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CHANGES IN COTTON NONCELLULOSIC CONTENT DURING THE YARN PRODUCTION PROCESS

Donald E. Brushwood
USDA, ARS, Cotton Quality Research Station
Clemson, SC

Abstract

Varieties common to three different domestic growing areas and single harvesting season were spun into yarns on ring, open-end, and Vortex systems. Samples were selected at various stages of processing to determine any possible alterations in the general or specific non-cellulosic content, where these changes occur, the magnitude of changes, and what (if any) effect may be seen on the finished yarn quality. Variations in fiber micronaire, which were highly related to growing location, influenced initial concentrations of total alcohol surface non-fibrous and wax extractables. In processing, non-significant changes were seen in the plant sugar or surface wax content. Alcohol extractables decreased in the fiber opening and carding and yarn spinning processes. Concentrations of the fiber residual light metals potassium, calcium, magnesium, and sodium were reduced in the fiber primarily in the opening and carding processes. The magnitude of reduction in alcohol surface extractables and light metal was found to be highly related to fiber micronaire.

Introduction

Raw cotton contains varying levels of naturally occurring non-fibrous materials. Along with man-induced contaminants, seed-coat fragments, trash, etc., are the naturally occurring waxes, plant sugars, metallic oxides and other noncellulosic organic materials (Rollins, 1965). Previous studies on cottons have successfully identified and quantified specific amounts of these materials (Perkins, 1971, Brushwood and Perkins, 1994). Variations in cotton non-fibrous content may be affected by fiber micronaire, growing location, variety, field weathering, foreign substances deposited on open bolls prior to harvesting, length of growing season, and harvesting and ginning practices. The combined concentrations of these materials on the fiber can easily exceed three percent of the fiber weight. Therefore, there is the potential for those noncellulosic materials in cotton fibers that are not removed during the opening and cleaning processes to have a substantial effect on fiber physical properties and the quality of finished textile yarns (Perkins, 1990, Brushwood, 2003).

Recent studies have explored potential relationships that may exist between different levels of noncellulosic materials on the raw unprocessed fiber and yarn frictional properties, spinning efficiency, and yarn quality (Brushwood, 2001, 2002, 2002). Since, most of the non-fibrous materials on raw cottons are presumed to be surface related, there is the potential for the levels to be altered as a result of passing fibers through different stages of yarn processing. To date, little or no work has been conducted to quantify any changes in fiber noncellulosic content that may occur in the production of yarn and how these may influence the finished product.

The purpose of this paper is to, (1) determine the changes (if any) in raw cotton noncellulosic material content for different three yarn spinning systems; (2) where these changes may occur; (3) if there are differences between spinning systems: and (4) what potential these changes may have on finished yarn quality.

Materials and Methods

To reduce effects that may be due to variations in multiple season cotton crops and differences between varieties, two single season varieties grown common to three major domestic areas were selected for this study. These were a part of a single season ATMI Variety Study, that was conducted by the USDA Cotton Quality Research Station at Clemson, SC., in cooperation with producers and ginners from the Southeast (Georgia), Midsouth (Mississippi), and the High Plains of Texas. Cottons were ginned regionally and shipped to Clemson for evaluation of physical properties and spinning into yarns. After complete blending into eight separate lots, each was processed on our equipment. Ring and open-end (20/1) and Vortex (35/1) yarns were spun from each.

At appropriate times in processing, triplicate samples of raw blended stock, carding sliver, ring, open-end, and Vortex finish drawing sliver, and yarn samples were collected for evaluation. These samples were conditioned in our laboratory for at least two weeks before triplicate moisture contents (ASTM Method D2495-01) were determined. Hence, the average moisture content presented in this paper is the results of nine measurements. The standard error for this oven moisture content method is ± 0.10 percent.

Determining Plant Sugars, Wax, and Other Fiber Extractables

Blended raw fiber, carding sliver, finish drawing, and yarn plant sugar concentrations (in triplicate) were determined using a standard YSI 2700 glucose test. Results presented in this study represent average values. The standard error for this test is 10% of the determined amount.

Wax was removed from the lint by six-hour soxhlet extractions with 1-1-1- trichloroethane solvent. A single extraction consisted of 100 ml of solvent to accurately weighed 2.50 grams of sample. After extraction, residual boiling flask solvent and extracted wax was poured into a pre-weighed weighing bottle. The solvent was evaporated overnight in an oven at 105°C, capped, removed from the oven, and placed in a desiccator to cool to room temperature before re-weighing. Final wax content was calculated from averaging all extractions. Alcohol extractables, which are traditionally accepted as an indicator of the noncellulosic content of cotton, were conducted as with the wax procedures, except the solvent used was absolute ethanol. The estimated standard error of determination for the wax and alcohol extraction procedures is ± 5% of the determined concentration.

Metals Determination

Preparation and analysis of samples by ashing followed the procedure previously reported (Brushwood and Perkins, 1994). At least duplicate measurements (triplicate samples) per specific metal were made. Therefore, metal content for each fiber is an average of at least six determinations. Analysis was conducted using a Atomic Absorption (Buck 200A) Spectrophotometer with an air/acetylene flame in the absorbance mode. Individual metal concentrations were based on a calibration curve using a minimum of four standard concentrations. A blank (no ash), was always included in each determination and used as a reference. Dilutions made to obtain effective absorbencies at each metal's respective wavelengths in their linear operating ranges were 1250X for potassium and 625X for calcium and magnesium and 125X for sodium analysis.

The significance of the above data averages was determined by SAS for Windows (SAS Institute, Cary, NC) and statistical t-tests. Correlation coefficients (r values) were based on linear regression (how well data points are related to each other).

Results and Discussion

Fiber micronaire (at least eight measurements per lot) were found to be growing area dependent (Table 1). The two Texas grown varieties averaged 2.89 (Fibermax 832) and 3.20 (Fibermax 966). The same varieties originating from Georgia averaged 4.04 and 4.35 micronaire, respectively. Mississippi-grown Fibermax 832 averaged 3.97 and Fibermax 966 average 4.53 micronaire.

Fiber Moisture Contents

Moisture contents for the raw fiber samples ranged from 6.7 to 7.2 percent, card sliver and finish draw sample from 5.9 to 6.6 percent, and yarn samples from 5.3 to about 6.3 percent. The average Texas cotton moisture content was found to be significantly different ($\alpha = 0.05$) from the average corresponding Georgia and Mississippi cottons (averaging about 5% higher at each stage of processing). No significant difference between spinning system was seen. When calculations were made for fiber extractables and metals at different stages of processing, corrections were made for fiber individual moisture contents.

Fiber Natural Sugar Content During Yarn Production

Raw fiber sugar concentrations for both varieties ranged from a high of about 0.20 percent for the High Plains of Texas an average low of about 0.05 percent for Mississippi cottons. Since these concentrations were low, no significant changes in sugar levels were observed at any stage of processing. Ring, open-end, and Vortex produced yarn sugar determinations averaged the same as the unprocessed blended fiber.

Wax Content During Processing

Extractable wax concentrations did not change significantly (within the standard error of determination of 5%) throughout processing for variety, spinning system, or growing location. Average wax concentrations were found to be highly related to fiber micronaire. The Fibermax Texas cottons averaged 0.721 percent for the 832 and 0.665 percent for the 966 varieties, respectively. Georgia averages were 0.515 and 0.508 percent and Mississippi averages were 0.463 and 0.449. The coefficient of simple correlation between wax concentrations and micronaire for the six samples was $r = -0.95$. As fiber micronaire increased, the concentrations of surface waxes decreased.

Total Ethyl Alcohol Surface Extractables During Processing

Initial total alcohol extractables for these samples were also found to be highly related to the fiber micronaire. Texas samples averaged from 3.04 percent for the 832 and 2.64 percent for the 966 variety. Total extraction averages for the same two varieties grown in Georgia were 1.74 and 1.78 percent. Mississippi averages were 1.39 and 1.49, respectively. The coefficient of simple correlation between raw blended fiber alcohol extractables and micronaire for these six samples was $r = -0.92$. As fiber micronaire increased, alcohol extractables decreased.

No significant differences in the amount of alcohol surface extractables removed from the fiber were detected between spinning system or the carding sliver and finish drawing processes. Therefore, comparisons were made between averaged the blended raw fiber, averaged sliver (carding and drawing), and averaged finished yarn extractables for all three spinning systems.

Table 2 shows the average alcohol surface extractables (all three spinning systems) for the two varieties at these stages of processing. Fiber alcohol surface extractables tended to decrease after the opening and carding processes and again in spinning. Hence, the amount of alcohol fiber extractables tended to decrease at two processing stages.
Some difference between the two varieties was also detected. The bulk of the reduction in extractables for the Fibermax 832 occurred in the opening and carding process, while most of the reduction in extractables for the 966 variety occurred in yarn spinning.

Percentage wise, the reductions in alcohol extractables were consistently higher for the Mississippi and Georgia cottons. For example, Mississippi Fibermax 832 cotton, which averaged 1.39 percent alcohol extractables, lost a total of 24 percent of its surface extractable materials in processing. The same variety, originating from Texas, at an average micronaire of 3.04, lost only 12 percent extractables in processing. When the total decrease in alcohol extractables for these locations was correlated with fiber micronaire, the coefficient of correlation was found to be r = 0.99. As fiber micronaire increased, a larger percentage of ethyl alcohol surface materials were removed in yarn production.

Changes in Fiber Light Metal Content in Processing

Potassium. Potassium, which is the most abundant metal on cotton fiber, usually accounts for 60 to 75 percent of the light metal content of the fiber. Raw blended stock concentrations in the two Texas varieties averaged between 5000 to 5100 ppm potassium before processing, followed by Georgia grown cottons in the 4000 to 4500 ppm range. Each Mississippi variety averaged below 4000 ppm. The correlation between the initial blended fiber potassium content and micronaire for these samples was r = - 0.53. Potassium content tended to increase as micronaire decreased.

No significant differences were seen between the potassium levels on the cottons when comparing spinning systems. The only significant decreases in fiber potassium in any of the yarn processing stages occurred in the opening and carding processes (Table 3). Levels in the higher potassium content Texas cottons decreased by a smaller percentage than the other growing areas. The magnitude of decrease for these three locations, as with decreases in alcohol surface extractables, was related to micronaire. A coefficient of simple correlation between decrease in potassium and fiber micronaire was r = 0.71. As micronaire increased, a higher percentage of fiber potassium was removed in the opening and carding processes.

Calcium, Magnesium, and Sodium Contents. Significant changes in the fiber levels of the metal calcium only occurred in the opening and carding processes of yarn production. No differences were seen between spinning systems. Average finished yarn and sliver concentrations were not significantly different. Changes were, therefore, determined between average blended fiber stock and the average combined sliver and yarn samples. There was no correlation found between the initial blended stock concentrations of calcium and micronaire. The degree of change (or decrease) in calcium content was, however; found to be related to micronaire (table 4). As micronaire increased, the percentage of calcium removed increased (r = 0.81). On a percentage basis, decreases in calcium content were much greater than those of the potassium. This would suggest that calcium on the fiber is much more surface oriented than that of the metal potassium. The higher micronaire fibers (Georgia and Mississippi) lost 35 percent or more of their original calcium in the opening and carding processes of spinning.

Fiber magnesium levels, which are usually slightly lower than the calcium concentrations were also reduced primarily in the opening and carding processes. Therefore, changes were calculated using the same approach used for changes in the calcium content (table 4). The correlation between initial fiber magnesium content and fiber micronaire (r = - 0.62). As micronaire increased, magnesium levels tended to decrease. No change in the fiber magnesium level was noted for the Texas samples (below 3.20 micronaires). The Georgia cottons averaged a loss of 12% and the Mississippi averaged about a 20% loss. When the percentage of change in fiber magnesium content was correlated with fiber micronaire, the coefficient of simple correlation was r = 0.86. As fiber micronaire increased, a higher percentage of the original magnesium was removed.

Fiber sodium concentrations, whose levels usually are below 200 ppm on the fiber, were found to be slightly higher in the higher micronaire cottons. The correlation between fiber micronaire and blended raw fiber sodium content for these six samples was r = 0.55. As fiber micronaire increased, sodium concentrations also tend to increase. Changes in the fiber sodium content in processing followed similar patterns seen for the other light metals (Table 4). The lower micronaire Texas cottons did not appear to lose any sodium in processing. Georgia and Mississippi (4.0 micronaire and above) lost an average of 50% of their sodium in the opening and carding processes. A calculated coefficient of correlation between fiber sodium loss and micronaire was determined to be r = 0.73. Increasing micronaire contributed to an increasing percentage of the sodium loss. Larger percent decreases in concentrations of the metal sodium (and comparable to losses of calcium content) as micronaire increased suggests that sodium is also more surface oriented than the metals potassium and magnesium.

Summary

Two single season varieties of cotton that were grown in three different domestic growing areas were processed by ring, open-end, and Vortex spinning systems at the USDA-CQRS Laboratory at Clemson. Representative raw stock, sliver, and yarn samples were selected at various processing stages to study the possible effects of processing on fiber noncellulosic material content. Fiber micronaire was determined to be highly related to growing location. Texas cottons averaged significantly lower in micronaire than the other two growing areas.

Plant sugars, which are low, and natural wax concentrations remained unchanged in yarn processing. There was a strong correlation found between wax content and fiber micronaire. As micronaire increased, wax content decreased.

Fiber alcohol solvent surface extractables decreased in the opening and carding and spinning process of yarn production. Most of the decrease occurred in opening and carding with one variety and in the spinning process for the other. The overall percent decrease in alcohol extractable surface materials in yarn processing was found to be highly related to fiber micronaire. In general, the reduction of ethyl alcohol extractable surface materials for these fibers was related to the initial fiber micronaire. Overall decreases were 20% or more for micronaires above 4.0.

Initial fiber potassium and magnesium contents were micronaire related. As micronaire increased, potassium and magnesium content on the fiber decreased. The unprocessed fiber sodium levels (all less than 200 ppm) appeared to increase as micronaire increased. Levels of fiber calcium were unrelated to fiber micronaire.

Concentrations of the light metals, potassium, calcium, magnesium, and sodium were all found to significantly decrease only in the opening and carding processes of spinning. No significant change in metal content was detected between the finish drawing and yarn spinning processes. Changes (losses) in the opening and carding stages of processing were all highly related to the fiber micronaire. As micronaire increased, higher levels of residual metals were removed. Overall decreases in total light metal content in these unprocessed fibers were reduced by about at least 20% for micronaires above 4.0 and less for lower micronaires. This could be a simple matter related to the physical contact of fibers with processing machinery.

Higher percentage losses in concentrations of the metals calcium and sodium (as compared to potassium and magnesium) in processing suggest that these metals may be more surface oriented than the others. Significant losses in levels of the metal calcium in processing could potentially affect any subsequent dyeing and finishing of the yarn. Lower concentrations of this metal would reduce the potential for certain insoluble calcium salts from forming in wet processing that may inhibit uptake and levelness in dyeing.

We were primarily concerned with changes that affected the fiber in processing. No attempt to analysis the opening and carding residues from these samples has been made to date. Perhaps future studies will look at these materials also.

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Table 1. Average micronaire for two varieties grown in different areas

	Micronaire*		
	FM 832	**FM 966**	**Location Average**
Texas	2.89a	3.20a	3.05
Georgia	4.04c	4.35b	4.20
Miss.	3.97b	4.53c	4.25

*means in a column having a common letter are not significantly different ($\alpha = 0.05$)

Table 2. Changes in alcohol surface extractables at different processing stages

	Extractables (%)				
	Raw*	**C.S.+F.D.**	**Dec.(%)**	**Yarn**	**Dec.(%)º**
FM 832 Tx	3.04	2.66	13	2.70	12
FM 832 Ga.	1.74	1.41	19	1.36	22
FM 832 Miss.	1.39	1.12	19	1.05	24
FM 966 Tx.	2.64	2.50	5	2.28	14
FM 966 Ga.	1.78	1.51	15	1.28	28
FM 966 Miss.	1.49	1.23	17	1.04	30

*r = - 0.92 (correlation between alcohol extractables and fiber micronaire – raw cottons)

º r = 0.99 (correlation between percent decrease in extractable materials and fiber micronaire)

Table 3. Changes in fiber potassium content during yarn production

	Potassium (ppm)		
	Raw	**Final***	**Dec.(%)º**
FM 832 Tx.	5080	4540	11
FM 832 Ga.	4020	3560	11
FM 832 Miss.	2280	1740	24
FM 966 Tx.	5020	4270	15
FM 966 Ga.	4430	3500	21
FM 966 Miss.	3840	2750	28

* Average of carding sliver, finish drawing, and yarn samples (n = 9)

º r = 0.71 (correlation between percent decrease and fiber micronaire)

Table 4. Changes in fiber calcium, magnesium, and sodium content during yarn production

	Calcium (ppm)			Magnesium (ppm)			Sodium (ppm)		
	Raw	**Final***	**Dec.(%)º**	**Raw**	**Final***	**Dec.(%)^**	**Raw**	**Final***	**Dec.(%)[a]**
FM 832 Tx.	889	738	17	695	694	0	105	104	0
FM 832 Ga.	1017	481	53	616	548	11	165	72	56
FM 832 Miss.	729	375	49	405	322	20	164	54	67
FM 966 Tx.	925	746	19	639	636	0	103	101	2
FM 966 Ga.	801	514	36	605	531	12	155	79	49
FM 966 Miss.	843	458	46	484	398	18	111	78	30

* Average of Carding sliver, finish drawing, and yarn samples (n = 9):

º r = 0.81 (correlation between percent decrease in calcium content and fiber micronaire)

^ r = 0.86 (correlation between percent decrease in magnesium content and fiber micronaire)

[a] r = 0.73 (correlation between percent decrease in sodium content and fiber micronaire)