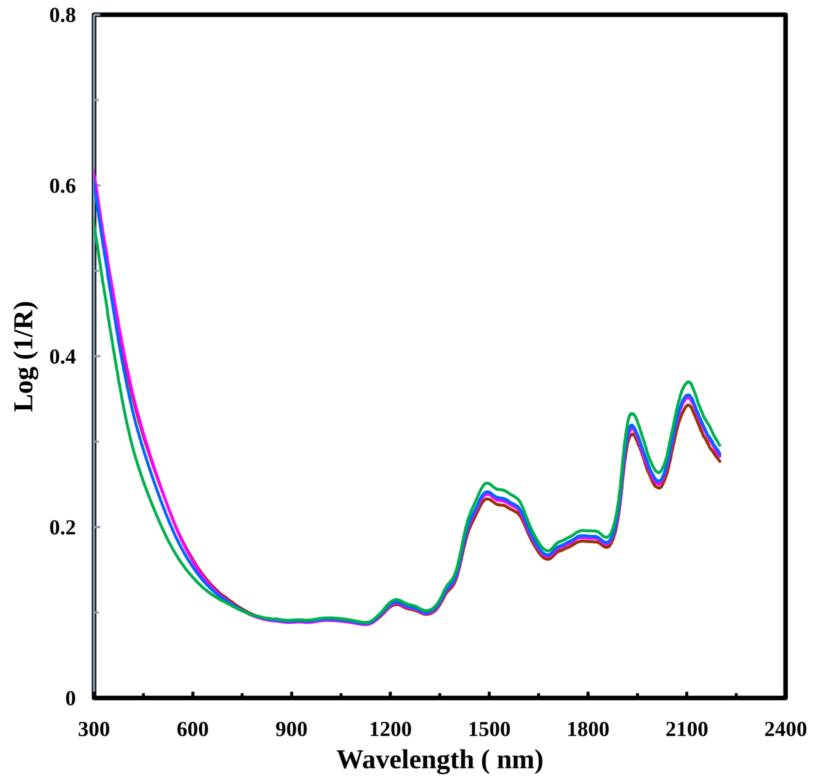

Fig.1 Representative spectra of cotton fibers

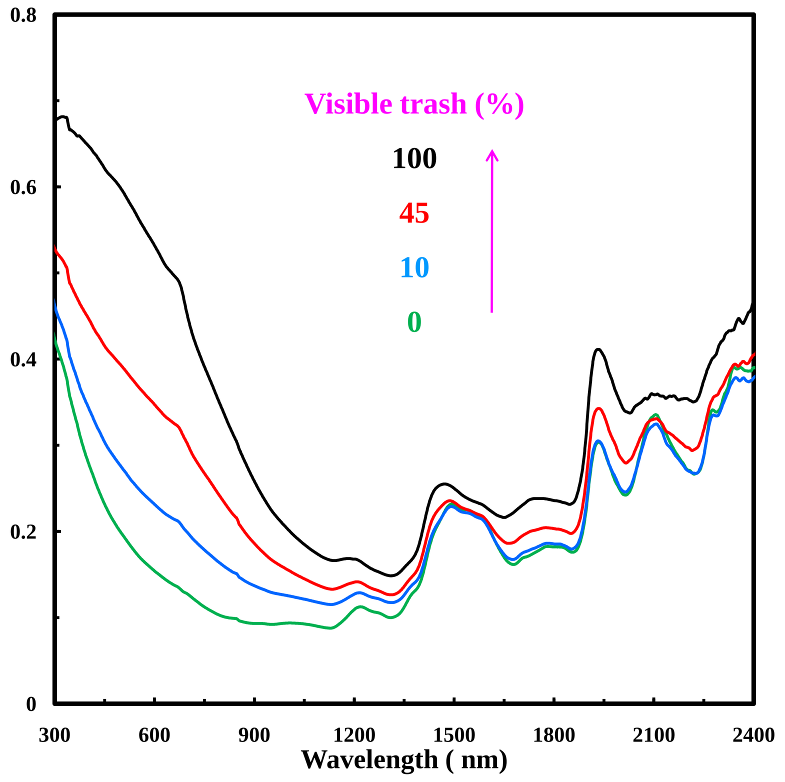

Fig.1 Typical spectra of trash contaminated cottons

Cotton fibers: UV/visible region represents the contribution from pigmentation compounds, while NIR bands originate from combination and overtone modes of cellulose.

Trash mingled cottons: distinctive spectral difference occurs in UV/visible/short-wavelength NIR region (< 1200 nm) and also the 2020-2200 nm region.

4.4 Statistics in calibration and validation sets

Fiber index / Spectral region	Spectral processing	Factor	Calibration R^2	Calibration RMSEC	Validation R^2	Validation RMSEV	RPD
Rd							
226 -2194 nm	MC	8	0.90	0.86	0.82	1.13	2.3
226 - 1100 nm	MC+MSC+1D	10	0.96	0.53	0.87	0.96	2.8
1100 – 2194 nm	MC	6	0.61	1.68	0.51	1.89	1.4
+b							
226 -2194 nm	MC+MSC	7	0.96	0.30	0.96	0.31	5.0
226 - 1100 nm	MC	8	0.96	0.32	0.94	0.39	4.0
1100 – 2194 nm	MC	5	0.82	0.66	0.82	0.66	2.3
ML							
226 - 2194 nm	MC+MSC	7	0.82	0.029	0.78	0.031	2.1
226 - 1100 nm	MC+MSC+1D	8	0.88	0.024	0.81	0.029	2.3
1100 - 2194 nm	MC	4	0.53	0.048	0.55	0.044	1.5
SFI							
226 - 2194 nm	MC+MSC+1D	4	0.82	0.75	0.75	0.87	2.0
226 - 1100 nm	MC+MSC	7	0.71	0.95	0.71	0.94	1.9
1100 - 2194 nm	MC+1D	2	0.52	1.21	0.55	1.15	1.5
STR							
226 -2194 nm	MC+1D	4	0.74	1.59	0.55	2.25	1.4
226 - 1100 nm	MC	12	0.74	1.59	0.63	2.11	1.5
1100 - 2194 nm	MC	4	0.31	2.58	0.20	2.91	1.1
MIC							
226 - 2194 nm	MC	7	0.97	0.14	0.97	0.14	5.9
226 - 1100 nm	MC	12	0.96	0.17	0.91	0.25	3.3
1100 - 2194 nm	MC	4	0.97	0.15	0.98	0.13	6.4
Visible Trash							
226 - 2494 nm	MC	5	0.86	7.32	0.90	6.42	3.0
226 - 1100 nm	MC+SNV	6	0.87	7.08	0.88	7.04	2.7
1100 - 2494 nm	MC+SNV	4	0.86	7.42	0.86	7.27	2.6

5. Conclusions

- Models have the ability to predict MIC and +b for quality control (RPD>5.0), and to assess Rd, ML, SFI, and visible trash content for screening programs (RPD>2.5).
- UV/visible/NIR determination of strength is a challenge. Other techniques of FT-IR and Raman should be considered.
- Despite of obvious spectral intensity differences, resultant trash models are not as robust as expected. Main reasons might be due to heterogeneous trash distribution, relative small sampling area, and gravimetric reference method.

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